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Agronomic Biofortification: Enhancing Crop Nutrition for Improved Human Health

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INTRODUCTION

Malnutrition and associated health problems are partly related to minerals and vitamins deficiencies where anemia and stunting are the major diseases affecting nearly half of pregnant women and about 20% children under age of five, respectively in developing countries (Melash *et al*., 2016). Agronomic biofortification has emerged as a promising strategy to address widespread malnutrition and improve human health by enhancing the nutritional quality of staple crops. Malnutrition, characterized by deficiencies in essential vitamins and minerals, poses significant health risks and hampers socio-economic development, particularly in low- and middle-income countries. Traditional interventions such as dietary supplements and fortification of processed foods have had limited reach and sustainability. In contrast, agronomic biofortification focuses on improving the nutrient content of crops at the source, offering a sustainable and cost-effective approach to combat hidden hunger. Cereals are staple food in most developing low-income countries of Asia and Africa, where they may contribute as much as 55% of the dietary energy (Prasad *et al*., 2014). Agronomic biofortification involves the application of agronomic practices to enhance the bioavailability of key micronutrients, such as iron, zinc, and vitamin A, in staple crops like rice, wheat, maize, and legumes. Through targeted fertilization, soil amendments, and crop management techniques, agronomic biofortification aims to optimize nutrient uptake, accumulation, and retention in edible plant parts. The significance of agronomic biofortification lies in its ability to reach populations at risk of malnutrition, particularly in regions where dietary diversity is limited, and access to fortified foods is constrained. By fortifying staple crops with essential nutrients, agronomic biofortification integrates nutrition into food production systems, making nutritious foods more accessible and affordable for vulnerable communities.

Moreover, agronomic biofortification aligns with principles of sustainable agriculture, promoting environmental stewardship and resilience to climate change. Furthermore, agronomic biofortification offers advantages over other intervention strategies, such as genetic modification or supplementation, including lower costs, minimal consumer behavior change, and broader acceptance among farmers. Agronomic biofortification holds immense potential as a scalable and sustainable approach to enhance crop nutrition and improve human health, particularly in resource-limited settings. By leveraging agricultural innovation to address malnutrition, agronomic biofortification contributes to global efforts to achieve food security, reduce malnutrition-related morbidity and mortality, and promote inclusive and sustainable development.

What is agronomic biofortification?

Agronomic biofortification of food grains involves enhancing the nutritional content of staple crops through agronomic practices. This approach focuses on optimizing soil fertility, nutrient uptake, and plant metabolism to increase the levels of essential vitamins and minerals in crops. Techniques such as targeted fertilization, soil amendments, and crop management strategies are utilized to improve the bioavailability of key nutrients such as iron, zinc, and vitamin A in food grains like rice, wheat, and maize. Agronomic biofortification offers a sustainable and cost-effective method to address nutrient deficiencies and improve human health outcomes, particularly in regions where malnutrition is prevalent.

Strategies of agronomic biofortification

Agronomic biofortification of food grains employs various strategies to enhance the nutritional content of staple crops, thereby addressing nutrient deficiencies and improving human health. These strategies focus on optimizing soil fertility, nutrient uptake, and plant metabolism to increase the levels of essential vitamins and minerals in food grains like rice, wheat, maize, and millets.

- **Targeted Fertilization:** Agronomic biofortification often begins with soil testing to assess nutrient deficiencies and pH levels. Based on soil analysis, targeted fertilization is employed to supply deficient nutrients such as zinc, iron, and selenium. Customized fertilization regimes may include the application of micronutrient-enriched fertilizers, foliar sprays, or soil amendments to ensure optimal nutrient availability for crop uptake.
- **Micronutrient-Enriched Fertilizers:** Specialized fertilizers containing micronutrients are used to fortify soil and enhance nutrient uptake by crops. For example, zinc sulfate, ferrous sulfate, and potassium iodate are commonly added to fertilizers to increase the levels of zinc, iron, and iodine in food grains. These micronutrient-enriched fertilizers are applied either directly to the soil or as foliar sprays during critical growth stages to maximize nutrient absorption and utilization by plants.
- **Soil Amendments:** Soil amendments such as lime, gypsum, and organic matter are utilized to improve soil structure, pH balance, and nutrient availability. Liming acidic soils helps reduce aluminum toxicity and enhances the uptake of nutrients like phosphorus and calcium. Similarly, gypsum application can alleviate soil salinity and improve the availability of micronutrients such as zinc and sulfur. Organic amendments such as compost, manure, and biochar contribute to soil fertility, microbial activity, and organic matter content, thereby promoting nutrient cycling and plant health.
- **Crop Rotation and Intercropping:** Diversified cropping systems, including crop rotation and intercropping, are integral to agronomic biofortification. Rotating nutrient-demanding crops with

legumes or cover crops helps replenish soil nutrients and break pest cycles. Intercropping complementary crops with different nutrient profiles enhances nutrient diversification and utilization, leading to improved overall crop nutrition. For example, intercropping maize with legumes increases nitrogen fixation and enhances the protein content of grains.

- **Water Management:** Optimal water management practices play a crucial role in agronomic biofortification by ensuring adequate soil moisture for nutrient uptake and translocation within plants. Irrigation scheduling, water conservation measures, and drainage management are essential for maintaining soil moisture balance and preventing nutrient leaching. Efficient water use also helps mitigate environmental stresses and maximizes crop yields, contributing to overall nutritional quality.

Advantages of agronomic biofortification

Agronomic biofortification offers several advantages, making it a promising strategy to address malnutrition and improve human health outcomes, particularly in regions where dietary diversity is limited and access to nutrient-rich foods is constrained.

- **Sustainable and Cost-Effective:** Agronomic biofortification is a sustainable and cost-effective approach to enhance the nutritional content of food crops. Unlike genetic modification or supplementation, which may involve high costs and regulatory hurdles, agronomic biofortification utilizes existing agricultural practices and infrastructure to fortify crops with essential nutrients. By integrating nutrient management into routine farming activities, agronomic biofortification offers a practical and scalable solution to address malnutrition in resource-limited settings.
- **Targeted Nutrient Delivery:** Agronomic biofortification enables targeted delivery of specific nutrients to crops based on soil nutrient status and crop requirements. Through soil testing and customized fertilization regimes, agronomic biofortification ensures that deficient nutrients such as iron, zinc, and vitamin A are supplied in optimal amounts for crop uptake and utilization. This targeted approach minimizes nutrient wastage and maximizes the effectiveness of nutrient delivery, leading to improved crop nutrition and human health outcomes.
- **Enhanced Nutrient Bioavailability:** Agronomic biofortification enhances the bioavailability of key nutrients in food crops, making them more readily absorbed and utilized by the human body. By optimizing soil fertility, pH balance, and nutrient cycling, agronomic practices such as targeted fertilization, soil amendments, and diversified cropping systems promote nutrient uptake and translocation within plants. This results in higher nutrient content and better nutrient quality in food grains, leading to improved nutritional status and health benefits for consumers.
- **Integration with Sustainable Agriculture:** Agronomic biofortification aligns with principles of sustainable agriculture by promoting soil health, biodiversity, and environmental stewardship. Through practices such as crop rotation, intercropping, and organic amendments, agronomic biofortification enhances soil fertility, water use efficiency, and pest management while reducing the reliance on chemical fertilizers and pesticides. By fostering resilient and diverse agroecosystems, agronomic biofortification contributes to long-term food security and agricultural sustainability.
- **Improved Crop Yields and Quality:** Agronomic biofortification not only enhances the nutritional content of food crops but also improves their agronomic performance, including crop yields and quality. By optimizing soil fertility and

nutrient management, agronomic practices promote healthy plant growth, root development, and reproductive success, leading to increased crop yields and better overall crop productivity. Moreover, improved crop quality, including enhanced nutritional value and sensory attributes, adds value to agricultural products and enhances their marketability and consumer acceptance.

- **Reduced Health Risks and Healthcare Costs:** By addressing nutrient deficiencies and improving overall nutritional status, agronomic biofortification helps reduce the risk of diet-related health problems such as anemia, stunting, and blindness. Improved access to nutrient-rich foods can also reduce the prevalence of micronutrient malnutrition and associated health complications, leading to better health outcomes and lower healthcare costs for individuals and communities. Moreover, by promoting healthy diets and lifestyles, agronomic biofortification contributes to disease prevention and public health promotion.
- **Social Equity and Food Security:** Agronomic biofortification has the potential to improve food security and promote social equity by increasing access to nutritious foods for vulnerable populations, including women, children, and marginalized communities. By fortifying staple crops with essential nutrients, agronomic biofortification addresses hidden hunger and malnutrition at the grassroots level, ensuring that all individuals have access to a diverse and balanced diet. This can contribute to poverty reduction, social inclusion, and sustainable development, fostering resilient and equitable food systems for future generations.

CONCLUSION

Agronomic biofortification represents a promising strategy to address malnutrition and improve human health by enhancing the nutritional quality of staple crops. Through targeted fertilization, soil amendments, diversified cropping systems, and water management practices, agronomic biofortification optimizes soil fertility, nutrient uptake, and plant metabolism to increase the levels of essential vitamins and minerals in food grains. This approach offers several advantages, including sustainability, scalability, cost-effectiveness, and integration with existing agricultural practices. By fortifying staple crops with key nutrients, agronomic biofortification contributes to global efforts to combat hidden hunger, reduce malnutrition-related morbidity and mortality, and promote inclusive and sustainable development.

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