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Biofortification Approaches: To Increase the Grain Micronutrient Concentrations in Wheat

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Globally, micronutrients deficiency is a serious health issues concern, leading malnutrition problem within the population. In 2019, the Food and Agriculture Organization (FAO) reported that over 200 million people in India were malnourished (FAO, 2021). Malnutrition resulted mainly due to the deficiencies of vitamin A, zinc, iodine, folate, and iron (Zou et al, 2019). Lack of dietary zinc is a major contributing factor for micronutrient deficiency amongst individuals, more than 2 billion people are at risk of zinc deficiency, even more people are iron deficient and children under the age group of five are stunted (Wani et al, 2022).

Trace elements viz., zinc and iron plays very important role in many enzymes that are involved inthe metabolism of auxin and carbohydrates, protein synthesis, and membrane integrity (Rehman et al, 2018). Zn element shows its role in the development of pollen, fertilization, and synthesis of chlorophyll etc. Fe element may take part in the ETC (Electron Transport Chain), Cyt (Cytochrome) and further aids in the activation of several enzymes.

Wheat (*Triticum aestivum* L.) as cereal staple crop being extensively grown and consumed that can be a suitable target for micronutrients bio-fortification for minimizing the nutritional deficiencies within population in cereal diet-based countries. In wheat, these nutrients are readily available in excess amount in the aleurone layer, but the bioavailability of Zn and Fe are very low due to the presence of anti-nutrients such as phytate present in wheat seeds which is considered as a major factor to chelate the metal ions.

Though there are number of approaches have been made, they aren't cost-effective and sustainable for combating this malnutrition like challenge (Hurrell et al, 2010). Effective approaches to solve this problem are supplementation, dietary diversification, fortification, agronomic biofortification.

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Biofortification of wheat:

Biofortification is the idea of breeding crops to enhance the nutritional value in an economic and sustainable manner (De Valenca et al, 2017). This can be done either by conventional selective breeding method or through genetic engineering. Cereal crops such as wheat usually are mineral deficient due to the presence of some barriers in the potential uptake of soil nutrients, for which fortification is required (Fageria and Baligar, 2008). The continuous applications of weak fertilizers in the field that is poor in mineral concentrations put negative impact on the nutrient availability of wheat (Fageria et al, 2002). So, bio-fortification acts as a possible way of delivering micronutrients within the population who have poor access to nutria-rich foods (Bouis and Saltzman, 2017; Garg et al, 2018). Biofortification in wheat can be done through various approaches such as Agronomic approach through direct foliar or soil application of fertilizers and Genomic approach which include genomic section, Marker Assisted Selection (MAS), and Quantitative Trait Loci (QTL) mapping.

A. **Agronomic Bio-fortification**: Agronomic biofortification can be adopted in the cereal crops either by applying micronutrient fertilizer to the soil or by foliar application directly to the leaves (De Valenca et al, 2017). Generally, farmers have used mineral fertilizers to improve the growth and vigor of the food crops. Also, fertilizer application is also a similay way, up to certain extent to enhance mineral addition by crop so as to increase nutrient concentration (Rengel et al, 1999). To increase the nutrient concentration in grains, understanding the different forms of fertilizers and the timing of soil and foliar application of these minerals is very important (Velu et al, 2013). Micronutrient follows a pathway from soil to crop plants and then from food into the human body. Several factors are affecting the success of agronomic biofortification, which primarily depends upon; bioavailability of micronutrients in the soil for plant uptake (soil to crop), translocation of mineral within plant and re translocation to the harvested food (crop to food), bioavailability of nutrient to human in food and physiological state of human body to absorb and utilize the nutrient (food to human) (De Valenca et al, 2017). Other factors such as soil organic matter content, soil pH, and soil aeration, interaction with other elements, soil moisture content, and the variety of crops determine the extent of bioavailability of soil nutrient to crop (Alloway, 2009). Although the application of nutrients through soil is common, the foliar application is considered to be more effective and economical (Sharma et al, 2020). Agronomic bio-fortification is common solution to the short-term problem as compared to the breeding approach (Cakmak, 2008). However, it has several shortcomings in regards to efficiency, sustainability, and economic aspects. The nutrients may be stored in leaves but not in seeds and fruits. Most often, even if crops accumulate nutrients effectively through the soil, the nutrient may not be bioavailable to the crop due to some limitations (Frossad et al, 2000). Fertilizers must be applied regularly so; this method is unsustainable. The expensive cost of fertilizers is another disadvantage. As compared to Genetic biofortification, agronomic biofortification is less acceptable on the basis of economics and environmental sustainability (Singh et al, 2016). Therefore, agronomic biofortification with Fe and Zn fertilizers, particularly foliar applications, performs well for wheat and provide edible parts of crop plants with sufficient nutrients to combat the global Fe and Zn malnutrition problem. The foliar and soil application of fertilizers in wheat is shown in figure 1.

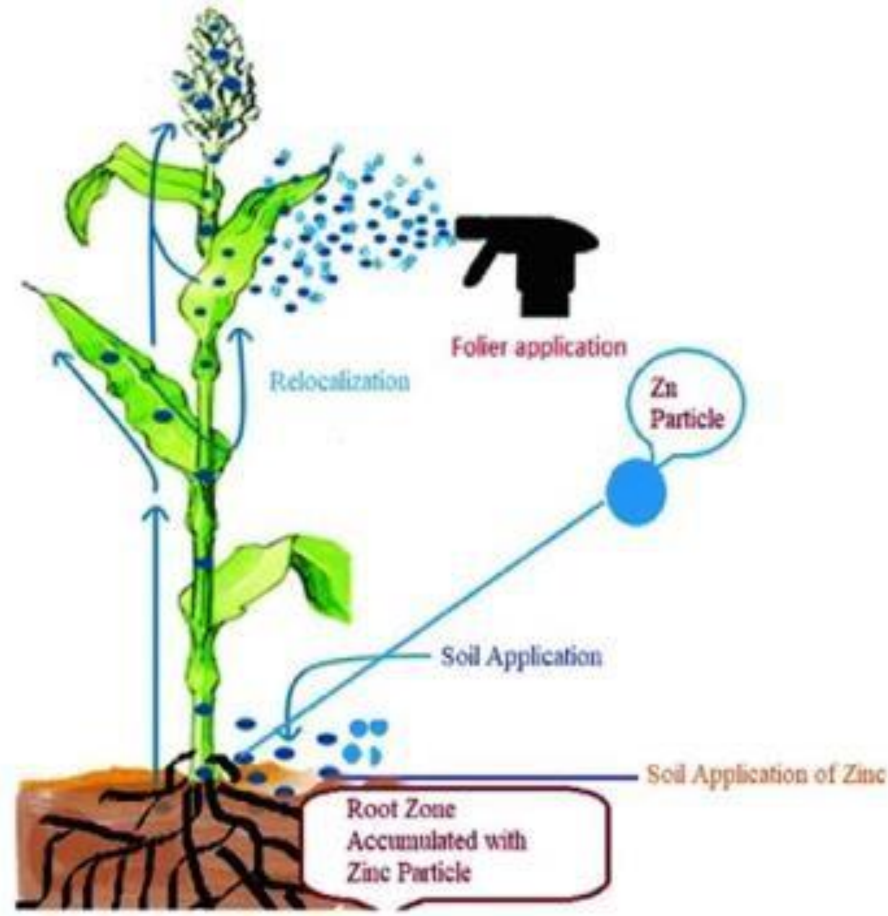

Figure 1: Agronomic biofortification (Foliar and soil application) in wheat

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B. Genetic Bio-fortification: Both conventional plant breeding and genetic engineering technology are applied to increase the bioavailability and the concentration of nutrients in crop plants is known as genetic bio-fortification. Through marker-assisted breeding, gene discovery, or classical breeding strategies can be used to characterize the genetic variations for micronutrient content in the grains (Grusak, 2002). Efficient genetic biofortification enhances the nutrient uptake by plants; increases micronutrient translocation to grains, decreases anti- nutrient compounds, and increases the bioavailability of nutrients (Mulualem, 2015). In recent years, a remarkable improvement has been made in the genetic Biofortification, to reduce the micronutrient deficiencies and provide a sustainable diet-based solution that supplement other interventions (Ludwig and Slamet-Wedin, 2019). The genetic bio-fortification approach is a long term, effective and practical approach to fight against the problem (Saini et al, 2020).

Plant breeders select and breed nutritious cultivar of wheat crop rich in Fe and Zn concentration that increase the micronutrient concentration of Fe and Zn in the developedcultivars. Targeted improvement for nutritional traits has led to the release or testing of 393 nutria- rich crop varieties in 63 nations across the globe and has been proved to be beneficial for 48 million populace (Virk et al., 2021). In India, development of Fe and Zn rich wheat varieties has gained a momentum in last few years. During 2021, 14 biofortified wheat varieties (less than five years old) were included in seed chains, and the highest breeder seed production was carried out in DBW187 (2315q) followed by HD8759 (420q) and DDW 47 (269.10q). During 2020–21, 14 biofortified wheat varieties contributed 19.54% (3334.60q of 17066.35q) of the total breeder seed indent, whereas 3890.60q of breeder seed of 14 biofortified varieties was produced for further multiplication as listed in Table1given below (Kamble et al., 2022).

Table1: Breeder seed indents and production of biofortified wheat varieties during2020–2021 in India.

S.No.	Variety	Growing conditions	Quality trait	Year of Notification	Breeder seed (quintals)	
					DAC Indent	Production (BSP IV)
1	DBW 187	NWPZ (IR-ES & TS) &NEPZ (IR-TS)	Fe (41.3ppm) &Zn (43.7 ppm)	2020	1617.35	2315.00
2	DDW 47 (d)	CZ (RI-TS)	Fe (40.1 ppm)	2020	155.00	269.10
3	PBW 771	NWPZ (IR-LS)	Zn (41.4 ppm)	2020	71.80	80.00
4	HD 3249	NEPZ (IR-TS)	Fe (42.5 ppm)	2020	35.80	40.00
5	PBW 752	NWPZ (IR-LS)	Protein (12.4%)	2019	71.80	77.00
6	PBW-757	NWPZ (IR-VLS)	Zn (42.3 pm)	2019	33.00	33.00
7	HI-8777 (d)	CZ (RF-TS)	Fe (48.7 ppm) & Zn (43.6 ppm)	2018	2.00	110.50
8	DBW 173	NWPZ (IR-LS)	Protein (12.5%) & Fe (40.7 ppm)	2018	170.00	198.00
9	MACS 4028	PZ (IR-TS)	Protein (14.2%), Fe (46.1 ppm) & Zn(40.3 ppm)	2018	2.00	5.00
10	UAS-375	PZ (RI-TS)	Protein (13.8%)	2018	2.00	3.00
11	PBW 1 ZN	NWPZ (IR-TS)	Fe (40 ppm) & Zn (40.6 ppm)	2017	191.00	240.00

12	WB-2	NWPZ & Bihar (IR-TS)	Zn (42 ppm) & Fe (40 ppm)	2017	80.20	90.00
13	HD-3171	NEPZ (RI-TS)	Fe (47.1 ppm)	2017	56.45	10.00
14	HI 8759	CZ(IR-TS)	Fe (41.1 ppm) & Zn (42.8 ppm)	2017	846.20	420.00
	Total				**3334.60**	**3890.60**

Conclusion:

Wheat contributes nearly one fifth of total daily dietary energy requirement globally and biofortified varieties can be a proven source for improving nutritional health. It is clear that genetic and agronomic biofortification offer sustainable solutions to the escalating micronutrient-related malnutrition problems. Genetic and agronomic biofortification approaches are actually not separate solutions; they are complementary and synergistic to each other. Targeted breeding for increased Zn and Fe could significantly impact the development and release of biofortified wheatvarieties in India.

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