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Agronomic Biofortification - A Potential Way for Nutritional Security

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Introduction

Worldwide, a population of more than two billion confront deficiency in micronutrient and acute malnutrition, mainly pregnant women, and children who are under the age of five. Malnutrition, the ambiguous devil of hidden hunger has already attained its zenith of importance after the setting of Millennium Development Goals (MDGs) followed by Sustainable Development Goals (SDGs). While the prevailing priority is on utilizing micronutrient supplements and industrial fortification of foods to aid exposed population, the most efficacious and sustainable approach for everlasting effect is unification of micronutrient fortification into crop production. Fortification is the enhancement of nutrient density in food through physical interventions such as the addition of salts while biofortification refers to enhancing the levels of bioavailable micronutrients using techniques such as conventional plant breeding, transgenics and agronomic biofortification (i.e., use of micronutrient-rich fertilizers) (FAO, 2017).

Need for Biofortification

Biofortification towers above as a pivotal scheme in the global war against malnutrition, especially widespread in developing countries. It gets to grip with the issue of hidden hunger by blossoming crops augmented with crucial nutrients such as vitamin A, zinc and iron. Micronutrient deficiencies stay as main public health problem and rank top among the causes of disability and death. Worldwide, zinc deficiency is regarded as the most critical micronutrient deficiency seen in crops. Globally, about 0.8 million people and nearly about 0.45 million children are at a threat of dying each year from zinc deficiency (WHO, 2015). In India, about 0.15 million children lose their lives each year due to zinc deficiency. Recommended daily intake of nutrients like vitamin A, iron and zinc are 900 µg, 25 mg and 15

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mg respectively (RDA, 2020). When consuming a diet that includes carbohydrates, it is essential to incorporate vegetables and pulses to establish a balanced intake of nutrients necessary for proper growth. In Northern India, the staple foods are roti and dal, while in Southern India, rice and sambhar dominates. In central regions, people generally consume rice or roti with dal. Unfortunately, a remarkable portion of the population neglects to include vegetables in their diet, overlooking on vital vitamins and micronutrients. Inspite of being aware of importance of vegetables, many people do not include them properly in their meals, leading to micronutrient deficiencies. Therefore, biofortification of cereal crops and pulses is crucial to provide a better nutrient profile, tackling the deficiencies effectively. The most widely consumed rice variety in India, Swarna, contains 0.78 mg Fe/100 g in white rice and 2.28 mg Zn/100 g in brown rice. Even if a person consumes rice 2-3 times a day, he can barely get 2-3 mg Fe and 7-8 mg Zn which is not meeting the required nutrient intake of these micronutrients. Thus, biofortification is necessary in order to cope up with the needs of the surging population. As per WHO (2015), fortification of zinc in food could save the lives of around 48,000 children in India. The aim of biofortification is not only to tackle the problem of calorie deficit but also succor the endurance of human health by introducing balanced diet with essential nutrients present in proper amount. Different types of biofortification are shown in Fig-1.

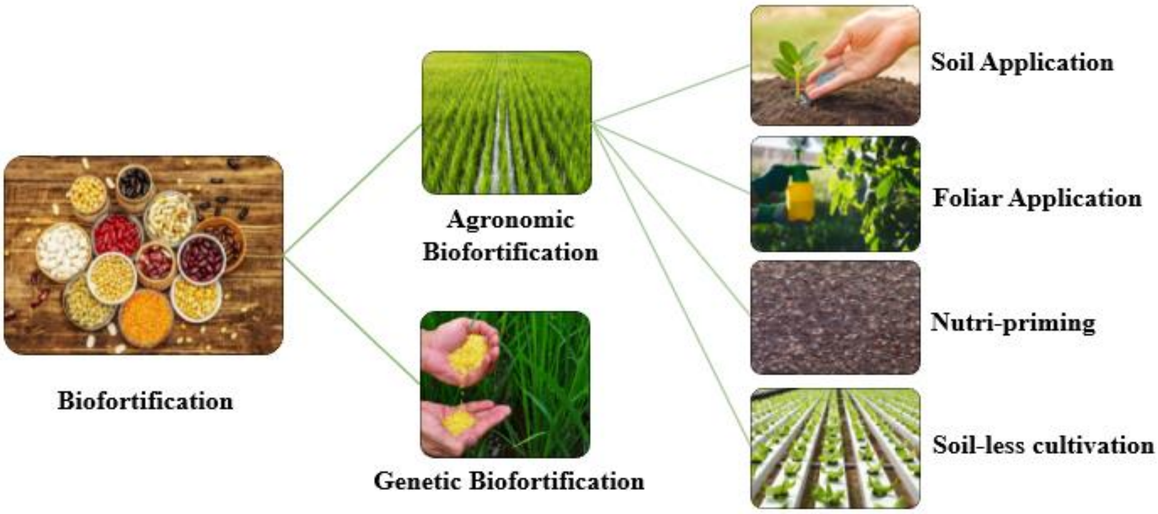

Fig-1: Types of Biofortification

Agronomic Biofortification

Several agronomic biofortification methods have been trialed and appraised on a global scale;

1. **Soil application**: This conventional method restores the soil where the crop is grown. Although, it is a less efficient and results in higher cost of production. It also pollutes the soil in long term due to excessive stagnation of unused micronutrients. In India, due to intensive cultivation, the soil is getting acidic. In acidic soils, the presence of high level of phosphorus negatively impacts the zinc uptake by the crops. This is due to antagonistic behavior between both the nutrients in plant nutrition. Phosphorus being a crucial nutrient, its availability in the soil can't be reduced. So foliar application along with soil application of zinc is done to counter this problem. Moreover, it is said that combination of both the applications is beneficial for increasing the grain yield. Soil application of molybdenum accompanied by foliar treatment of $FeSO_4$.7H2O (0.5%) and $ZnSO_4$.7H2O (0.5%) noticeably increased cowpea production, nodules per plant, nutrient concentration and root length (Dhaliwal et al., 2022). Zinc applied to the soil raised the zinc content in wheat grains from 22.4 mg/kg to 30.6 mg/kg, according to Joy et al. (2015).
2. **Foliar application**: In this method the loss of micronutrients is minimum. Foliar application is viewed as a crucial approach in arid and semi-arid crops. It is the most common method for micronutrient biofortification as it is easy and does not require more infrastructure and technical knowledge. Dola et al. (2022) reported that the foliar application of nano-iron to soybean improved seed yield, quality and drought tolerance. Foliar spraying of FeSO4 at the time of anthesis increased the protein content of grain and the gluten content in durum wheat (Melash et al., 2016). Foliar spraying of iron and zinc each at the rate of 0.1% at the time of silking and grain filling stages resulted in the highest zinc (31.8 mg/kg) and iron (153.6 mg/kg) content of maize (Saleem et al., 2016).
3. **Nutri-priming**: It is the soaking of seeds before planting in a solution containing nutrients (Lutts et al., 2016). This method was initially used to improve seed germination, root growth and yield improvement. It does not add to cost as micronutrients are enriched in the seed before sowing. It is environment friendly and enhance crop yield. However, this method is not very popular as it includes technical primary knowledge. It could also shorten the shelf life of the seeds, so the treated ones would need to be sown right away or stored properly. Nutri-priming with $ZnSO_4$ (0.4%) increased the zinc content in grain by 29% and 12-15% in chickpea and wheat respectively (Praharaj et al., 2019).
4. **Soilless cultivation**: This method is a recent approach towards crop production utilizing inert media with controlled nutrient availability. It ensures inline nutrient uptake, year-

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round production and controls soil limitations. However, infrastructure requirement may increase the cost but it controls weeds effectively and reduces labour. Application of iron chelates in hydroponic condition increased the iron content in rice grains by 51% (Chen et al., 2017).

Table-1: Techniques for application and the percentage of fortification achieved for different micronutrients for various crops.

Application techniques	Crop	Nutrient	Conc. without application	Conc. with application	Fortification percentage	Reference
Soil application	Rice	Zn	18.8 mg/kg	16.9 mg/kg	-10.12%	Joy et al., 2015
	Wheat	Zn	15.8 mg/kg	22.4 mg/kg	41%	
	Maize	Zn	19.0 mg/kg	23.4 mg/kg	23.16%	
	Chick pea	Zn	37.05 mg/kg	39.18 mg/kg	5.75%	Hidoto et al., 2016
		Fe	1.20 mg/100g	3.63 mg/100g	202.50%	Khalid et al., 2015
Foliar application	Rice (panicle initiation and early grain milk stage)	Zn	15 µg/kg	21 µg/kg	40%	Prom-U-Thai et al., 2020
		Fe	11.3 µg/kg	13.2 µg/kg	16.81%	
		Se	404 µg/kg	602 µg/kg	49.01%	
		I	5 µg/kg	133 µg/kg	2560%	
	Wheat (application at tillering, jointing and booting stages)	Zn	54.8 mg/kg	66.3 mg/kg	20.98%	Aziz et al., 2019
		B	2.29 mg/kg	2.87 mg/kg	25.33%	
		Fe	38.7 mg/kg	47.2 mg/kg	21.96%	
		Mn	39.2 mg/kg	47.9 mg/kg	22.19%	
		Cu	6.3 mg/kg	9.3 mg/kg	47.62%	
		Zn	14.3 mg/kg	31.8 mg/kg	122.38%	

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	Maize (silking and grain filling stage)	Fe	74.1 mg/kg	153.6 mg/kg	107.29%	Saleem et al., 2016
Nutri-priming	Mungbean (seed soaking)	Zn	23.58 mg/kg	37.02 mg/kg	57%	Haider et al., 2020

Table-1 depicts the research work of various scientists on different crops using agronomic biofortification methods clearly showing the change in micronutrient concentration in the grains.

Advantages of Agronomic Biofortification

Agronomic biofortification offers several key advantages;

1. It can be applied to existing crop varieties, familiar to the farmers, ensuring increased consumer acceptance.
2. It provides the ability to improve micronutrient levels in crops within the same growing season.
3. Minimum requirement of micronutrients, specifically in case of foliar application.
4. It efficiently presents a win-win scheme for the developing nations.
5. There is no necessity to invest in new varieties of seeds which diminishes losses, cost and time.

Constraints

Agronomic biofortification, while being benefic for improving crop nutrition content, is also prone to crucial challenges that must be addressed to optimize its full potential. This includes;

1. Convenient availability to farmers: Farmers mostly lack in-time access to micronutrient rich fertilizers, which leads to skip of usage resulting in deficiencies.
2. Reduced nutrient use efficiency: Plant absorption of micronutrients such as copper, iron, and zinc is limited due to their low efficiency, ranging from 1-5%.
3. Lack of public recognition: Zinc and iron deficiencies are worldwide but often obscure. Therefore, public awareness is crucial yet challenging.

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4. Safety concerns of biofortified crops: Detailed analysis of biofortified crops is required to ensure their safety before market release.

The Way Forward

In conclusion, soil application and foliar application are the best methods for agronomic biofortification. Promotion of these practices should be encouraged, which will lead to successful increase in nutritional profile of the crops. Furthermore, it is crucial that public sector organizations concentrate their efforts and develop policies for promotional campaigns aimed at augmenting the uptake of agronomic biofortification practices. The supply of micronutrient fertilizers and diverse bio-inoculants, such as PGPR, AMF, and cyanobacteria, can expedite the spread of these practices. The guarantee of premium prices for these products will incentivize farmers to cultivate a greater quantity of biofortified crops. Also, investing actively in extension activities will stir awareness among the farmers and consumers regarding the availability and utility of biofortified crops.

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