1 Agronomical Approaches for Biofortification of Cereal Crops

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Abstract

Cereals are the primary staple food crops based on a traditional diet in developing countries; sometimes, rice, wheat, or corn constitutes the entire diet. Half of the global community depends upon grains such as rice, wheat, and maize for consumption, which provide 30.4% of total energy and 20%–30% of protein for the average polish diet for day-to-day activities. More than a third of the world's population is deficient in micronutrients, vitamins, and minerals; notably, 60% suffer from iron and 30% from zinc deficiencies. The quantity of trace elements like iodine (I), selenium (Se), etc., are also found only in minute quantities in the cereal grains. These trace elements act as precursors of vitamins and minerals and are also necessary to fulfill dietary requirements. The WHO has predicted deficiencies of multinutrients to nearly 2 billion people worldwide, which gives birth to the global hidden hunger and malnutrition that affect children's mental and physical capabilities and development. The deficiencies of micronutrients can be alleviated by dietary diversification, extra input of mineral elements, food fortification, and crop biofortification. But this is probably not the case for poor people, especially in developing countries. Biofortification is an essential process of enriching crops with higher nutrients, vitamins, and minerals using agronomic methods, plant breeding, and biotechnological approaches. Biofortification aims to increase the nutritional content of the diet

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by increasing the available content of micronutrients and vitamins. The agronomic approach to biofortification of food crops is reasonable and cost-effective, which depends on several factors such as management practices, soil factors, plant factors, etc. It is a practical solution to overcome micronutrient deficiencies in different cereals that optimize fertilizer application with different strategies to improve the nutrient quality of crops without scarification on yield with no objection to the acceptance of the product.

Keywords

Cereals · Biofortification · Agronomic biofortification · Hidden hunger · Micronutrients

1.1 Introduction

As the proverb "Health is wealth," health is the greatest asset for a human being. A good and nutritious diet is the secret of a healthy life, and it also depends on the intake of a balanced diet. To date, the global agriculture sector is focusing on the higher crop production to feed the growing population. The way of farming has changed after the green revolution for achieving higher production in all possible ways that have disturbed nature's harmony due to overapplication of fertilizer, high-yielding varieties, and overproduction from the soils. The use of an excessive and unbalanced amount of fertilizers in the field leads to a deficiency of essential nutrients in food crops which ultimately affects the health of human beings.

In these groups, micronutrients are the main precursors of amino acids, proteins, and vitamins. The deficiency of these micronutrients will be a significant cause of "hidden hunger" due to "micronutrient malnutrition." It is mainly seen in poor and developing countries, where staple food crops such as rice, wheat, ragi, millet, and maize dominate the diet (Khush et al. 2012). Current agricultural systems are trying to replace food crops with insufficient nutrients and focusing on nutrient-rich food crops to facilitate the fight against nutrient deficiencies. But in the present situation, cereals are the major food crops across the world. Its availability and a major component of the diet led to an imbalance in the nutrients. The replacement of traditional staple food crops is not possible in developing and nondeveloped countries due to the economic condition of the people. Therefore, the only possible way to fight such conditions is to enrich the micronutrient content in staple food crops to protect the peoples from micronutrient deficiency without changing their stable diet. Such enrichment is called biofortification.

Biofortification of crops is a promising, sustainable, and cost-effective technique of delivering micronutrients to populations with limited access to diverse diets and other micronutrients. In biofortification, the density of essential ingredients like vitamins, minerals, amino acids, etc., in important food crops is increased to upstand the quality of diets (Bouis and Saltzman 2017). It offers sustainable production of nutrient-rich food crops and assures its availability, especially to poor peoples in developing nations. Biofortified crops with better bioavailability of necessary micronutrients are the best way to create rich food availability through traditional farming and food trade activities. It can help to provide people with a wide variety of foods in the diet of malnourished and low-income groups in a viable way. Based on the examined economic perspective, the development of biofortified crops is a one-time investment that provides a cost-effective solution to combat micronutrient malnutrition. Once biofortified crops are generated, there is no further investment for supplementation, and they are incorporated into food resources at the time of processing (Pfeiffer and McClafferty 2007).

Agronomic biofortification helps in the better growth and development of plants. It helps improve the nutrient profile of the crops in which the required elements are present in less quantity or absent. It also helps develop better agronomic characters (yields, resistance to pests, tolerance to stress), increases food availability, and helps in the fight against poverty and starvation. Some research suggested that micronutrient quantity in the crops required more effort and information to increase the essential micronutrient content affected by different factors. These factors have an influential role, from crop sowing to crop harvest and postharvest storage. Among these factors, soil, pH, available nutrient, texture, organic matter content, soil water relationship, rainfall, and temperatures are essential. Future research for better management and agronomic practice needs to be identified to maintain or improve the crop yield and its nutritional content sustainably (Hornick 1992).

1.2 The Global Prevalence of Micronutrient Deficiencies

The source and sink relationship is well known to everyone. This relationship can also be compared with the host and guest. Similarly, food crops also depend on their host/sink for the nutrient's uptake. If the availability of nutrients is not sufficient to be utilized by the plants, it becomes deficient or limits minerals to plants, which ultimately affects the food synthesis system of a plant. However, a plant can survive or adjust to any environmental system, but it creates a severe issue for humans because humans eventually depend on the plant for food as a sink. The resulting deficiency of nutrients in staple food crops (wheat and rice) becomes a global health problem, affecting the physical and mental development of children and pregnant women due to malnutrition and ultimately resulting in increased susceptibility to the disease that caused illness to mental health, blindness, and loss of productivity. According to WHO-estimated reports globally, more than 2 billion people are affected by micronutrient deficiencies.

In contrast to macronutrient, micronutrient, vitamins, and minerals are required in lesser quantities, and among them, iron (Fe), zinc (Zn), calcium (Ca), iodine (I), vitamin A, B complex, and vitamin C help the cell to perform essential biological processes. Improper diet and imbalance in the nutrient were observed in the developing countries. Every year nearly 40% of preschool child and most pregnant women are suffering due to anemia. According to FAO, such types of malnutrition problems have been mostly observed in developing countries worldwide, whereas

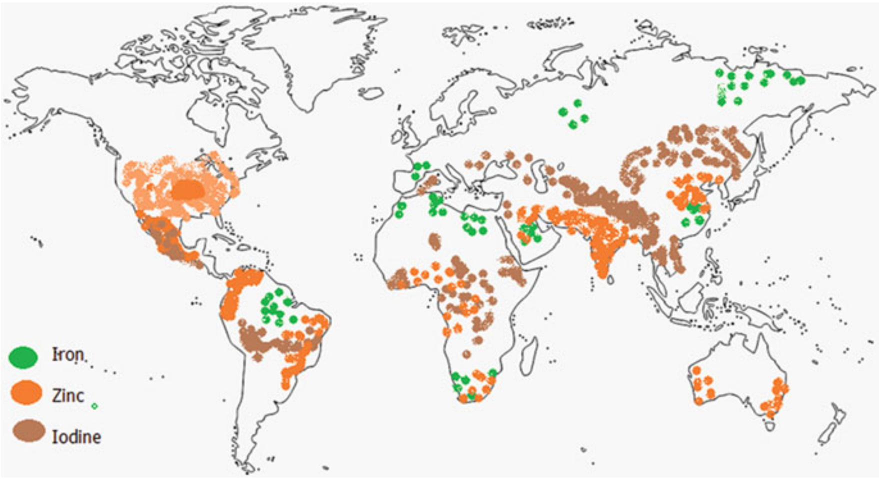

Fig. 1.1 Countrywide deficiency of mineral nutrient in the crop plants indicated in the world graph

780 million people out of 792.5 million world undernourished people belong to the developing countries (McGuire 2015).

These days, micronutrient deficiencies have become common among people due to change in eating habits toward fastfood that is unbalanced dietary habits. Most of the world's population is suffering from various nutritional deficiencies such as 60% iron (Fe), 30% zinc (Zn), and iodine deficiency, and 15% of the people are suffering from selenium deficiency other than calcium (Ca), copper (Cu), and magnesium (Mg) deficiency available communally (Kaur et al. 2020). According to a report published by WHO (World Health Organization), zinc deficiency is the fifth leading cause of disease and disorders in developing countries and 11th globally. Micronutrient deficiencies in soil vary from place to place and around the world. The soil present in almost all continents is the deficit in Zn. America and the southern parts of Asia mostly suffer from Zn deficiencies. Iron deficiency is predominant in southern parts of America, Africa, and northeast Asia. Iodine is deficient in soils of eastern regions of Asia and Central Africa (Fig. 1.1).

About half of the world's population are suffering from micronutrient malnutrition, including Se (selenium), Zn (zinc), and I (iodine), which are primarily associated with low dietary intake of micronutrients in a diet with a low variety of food (Mao et al. 2014). Crops are the primary source of essential nutrients, which provide food and energy to the living being. Among all the crops, three bowls of cereal crops are the stable and dominant food source to the four billion people and about 60% of plant-based energy intake by the human being (Frison 2016). But they do not get enough essential nutrients required in a human being's diet due to a deficit in soil and plants. The status of micronutrient deficiencies in the global soil system is displayed in the graph below (Fig. 1.2.).

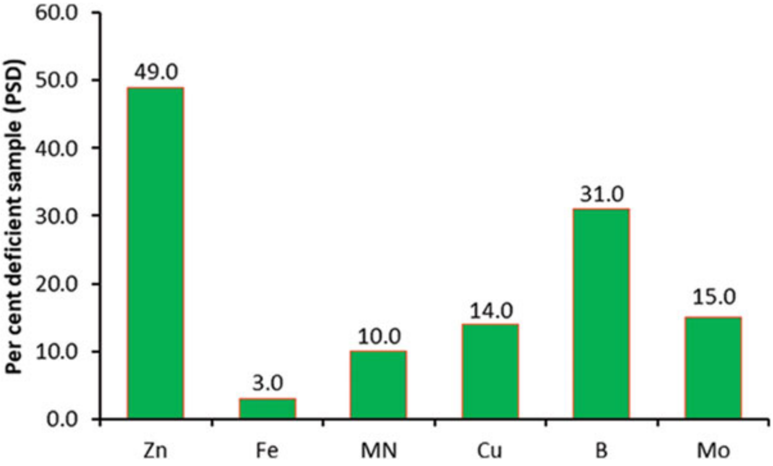

Fig. 1.2 Global status of micronutrient deficiency in a worldwide agricultural soil

1.3 Micronutrient Status in Indian Soil

India built up adequacy in food production in the mid-1960s after introducing high-yielding varieties that responded well to fertilizer application. The increased cropping intensity and exhausted uses of major fertilizers like NPK resulted in a lack of secondary nutrients and micronutrients. The shortcoming of nutrient or unavailability of essential nutrients from food crop becomes a critical hurdle for incrementing sustainable crop yield that has been commonly observed in crops such as cereal, oilseed, legumes, and vegetable crops. Crops grown in approximately half of the soils in the country suffer from several micronutrient deficiencies (Takkar et al. 1990). According to the study of more than two lakh samples of soil collected from 508 districts of the country, on average, 36.5%, 12.8%, 7.1%, 4.2%, and 23.2% of soils are deficient in Zn, Fe, Mn, Cu, and B, respectively. More than 50% of the samples are found inadequate in Zn and B in 110 and 63 districts, respectively (Table.1.1). The deficiency of nutrients in the Indian soil is represented in the graph in Fig. 1.3. Field-scale zinc (Zn) deficiency was first observed in the Tarai soils (molisols) of the Himalayan foothills, causing complete failure of the rice crop (Nene 1966). This type of Zn deficiencies has been observed strictly in alkaline soils where high yielding rice and wheat varieties are cultivated intensively. Initially, zinc (Zn) deficiency, and later iron (Fe) deficiency in rice, and manganese (Mn) deficiency have been observed in wheat, leading to reduced yield in crops.

Table. 1.1 The spectrum of micronutrient scarcity in soils of India (Shukla et al. 2021)

	Percent deficient sample (PSD)					
States	Zn	Cu	Fe	Mn	B	Mo
Andhra Pradesh	46.8	<1.0	2.8	1.2	53.0	49.0
Assam	34.0		2.0	20.0	17.0	
Bihar	54.0	3.0	6.0	2.0	1.0	1.0
Gujarat	23.9	4.0	8.0	4.0	57.0	8.0
Haryana	60.5	2.0	20.0	4.0		
Himachal Pradesh	42.0	0.0	27.0	5.0	32	5.0
Karnataka	72.8	5.0	35.0	17.0	53	49
Kerala	34.0	3.0	<0.1	0.2	17	
Madhya Pradesh	44.2	<1.0	7.3	0.2	49	30
Maharashtra	83.0	0.0	24.0	0.4		
Meghalaya	57.0	2.0	0.0	23.0		
Orissa	52.5	<1.0	0.0	0.6		
Pondicherry	8.0	4.0	2.0	3.0		
Punjab	46.1	1.1	14.0	2.3		
Rajasthan	21.0				14	
Tamil Nadu	58.6	6.0	17.0	6.0	68.0	
Uttar Pradesh	45.7	1.0	6.0	3.0	45	12
West Bengal	36.0	0.0	0.0	3.0	49	30

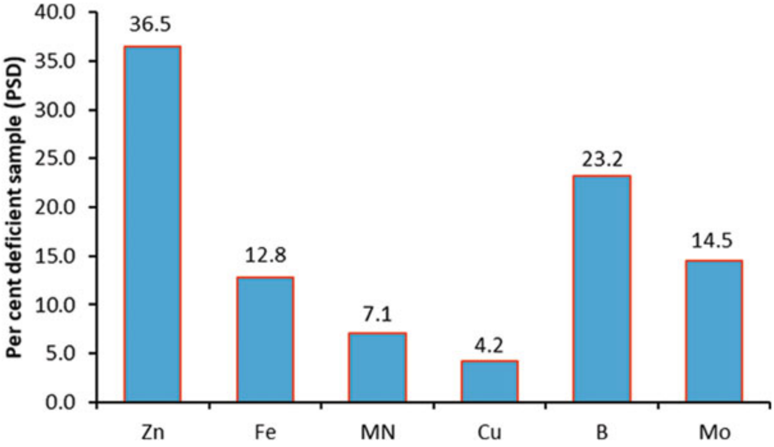

Fig. 1.3 Micronutrient deficiency in Indian soils (Shukla et al. 2019)

1.4 How to Fight Against Micronutrient Malnutrition?

The condition of malnutrition occurs due to the unavailability of essential supplements in diets such as vitamins, minerals, and micronutrients that contribute to the deaths of about 20% of children under the age of 5years. Some of the children go blind permanently every year due to vitamin A deficiency. Iron deficiencies cause anemia, mainly affecting children and women. In adults, it causes a reduction in the working and standing capacity, sometimes reproductive impairments. The strategies to fight hidden hunger globally are as follows:

1. Dietary diversification and food fortification.
2. Supplementation of specific micronutrients.
3. The intervention of horticulture crop to ensure regular consumption.
4. Prevention and control measure of public health and other diseases.

In India, a program is implemented to prevent deficiencies in preschool children and women, with special care of pregnant women. Under this program, there is a periodic distribution of vitamin A, iron, folic acid tablets, and iodized salts. However, these programmers have been running for decades. They do not have any biological impact on micronutrient malnutrition prevalence. The aim of fighting against malnutrition can be achieved successfully by utilizing nutrient-rich food in main diets instead of additional supplements. There is a way implemented to increase the nutrient of the crop, known as biofortification. Several biofortification techniques are used to enhance nutrients, such as agronomical biofortification, conventional plant breeding, genetic modification, etc. Agronomic biofortification benefits fast application and a simple process of biofortification of crops that can help develop crops in poor mineral soils—objectives and advantages of biofortification that help fight against micronutrient malnutrition.

The significant goals of biofortification are the following:

- To provide enriched food with the essential nutrients in the main diet rather than to take an additional supplement.
- To alleviate the micronutrient malnutrition from the developing countries.

Biofortification is a cost-effective approach to provide nutrient enhancement from the food source. It is a feasible and natural way of supplementing the nutrient. The process of biofortification improves soil's physical and chemical properties, and the plant gets benefitted after fortification in terms of production, vigor, quality, and stress tolerance. Soil health in cultivated land declines due to the depilation of various micronutrients in monoculture and improper fertilizer application (Bouis and Saltzman 2017). The process of agronomic biofortification helps in improving the physical and chemical properties of the soil, leading to higher crop yields.

1.4.1 Biofortification by Agronomic Practices

The process of biofortification requires a long time, but with agronomical practice, it can be achieved in a short time in a cost-effective manner (Hefferon 2015). The agronomic biofortification process is a simple, inexpensive method that requires a variety of physical methods to improve the nutritional and health status of crops and soils (Cakmak and Kutman, 2018). Agronomic strategies are effective in increasing crop yield and nutritional quality. These strategies include the use of appropriate amounts of NPK and S fertilizers along with other agrotechnical measures such as crop rotation, soil moisture management, tillage, and organic farming. The application of micronutrients, mineral, and nutrient-deficient soil is ultimately used to enhance the quality of crop grains and mineral and nutrient deficiencies used to supply through fertilizers. Fertilizer application to crops depends on the stage of their growth and development, which can be done through various methods such as seed treatment, soil application, and foliar application (Yang et al. 2011). Micronutrients can also be applied along with soil amendment substances to increase crop yield and nutritional quality (De Valença et al. 2017). Fertilizers, along with organic matter, significantly improved micronutrient content in soil and enhanced their bioavailability.

Additionally, the cropping system, intercropping, and crop rotations improve yield and quality of crops (Zuo et al. 2004). The application of zinc fertilizer and green manure has been seen as effective in the grain quality and quantity of Basmati rice in India (Pooniya and Shivay 2013). Foliar application is an effective and useful agronomic biofortification approach that provides mineral in the most appropriate ways known as phyto-available form (Lawson et al. 2015). However, it is not a feasible approach in windy and rainy areas. There is no single approach to get superior results in biofortification. Nevertheless, the incorporation of high Fe and Zn content into edible parts of plants requires integrated management of micronutrients.

Agronomic biofortification increases the targeted mineral's dietary intake directly from the plant to its edible portion of the crops. Such biofortified crops can reach the most vulnerable and poorest peoples, which impart a nutritionally significant impact on farmers and consumers' lives. Today more than one million people in Asia, Africa, and Latin America benefit from using biofortified foods. There are different agencies and organization who have been playing a prominent and outstanding role such as Harvest Plus and Biofort; grand challenges on global health, India biofortification program, and organization also play an essential role in food crops such as wheat and maize from the International Maize and Wheat Improvement Center (CIMMYT), vitamin-A- and zinc-enriched maize varieties from the International Institute of Tropical Agriculture (IITA). Biofortification aims to ensure the availability of essential micronutrients, vitamins, and minerals required in amounts of less than 1 mg/day. Agronomic biofortification strategies are conducive and virtuously effective in improving food quality. This approach entirely depends on the application of fertilizer and micronutrients. The application of micronutrients depends on crops' requirements without wastage of these supplements to give a fair and cost-effective way to produce biofortified crops. There are different ways to provide these supplements to the plant; the most common and conventional fertilizer supply method to the plant is the soil's application; another one is a foliar application (Cakmak 2010). An integrated approach of micronutrient application emerged as the most significant and critical factor in agronomic biofortification. It becomes more effective by combining NPK with organic fertilizer and high yielding varieties (De Valença et al. 2017). Eventually, it will result in the increment of nutritional quality and yield of the crops that directly benefit human health by making the availability of vital microelements.

1.4.1.1 The Agronomic Measure of Biofortification

- Site-specific application of fertilizers.
- Application of fertilizer with coating, e.g., zinc-coated fertilizer.
- Use of soil amendments in the problematic soils, e.g., lime in acidic soil and gypsum in salt-affected soils.
- Application of biofertilizer and green manures, e.g., *Rhizobium, Azotobacter,* and *Azospirillum.*
- Balanced application of N, P, K, and S fertilizers.
- Crop rotation.
- Soil moisture management and tillage practice.

1.5 Agronomical Practices for Biofortification in Cereals

Cereals *are a*n essential part of the dietary requirement in most people. Therefore, the biofortification of cereals is more imperious (Cassman 1999). In poor and low-income countries, people do not have access to the right quality of foods, health care, and living condition. In such places, especially women are more vulnerable to chronic diseases. To date, we are trying to focus on the biofortification of significant and stable food crops of cereals such as wheat, rice, maize, barley, sorghum, millets, oats, and rye. It can provide most of the essential mineral elements required for humans' well-being (Graham et al. 2007). The flow of nutrients always occurs in a pathway from producer to consumer or from source to sink; in the case of essential micronutrients, they flow from soil to plant and then to humans, which is the final consumer in most cases. The micronutrients are absorbed by the plant and deposited in their edible form for storage such as Fe, Zn, Co, Mn, I, Se, Mo, Co, and Ni, with varying amounts. Several factors are involved in agronomic biofortification's success to gratify micronutrients deficiencies from the population. These factors affect the bioavailability of nutrients from food to humans such as the uptake of nutrients from the soil to crop. These factors include the allocation of nutrients within the plant, the retransfer of the part of the plant consumed by humans (food from the crop), the process of preparing food (from food to humans), and the physiological state of the human body that determines its ability to absorb and use nutrients (Fig.1.4.) (Mayer et al. 2011). The soil has various complex systems that influence the availability of micronutrient uptake from soil to crops, such as physical and

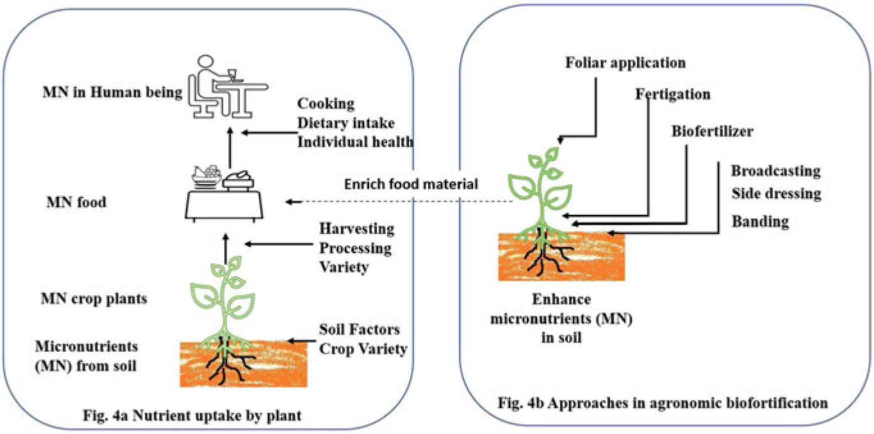

Fig. 1.4 The flow of micronutrients from plant to human

chemical properties, including pH, organic carbon, soil moisture, aeration, and interactions of other elements. It is also influenced by the farmers' crop variety, as the absorptions depend upon the structure and functioning of the root systems. The diversity of microorganisms in the rhizosphere region promotes plant growth and enhances nutrient mobility, thereby improving the nutritional status of the edible parts.

1.5.1 Biofortification Through Fertilization

The deficiency of micronutrients in the soil can be improved by adding mineral fertilizers to the soil. Vigilant use of chemical fertilizers can increase the soil nutrient status and absorption by the crops, leading to the biofortification of crops and enhancing the yield and nutritional quality sustainably with the balanced combination of primary and secondary micronutrients in the small amounts (Voortman and Bindraban 2015). For example, adequate application of phosphate fertilizers can stimulate root growth and, thus, micronutrient uptake. It has been observed that the presence of P fertilizer or the addition of small amounts of P fertilizer in the soil does affect the availability of Zn that lead to deficiencies of Zn in the soil, resulting in the reduction of Zn uptake from soil to plants (Zingore 2011; Singh et al. 1988).

1.5.1.1 Fertilizers Application to Enhance Micronutrient Elements in Cereal Crops

The green revolution helps to sustain and enhance the productivity of agricultural products. But this was achieved by utilization of higher dose of chemical fertilizer and high yielding varieties. Fertilizer application is an important step in maintaining soil fertility and increasing the yield of crops. It has been observed that the application of NPK fertilizer improves the yield and vigor of the crop (Brady and Weil

2008). Fertilizers provide essential nutrients to the crop plants for germination, flower development, and grain formation. Many fertilizers used to work with soil and help in maintaining soil moistures, airflow, and better root developments. The proper supplies of nutrients in the crop plants can be achieved by exploring micronutrients' genetic variability in the crop plants. Various external and internal factors must be considered to determine the inadequate supply of the micronutrients Zn, Fe, Mn, Cu, and Se. Because of high environmental factors, epically the soil variability required higher knowledge and advanced technology to determine the exact demand and nutrient variability among the crop plants. That can be succeeded by agronomic intervention and the external supplies of the fertilizer to the crop plant. To supply these essential nutrients to the crop plants there are various commercial fertilizers are available, which apply to the plant using different mangement practices, cropping systems, and equipments.

1. Broadcasting: Applied in larger fields, incorporated with the help of cultivator, left in the soil to filter the nutrients.
2. Banding: Used to apply for a small number of fertilizer requirements in small areas, in the no-tillage cropping system, involved in the furrows as the in-band pattern, e.g., anhydrous ammonia and liquid nitrogen.
3. Side-dressing: Fertilizer used to apply in the soil after the plant growth (early to mid-growth). Fertilizer can be broad using a hand near the plant or banded down in the middle row, e.g., nitrogen fertilizer is more often used in this way.
4. Fertigation: Application of fertilizer with irrigation of water known as fertigation. For example, nitrogen and potassium are most used in this method, but the application of phosphorous required extra care during application because it is used to form clog due to the variation in the pH.
5. Foliar application: Plants have more advantages in using the foliar application because of the plants' rapid absorption and utilization. At the plant's critical requirement, this method can also be applied in the soil, but it is not suitable for soil application.

There are different criteria for the classification of fertilizer. The most common standards are defined by Arnon 1954, for the requirement of nutrients to the crop plants, and are categorized in the following manner.

1. Based upon nutrient composition:
   (a) Straight—e.g., urea, ammonium sulphate, potassium sulphate.
   (b) Complex—e.g., DAP.
   (c) Mix fertilizer.
      - Open formulated fertilizer mixture—e.g., quality of ingredients are disclosed.
      - Closed formulated fertilizer mixture—e.g., quality of ingredients are not disclosed.
2. Based on physical forms:

Table 1.2 Percentage nutrient content in micronutrient fertilizers

S. No	Source	% Nutrient
1	Magnesium sulfate (Epsom salts)	9% Mg
2	Magnesium-potassium sulfate	11% Mg
3	Dolomitic limestone	9% Mg
4	Magnesium oxysulfate (granular)	36% Mg
5	Calcium sulfate (gypsum)	15%–18% S
6	Ammonium sulfate	24% S
8	Borax	10%–15% B
9	Solubor	20.5% B
10	Calcitic limestone	35% Ca
11	Calcium sulfate (gypsum)	22.5% Ca
12	Iron sulfate	40% Fe
13	Manganese oxysulfate	28% Mn
14	Manganese chelates (soluble powder)	20% Mn
15	Zinc oxysulfate	36% Zn
16	Zinc chelates (soluble powder)	25% Zn

 (a) Solid fertilizer—e.g., in the form of crystals, prill, and super granules.
 (b) Liquid fertilizer—e.g., N, P, and K entirely dissolved in water.

3. Secondary and micronutrient fertilizer; required in small quantity (PB1637 2017) (Table 1.2).

1.5.2 Application of Micronutrient Fertilizers

The uptake of nutrients in plants can be increased by the use of fertilizers containing micronutrients. This can be achieved either by applying fertilizer to the soil or directly applying foliar to the plant. Plants can now absorb nutrients and enhance the nutritional quality of crop production. However, it is a crucial practice used to strengthen zinc concentrations in cereal grains. The practical methods are applying combined micronutrient compounds and N, P, K fertilizers or formulation of compound fertilizers by coating complexes with micronutrients or by a bulk blending of micronutrients with granular fertilizers (Singh and Singh 2013).

1.5.3 Application of Other Soil Amendments

The bioavailability of micronutrients can also be improved by using soil additives such as lime, organic matter, etc. This will enhance soil conditions and accelerate the absorption of micronutrients in plants.

1.5.4 Inoculation of Biofertilizers to the Soil

Biofertilizers are natural fertilizers that contain microbial strains. These microbes keep the soil in a healthy condition and increase the availability of nutrients to the plants. Various microorganisms such as *Bacillus, Pseudomonas, Rhizobium, Azotobacter,* etc., are generously available in the soil, which can be used to increase the mineral phyto-availability in the cropping system (Smith and Read 2010). The addition of various microorganisms increases the bioavailability of multiple micronutrients by converting them from complex organic forms to more available inorganic forms through the solubilization process. The addition of nitrogen-fixing bacteria in nitrogen-limited soils increases productivity by fixing atmospheric nitrogen (Sprent et al. 2004). The high availability of nitrogen stimulates plant growth and also helps in the absorption of other micronutrients. Mycorrhizal fungi, found attached to crops, can release organic acids, siderophores, and enzymes, which can degrade organic compounds and increase mineral concentrations in the edible part of plants (Cavagnaro 2008). There are various successful agronomic biofortification examples in cereal crops, such as rice, wheat, maize, barley, and sorghum.

1.6 Rice

Worldwide, cereal crops are grown over a large area and provide more energy. Rice is one of the most consumed cereal crops of the rural household. More than half of the world's population depend on rice for their one-time meals. The Asian continent has more than 90% of rice consumption and production worldwide (Cavagnaro 2008). India is the second-largest producer and the largest consumer of rice (USDA 2019). In rice, zinc deficiency is a significant problem that occurs in rice grains. Foliar supply of zinc fertilizers is the standard method to overcome zinc deficiency of rice crops. It increases the concentration of zinc in rice grains (Singh and Singh 2013). However, foliar sprays serve as a valuable method of fertilizer applications into the various crops. But in rice, soil application of Zn fertilizers works well in soils deficient in Zn in rice (Guo et al. 2016). The application of zinc fertilizer for the efficient improvement of Zn content in grain depends on the soil and climatic factors of the regions. In general, zinc sulfate heptahydrate ($ZnSO_4.7H_2O$) at 10–20 kg/ha can be applied in zinc-deficient soil.

To maximize the uptake of micronutrients and enrichments of crop produce, the combined application of fertilizers in the soil and foliar application substantiates a practical approach (Singh and Singh 2013). However, iron's foliar application has a strong effect in promoting iron concentration in the rice grain. Also, the fortification of ferrous sulfate in germinating rice plantlets increases the iron concentration in brown rice (Yuan et al. 2013). Similarly, foliar application of selenium in rice works very well. Selenium is an essential trace element for humans that helps enhance immunity by acting as a potential antioxidant (Ram et al. 2016).

1.7 Wheat

Agronomic biofortification can be effectively used to improve the quality of wheat grain. The incorporation of iron and foliar application of nitrogenous fertilizers have been correlated with higher iron accumulation (Zou et al. 2012). In all the cases, foliar application of zinc worked well and helped reduce Zn deficiency disease, particularly in zinc-deficient soil and conjointly improved its bioavailability and reduced antinutrient factors like phytate (Yang et al. 2011). Zn deficiency in wheat is primarily due to the shortage of soil moisture because of irregular and scanty rainfalls, so proper irrigation management also triggers the Zn content in wheat grains. Zinc fertilizer has significant effects on the increment of wheat grain. The wheat-growing area has also been observed with the application of NPKs in the field from 1994 in Turkey with the record yield improvement of 400,000 tons per annum in 10–15 years. In rural areas of Turkey, the improved quality of wheat with Zn has directly benefited human health because the majority of Turkey's population depends on wheat for more than 50% of calorie uptakes on wheat (Cakmak 2008). Since 1984, compound fertilizers supplemented with Se have been used, which results in increased selenium in humans. Researchers have also investigated the role of biofertilizers and chemical and organic fertilizers, in improving grain yields. The addition of organic manure was found to be effective positively with the essential element in wheat grains. Conjugate application of chemical and organic fertilizers was found to strengthen the micronutrient uptake in wheat crops (White and Broadley 2005). Integrated use of AMF (arbuscular mycorrhizal fungi) and fertilizers was also found to have a synergistic effect on micronutrient uptake in wheat. We cannot neglect the role of microorganisms' in modern agriculture with various advantages supporting micronutrients to the plants. The Zn solubilizing bacteria *Bacillus aryabhattai* has a significant role in plants' growth by nutrient mobilization from the vertisols in Central India (Ramesh et al. 2014). However, iron enrichment in wheat grain has been achieved successfully by integrating organic and chemical fertilizers (Ramzani et al. 2016).

1.8 Maize

Zinc is the major micronutrient affecting the yield and nutrient quality of maize grains. To enhance Zn concentration, various treatments for zinc fertilizer and foliar applications were performed in maize crops (Alvarez and Rico 2003). Agronomic approaches with the integration of PGPR (plant growth-promoting rhizobacteria) helps in the uptake of nutrients from the soil to plants which has become an effective strategy for biofortification of staple crops. The use of biological agents with ash can efficiently reduce the Cd content in maize grains (Fahad et al. 2015). Selenium content can enrich food grains with biofertilizers as part of agro-based biofortification that ultimately impact the health of humans and animals (Ros et al. 2016).

1.9 Barley

Barley is one of the most critical cereal grains known from ancient times for its nutritional quality, health benefits, and delicious flavor worldwide. Barley is used as animal feed, fodder, and for malting purposes. In the ancient literature of the world, barley is also known as "king of grains" due to its health benefits. Barley is a storehouse of dietary fibers ranging from 11% to 34% for nutritional fiber, while soluble dietary fiber is present in 3% to 20%. Soluble fibers contain beta-glucan, pectin, and hemicellulose, which have been associated with many health benefits.

Even though being known as the king of cereal, barley requires improvement in the nutrient profiles that can be achieved by applying various organic and inorganic biofertilizers. The application of biofertilizer and inorganic manure and compost has worked well in barley to improve zinc and iron concentrations (Maleki et al. 2011). Some of the barley's antinutritional factors reduce the bioavailability of nutrients in barley that can be reduced by increasing nutritional enhancer levels. Biofortification barely enhances the concentration of Se in its grain, which helps in the adequate supply in the food of humans and animals with a lot of health benefits such as prevention of cancers, immunity boost up, and prevention of several cardiovascular diseases. Se-biofortified grains help in the development of good beers. The organic form of selenomethionine is more efficiently absorbed in the human body compared to the inorganic forms, which is also not affected by the antinutritional factors (Rodrigo et al. 2014).

1.10 Sorghum

Sorghum is also known as "great millet" with a nutty flavor and chewy texture, which were initially domesticated in Africa. This crop often suffers the challenge of growing in nutrient-poor and contaminated soil. Cultivation of sorghum is often faced with the challenge of growing it in nutrient-depleted soil with little care. But the biofortification strategy in sorghum has a positive impact on the quality and quantity of its yield. In addition, the use of Azospirillum alone or in combination with other bacteria that can provide soluble phosphate content in soil results in increased grain yield and nutrient content such as proteins, amino acids, etc. (Patidar and Mali 2004).

1.11 Application of Prebiotics as Micronutrient Promoters

Application of prebiotics to the crop plant works as a booster for crop plants' growth and development. The use of prebiotic works as a stimulator to the plant and helps absorb several minerals to improve the update of micronutrients by increasing the availability of Fe, Zn, Se, etc. (Choudhari et al. 2008). These micronutrients also work as a biostimulant by enhancing crop productivity, nutritional quality, and plant capacity to withstand environmental stress. These micronutrients become available in the soil due to the process of mineralization. Still, they are not readily available to the plants due to adsorption by the soil colloids (microscopic particles of soil) or becoming a saline soil solution. The best alternative source is for the easy uptake of micronutrients by the plants' decomposition of organic matter. There are different factors to consider for the availability and uptake of micronutrients in crops (Sims 1986: Laurent et al. 2020).

- Low (less than 2.0%) and higher (over 30% to a depth of 30 cm) percentage of organic matter in the soil.
- Cool or wet region soil.
- Higher pH of the soil (molybdenum is an exception).

Adsorption reaction, precipitation reaction, nutrient cation form, variable charge in minerals (e.g., Fe oxide), and environmental conditions play a major role in the availability of micronutrients to plants. Among the micronutrients present in the soil, the plant used to uptake most of them in their cationic form (Fe, Mn, Cu, Zn, Ni, and B), whereas Mo and Cl took in their anionic form (Welch and Shuman 1995). Unfortunately, there is a lack of knowledge about the uses of prebiotic in the crop plant for biofortification of crops. The benefits of plant biostimulants or prebiotics increase the interest of farmers and agrochemical industries as they increase nutrient use efficiency. Using this prebiotics with the arbuscular mycorrhizal fungi in crop plants' roots helps uptake water and nutrient from the soil, especially in the low fertile soils (Rouphael et al. 2015). Similarly, foliar and root application of protein hydrolysates helps in the C and N metabolism and uptake of micronutrients that can increase the yield and quality of produce (Colla et al. 2015). The quality and quantity of micronutrients have been observed to effectively increase in the olive tree after the foliar application of Se fertilization (Mattioli et al. 2020).

1.12 Limitations of Agronomic Biofortification

The efficiency of agronomic biofortification depends only on the method of application of fertilizers. There are different methods of application of fertilizers that have differential effects on the concentration of micronutrients of the grain. A high dose of micronutrient fertilizers may sometimes reduce crop yield, affecting the plant's physiology. Sometimes the use of micronutrients as fertilizers can increase grain yield rather than the micronutrient content of the grain. Foliar application of fertilizers is most effective compared to the other methods. But the foliar application requires knowledge of the crop development stage to get better results with the enriched quantities in the grains. In other stages, the foliar application will not be much helpful in the cereal crops.

1.13 Conclusion of the Agronomic Biofortification

The agronomic biofortification approach depends on micronutrient application using various sources and agronomic practices to make them available to the crop plant to utilize the soil nutrients in their growth and development efficiently. Application of fertilizer with the enriched content of micronutrients improves the health of the soil and crop plant. It reduces the negative effect on the environment when it is used at inappropriate rates. The agronomic biofortification approaches are working very effectively with the combination of micronutrients, resulting in an increment of plant yield and nutrition of the crop that ultimately benefited humans and animal health. It works faster than the other approaches for cereal crops and many more in an economical way.

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