Chapter 4
Biofortification of Plant Nutrients: Present Scenario

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Abstract A huge portion of global population is facing nutrient deficiency; particularly peoples of developing countries are the foremost sufferers. Although much development has been made till now, the problem of malnutrition seems to be unsettled. Recent estimates suggested that this problem will become more pronounced in the upcoming years. Unfortunately all of our key edible crops are deficient of certain vital micronutrients and vitamins which are crucial for normal growth, such as milled cereal grains which are deprived of lysine, vitamin A, folic acid, iron, zinc and selenium. Several strategies are there to enhance the quality and quantity of edible crops; among them biofortification seems to be an emerging tool to solve this malnutrition problem by elevating the concentration of bioavailable vitamins and nutrients. Biofortification is a cost-effective technique as there is only single time investment in research; it improves nutritional status of those crops which lack sufficient quantity of nutrients and is sustainable also because seeds and proliferation materials can be stored for long time. This approach owns great promise in achieving improved nutritional status of peoples and should carry on to be explored. The main focus of present chapter is to give a broad outlook of causes and solutions for micronutrient malnutrition in the world and also to discuss the current information, developments and future potential of biofortification for improvement of major edible crops.

Keywords Biofortification · Edible crops · Malnutrition · Micronutrients · Nutrient deficiency

4.1 Introduction

The nutrients which are the core substance for our body growth ultimately come from plants in the human diet. Foods provide calories for energy, in addition to which humans entail more than 40 nutrients and 20 minerals from daily food to

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M. Hasanuzzaman et al. (eds.), *Plant Nutrients and Abiotic Stress Tolerance*,
https://doi.org/10.1007/978-981-10-9044-8_4

keep themselves hale and hearty. Unfortunately, our meals are usually deficit of ample amount of these vital nutrients, which often give rise to under nutrition also termed as micronutrient malnutrition (Dutta et al. 2014). In developing countries like India, millions of people experience this insidious type of starvation of micronutrient malnutrition. Malnutrition is the most important reason of more than three million demises each year in the world. India is leading in having the largest number of malnourished people found in any single country. India, with a population of more than a billion, has about 48 million malnourished people (UNICEF 2009). Recent data from UNICEF shows that despite significant progress, about 42.5 million under 5 years are under weight. In India, malnutrition has been recognised as the major reason behind slow down progress in human development, and it also hampers the reduction in infant mortality (Measham et al. 1999).

This problem of malnutrition can be cured by enhancing the plant nutritional quantity and quality both. Plants can provide us these vital nutrients, and they obtain these from the soil or their growing medium. The study which deals with the chemical elements and compounds which are essential for the nourishment of plant, growth of plant, their metabolism and their external supply is known as plant nutrition. Besides carbon dioxide, water and oxygen, plants also need about 14 minerals for their sufficient growth. The list consists of macronutrients, calcium (Ca), magnesium (Mg), nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), and the micronutrients, boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn). Plant growth and crop yield were often affected by deficiency or low phytoavailability of any of these essential elements (Marschner 1995; Mengel et al. 2001). Enhancement and fortification of foodstuff have been used since decades, for instance, vitamin D added to milk or iodine to salt. Fortified food manufacturing is a long-term strategy that involves high costs to develop and test these food products before launching them in the market. Therefore they are very expensive and unaffordable to the majority of population.

Nowadays, scientists are very successfully using process of biofortification for enhancing plant's nutritional properties. Unlike conventional fortifications which involve the purchase of commercial food, biofortification of plant nutrients offers customers the ability to produce higher-nutrient foods. This is a relatively new concept, using multiple techniques to increase the nutrient content of edible food. Using certain techniques (genetical, breeding, biotechnological, physiological, agronomic, etc.), the plant traits are modified, or the absorption of nutrients from the soil and their accumulation in fruits or seeds (edible parts) are increased, and once these crop varieties are stabilised with these traits, they may be released. Hence, continued investment will no longer be required, and huge number of persons will be benefited from enhanced nutrition in agriculture products. Biofortification plays very vital role in improving nutrient value of staple food, which reduce the incidence of heart disease, anaemia, blindness, early mortality, etc.

4.2 Essential Micronutrients and Consequences of Their Deficiency

4.2.1 Iron

Iron is a vital nutrient for plants as well as humans. More than one-third of the world's population is suffering from anaemia, due to the deficiency of iron in human body (ACC/SCN 2000; Stoltzfus 2001; Tables 4.1 and 4.2); half of these cases are caused by dietary deficiency of iron (WHO 2001). Other than anaemia, deficiency of iron also adversely affects cognitive development, immune system, working capacity, efficiency and lot of problems in pregnant lady (Mayer et al. 2008).

4.2.2 Vitamin A

Vitamin A plays a very significant role in maintenance of vision of eyes, immune response, cell and bone growth, reproduction, development of embryo and adult gene regulation. Night blindness is a very common disease that occurs due to

Table 4.1 Consequences of micronutrient deficiency

Deficient micronutrient	Occurrence in developing country	Most affected groups	Consequences
Iron	2 billion	All but mainly women and children	Reduced cognitive ability, childbirth complications, reduced physical capacity and productivity
Vitamin A	250 million	Children and pregnant women	Increased child and maternal mortality, blindness
Zinc	1.5–2 billion	Women and children	Illness from infectious diseases, poor child growth, pregnancy and childbirth complications, reduced birth weight

Source: ACC/SCN (2000)

Table 4.2 Nutritional quality for mega-staple crops

Nutrient	Maize	Rice	Wheat
Calcium (Ca) (mg/100 g)	6	1	34
Iron (Fe) (mg/100 g)	3.45	1.46	3.88
Vitamin A (mg/100 g)	0	0	0
Vitamin C (mg/100 g)	0	0	0
Vitamin E (mg/100 g)	0.42	0	0.82
Niacin (mg/100 g)	3.63	1.49	6.37
Protein (g/100 g)	8.12	2.36	13.70

Source: Kumari et al. (2014)

deficiency of vitamin A (Mayer et al. 2008). Deficiency of vitamin A is common among the persons who preferably use micronutrient-deficient and carbohydrate-rich diets (Potrykus 2003).

4.2.3 Iodine

Iodine is an essential factor for the thyroid gland hormones, which mainly regulates the basal metabolic rate and also the growth and development of the body (WHO, FAO 1998; Lyons et al. 2004a). Iodine also have some of the combined function with selenium, iron and zinc (Lyons et al. 2004a, b; Zimmermann and Qaim 2004). It is reported that deficiency of iodine causes physical and mental retardation (WHO 2004).

4.2.4 Zinc

Zinc is an essential cofactor for the enzymes which are involved with RNA and DNA synthesis. Zinc deficiency commonly occurs in plants as well as humans and is responsible for diarrhoea, impairment of physical growth, low immunity, weak learning ability and inadequate repair of DNA damage which can lead to cancer (Hotz and Brown 2004; Prasad 2007). On average one-third of world's population is affected with zinc deficiency (Hotz and Brown 2004). The severity and frequency of dietary zinc deficiency have been acknowledged by WHO and FAO, and both have jointly recommended for the zinc fortification (Allen et al. 2006).

4.2.5 Calcium

Calcium is one of the most copious mineral elements in the human body, greater than 99% of which is located in the skeleton. Calcium maintain the rigidity and potency of the bones; along with this it is also concerned with several metabolic processes such as clotting of blood, cell proliferation, differentiation and linkage, muscle contraction and expansion, release of hormones and neurotransmitters, glycogen metabolism, etc. (Theobald 2005). Deficiency of calcium causes osteoporosis, a disease which is characterised by skeletal fragility and fractures.

4.2.6 Folate

Folates are vitamin B, extensive losses of which have been reported in boiled vegetables (Dang et al. 2000). Folate deficiency is related with a higher risk of cardiovascular diseases, impaired cognitive function and causes of cancer and also found associated with an increased risk of neural tube defects in newborns (Botto et al. 1999). Its deficiency is also related with megaloblastic anaemia in pregnant ladies and often intensifies the previously existing anaemia (Rush 2000).

4.2.7 Tocopherol

Tocopherols are vitamin E-containing chemical compounds. The rich sources of vitamin E are vegetable oils, for instance, oil from olive, corn, palm, sunflower and soybean. Nut products, whole grains, fish and green leafy vegetables also provide rich dietary supply of vitamin E. The antioxidant activity of vitamin E has proved its ability to prevent chronic diseases, especially an oxidative stress component such as cardiovascular diseases, atherosclerosis and cancer (Brigelius-flohe and Traber 1999).

4.3 Causes of Micronutrient Malnutrition

The prime reason of micronutrient malnutrition is intake of diets deprived of nutrients. People usually take high amount of staple food but consume very less amount of lentils, fruits, vegetables, fish and animal produce, which are major sources of bioavailable mineral elements and vitamins (CIAT/IFPRI 2002). The human body has no capacity to synthesise vitamins. Most of the atrophied are poor people whose major food are rice, as they cannot buy high-quality, micronutrient-rich food in large quantities because of its high cost. These people want to consume animal and fish products which contain rich supply of available micronutrients but are unable to meet the expense of this type of food. The plant foods like vegetables, fruits and lentils offer very dense supply of mineral elements and vitamins, but the rising trend of nonstaple food prices keeps them away from the reach of common people.

Nowadays, the cropping system has changed completely; the excessive use of cereals and cash crops and total reliance on cultivars which give high yield have resulted in remarkable decrease in food diversity as well as micronutrient intake. To make the most profit, farmers chose to grow high-yielding crops and use very few production technologies leading to a drop-off in the micronutrient and protein dense legumes (Pfeiffer et al. 2005). This trend is marked by a proportional decline in cereal cost and an increase in the cost of legumes, vegetables, fruits, animal and fish protein. It has been contributed considerably in micronutrient deficiency caused by these less nutritious cereal crops becoming readily accessible and more affordable.

4.4 Approach to Reduce Micronutrient Malnutrition

Poor people tend to eat large amounts of one or two staple foods daily that often contributes up to 70–85% of their total calorie intake. Such poor monotonous diets low in micronutrients lead to micronutrient deficiencies. There are three types of intervention to reduce such micronutrient deficiencies – food-based approaches for diversifying diets, distribution of supplements and public health interventions.

4.4.1 Dietary Diversification

For healthy life it is important to have an assorted diet whether it is a vegetarian or non-vegetarian diet; both may have similar concentrations for important nutrients, but their bioavailability may vary. For instance, the iron from a vegetarian diet is less accessible for absorption due to the dissimilarity in the heme and nonheme form of iron and also due to the presence of phytochemicals that allow or hinder iron absorption (Food and Nutrition Board 2001). Heme form of iron is more readily absorbed as compared to the nonheme form of iron present in foods (Roughead and Hunt 2000). Vegetarian diet is deprived of this available heme form of iron, and about 40% of non-vegetarian diet contain the iron in heme form. Although it is feasible to plan an iron-rich vegetarian diet, most estimations related to female vegetarians suggest that most people fail to do so, which results in much lower average iron intakes (11–18 mg/day) (Alexander et al. 1994; Perry et al. 2002).

4.4.2 Supplementation

Supplementation means stipulation of large dosage of micronutrients as medicine, directly in the form of tablets, capsules and/or syrups. These programmes have been extensively used in developing countries to supply iron, folic acid and vitamin A to the needy people like pregnant women, postpartum women, infants and children (Nantel and Tontisirin 2002; WHO 2009). World Food Programme (WFP), WHO and UNICEF suggested supplementation to be used in extreme conditions like in refugee camps to provide micronutrient as well as also in treatment of some diseases, such as in acute diarrhoea (Hotz and Brown 2004; WHO/WFP/UNICEF 2007). The circulation of vitamin A and iron supplements has most economical and successful programmes in the developing countries (Hunt 2002; Shrimpton and Schultink 2002). But, due to each year investment and requirement for highly trained health-care workers, certainly high cost involved in supplementation, and also there is a possibility of toxicity due to over-ingestion of supplements. These things make supplementation unsustainable.

4.4.3 Food Fortification

Food fortification means the adding up of more and more micronutrients in the processed food. This is one of the most worthwhile long-term schemes for enhancing mineral elements (Horton 2006). It has been used effectively since long back as a part of public health initiative for solving the problem of nutritional deficiencies which was a cause for extensive national public health problems (L'abbe et al. 2008). In the early 1920s, medical researchers announced that iodine could prevent goitre, which was widespread at that time. Iodisation of table salt reduced goitre incidence by 74–90% in the areas surveyed (Gomez-Galera et al. 2010). The success stories for food fortification are fewer for the rural poor and in developing countries since this strategy depends on the economic condition of the people to buy the product and the accessibility to the product (Parker et al. 2008). This approach has led to comparatively fast improvements in upgrading the micronutrient content of peoples. If help of available technologies and local distribution network is provided, this strategy will prove to be very cost-effective. However, in the absence of distribution networks, roads and shops, food product supplementation is simply ineffective in reaching the rural poor.

4.4.4 Agricultural Solutions

Agricultural solutions are the other means of reducing micronutrient malnutrition. The earlier described solutions improve the micronutrient in human diet by using diverse diets, supplements or modified food products, but agricultural solutions give a way to enhance the micronutrients directly in growing plants that produce the food products. This can be achieved by one of the following ways: fertilisation and biofortification.

Fertilisation is the process of supplying vital mineral elements to crops in the form of fertilisers to attain greater yields. It is mainly used for small-scale crop production and especially in areas with low phytoavailability. Macronutrient fertilisers containing nitrogen, phosphorus, potassium and sulphur and micronutrient fertilisers that consist of zinc, nickel, iodine, cobalt, molybdenum and selenium can cause significant effects on the accretion of nutrients in edible plant parts (Allaway 1986). Even though this strategy seems simple and inexpensive, it is doing well only in some cases of particular geographical area, due to the limitations of fertiliser and soil chemistry, together with the added complications of nutrient mobility and storage within the plant (Zhu et al. 2007). In soil zinc is found in mobile state, so the application of zinc sulphate will enhance the plant yield and also the zinc concentrations in legumes and cereals (White and Broadley 2005). For other important micronutrients such as iodine, nickel and selenium, enhancing soil-available supply of these micronutrients to edible crops can result in considerable increase in their amount in edible part of the plant (Graham et al. 2007; Hartikainen 2005). Similar to supplementation and fortification, agricultural intervention is probably more useful in niche conditions and when combine with other approaches (Cakmak 2008). In contrast, micronutrient elements like iron have not been successful to obtain a positive result using fertilisers because of low mobility of iron in soil (Fernandez et al. 2004; Grusak and DellaPenna 1999). For increasing concentration of iron in grains, foliar application of the iron-containing solutions is the only effective fertilisation practice (Rengel et al. 1999). Proper use of fertilisers also requires training by the applicators, to protect themselves and the rest of the environment (Graham 2003; Sors et al. 2005). Generally, these types of approaches cannot be universally applicable as a strategy to improve the nutritional quality of edible crops because these are appropriate to particular crops and minerals (Kendal 2009).

Biofortification is economical and environmentally feasible approach which can utilise either plant breeding or genetic engineering or both (Stein et al. 2008). It can supply micronutrients to a large number of persons at relatively very low cost (Nestel et al. 2006; Pfeiffer and McClafferty 2007). In addition, biofortification is more likely to reach all family members as staple crops are eaten by everyone and do not rely on proper implementation of a protocol (Bouis et al. 2000). Biofortified staple crops are also capable of serving the rural and urban poor, simultaneously, unlike the other micronutrient malnutrition intervention strategies (Nestel et al. 2006). Detail of biofortification approach for micronutrient enhancement is given below.

4.5 Biofortification

All of the previously mentioned solutions to micronutrient malnutrition suffer from some common problems. All require an annual investment, whether the investment is made by a governmental agency or non-governmental organisation (for supplementation schemes) or by private industry and the individual (for food fortification and fertilisation schemes). All require some degree of local infrastructure, to distribute the products to people that have been educated in their use. These limitations are major barriers to the implementation of sustainable solutions for malnutrition affecting those at the lowest end of the socio-economic scale. Biofortification is therefore an alternative reliable approach for improving mineral nutritional quality of crops and thus addresses micronutrient malnutrition in humans (Zhu et al. 2007). Perhaps the strongest argument for biofortification is the cost-effectiveness (Bouis et al. 2000), because investment is needed only once during the growth of the germplasm relative to ongoing costs associated with other strategies (Table 4.3) (Jeong and Guerinot 2008).

Table 4.3 Cost comparison between micronutrient malnutrition-reducing strategies, considering an US$ 80 million investment

Supplementation	Food fortification	Biofortification
Provides vitamin A supplementation to 80 million women and children in South Asia *for* 2 years, 1 in 15 persons in the total population, at a cost of 25 cents for delivery of each pill, each effective for 6 months	Provides iron fortification to 33% of the population in South Asia *for* 2 years. Costs of fortification are estimated to be 10 cents per person per year	Develops six nutrient-dense staple crops for dissemination to *the entire world's* people for consumption *year after year*. This includes dissemination and evaluation of nutritional impact in selected countries

Source: CIAT and IFPRI (2002)

Micronutrient bioavailability can be defined as the proportion of nutrient that is absorbed in the human body after storage, processing and cooking of the diet and is used for normal body function (White and Broadley 2005; Nestel et al. 2006). Biofortified crops must win over farmers by maintaining the yield productivity along with offering a benefit to health of human; micronutrient enhancement characters must be comparatively constant across diverse type of soil and climatic conditions and finally must meet consumer acceptance for taste and cooking quality (Welch and Graham 1999). Biofortified crops such as iron rice and golden rice hold a particular promise for India, as the people are predominately vegetarians. The massive Indian population must obtain their micronutrient content and vitamins through plants because of their vegetarian nature. Even if we succeeded in achieving a small increase in the plant nutrient contents, it will cause a great impact on the human health.

Biofortification has multiple advantages over the previously mentioned solutions:

- Biofortification takes advantage of increasing micronutrient in staple foods which are daily consumed on regular basis by all family members in a house. As staple foods dominate in the plate of poor people, this policy aims completely towards the low-income family (Nestel et al. 2006).
- This technique is a one-time investment, since, once the crop has been fortified, the seeds will fortify themselves.
- Biofortification is an advancement over fortification in case of providing nutrients to the deprived rural population because they hardly have any approach to obtain the nutrients from commercially fortified foods, by placing the means to the micronutrient malnutrition problem in the hands of the rural poor themselves (Yassir 2007).

4.5.1 *Types of Biofortification*

4.5.1.1 Conventional Breeding

The goal for most plant breeders has been to increase yield potential for their target crops. This has largely been accomplished by increasing yield but also via. the introduction of resistance genes for various diseases and pests. Attention has been given to improving crop quality, which can include improving nutritional content (WHO 2007). The effective biofortification programme should be able to reach the rural poor. The available genetic variation in vital nutrient content should permit breeding programmes to enhance the content of mineral elements and vitamins in crop plants (Cakmak 2008; Monasterio and Graham 2000). There are a variety of possibilities for improvement of micronutrient content through plant breeding, which include:

(i) Enhancement in micronutrient contents such as iron or zinc, or vitamins as beta-carotene
(ii) Reduction in the quantity of anti-nutrients, for example, phytic acid
(iii) Increasing the amount of sulphur-containing acids, which support the assimilation of zinc (Ruel and Bouis 1998)

It has been recommended to cross wild species with cultured varieties to increase the micronutrient concentration (Cakmak 2002; Monasterio and Graham 2000). Through mutagenesis new characters can directly be introduced in the required varieties (Raboy 2002).

4.5.1.2 Transgenic Approach

Conventional breeding-based biofortification strategy has not accomplished all the requirement and hence gathers very limited success). This technique of conventional breeding would require several years to attain noteworthy improvement in locally adapted plant varieties. The complications of the process also increase when breeding is concerned with more number of minerals and vitamins. Hence, an appropriate approach to improve these schemes is the introduction of genes encoding key enzymes using transgenic methods (Christou and Twyman 2004; Zhu et al. 2007). Plant transformation may be faster than the conventional breeding to achieve the nutritional target. Transgenic approaches can be a valid alternative, where breeding approaches are not successful (Brinch Pedersen et al. 2006; Zhu et al. 2007). The two primary limitations to biofortification via. transgenic crop improvement are lack of knowledge and regulatory difficulties. First, the transgenic approach requires genes with known functions to affect the trait of interest. In the absence of such knowledge, it is not possible to use plant transformation. Second and perhaps more important, regulatory issues greatly restrict the use of plant transformation for biofortification. These related regulatory obstacles with transgenic strategy make this technology commercially unviable (Johnson et al. 2007; Powell 2007). These problems also extend because of trade barriers and dissimilarity in national regulatory schemes, which hinder the manufacture, transportation and utilisation of transgenic produce (Ramessar et al. 2008). Developing countries like India and China are forced not to produce transgenic crops for the export, although they might be benefitted with the approach (Stein et al. 2008; Christou and Twyman 2004).

4.6 Utility of Biofortification in Present Scenario

Conventional breeding methods and biotechnological approaches can be helpful to bring the desirable changes in quantity and quality of micronutrient. The micronutrient contents can be enhanced by improving the content of desired micronutrient directly in cultivated crops or by the method of bioengineering. The nutritious crops which are unable to grow vigorously or which have dropped out during Green Revolution due to the enormous development made to cereals can be managed by bioengineering. Thus, it decreases the farm cost involved and improves the productivity and earning power of farmer along with meeting nutrient requirement (CIAT/IFPRI 2002). The requirement and demand of a biofortified food have to be sufficient to drive the product through complicated developmental stages and to equalise the associated expenditure. This purpose can be solved by publicising the health benefits of biofortified food clearly to the consumers. The following section shows few studies that have confirmed the nutritional value and cost-effectiveness of some biofortified crops.

4.6.1 Crops Rich in Iron

Iron-rich crops, for example, iron pearl millet, are enhancing the nutritional status of selected populations. The effectiveness of this iron-rich crop was estimated in secondary school children of Maharashtra, India. The children were fed twice in a day for 4 months with biofortified pearl millet flat bread, and a noteworthy enhancement in body iron content was observed in young boys and girls which were previously iron deficient. The children who were at the baseline of iron deficiency were significantly (64%) more likely to resolve their iron deficit problem in 6 months (Finkelstein et al. 2015).

4.6.2 Crops Rich in Vitamin A

Orange sweet potato (OSP) has the elevated levels of beta-carotene which is a building block for vitamin A. Studies conducted on the bioavailability of vitamin A showed efficient conversion of provitamin A to retinol, a usable form of vitamin A by the human body. Observations confirmed that an increase in consumption of provitamin A through biofortified crops as OSP resulted in increased beta-carotene concentration and also has a significant effect on vitamin A status of individuals. Analysis showed that 75% of the beta-carotene is retained in OSP even after its boiling during preparation of a meal. Intake of OSP has resulted in a considerable increase in vitamin A concentration among several age groups (Haskell et al. 2004;

Van Jaarsveld et al. 2005). Satisfaction of consumers and nutritional impacts of OSP have made this crop widely accepted.

4.6.3 Zinc-Rich Crops

Biofortification study with zinc has confirmed that biofortified wheat contains zinc in bioavailable form which can readily be absorbed in human body (Rosado et al. 2009). Because of the limitations of the available zinc biomarkers in evaluating the alteration in dietary zinc, research to discover more sensitive biomarkers are in progress these days.

4.7 Future Aspects of Biofortified Crops

As malnutrition is one of the major problems worldwide, biofortification along with conventional breeding and nutritional modification has become the first choice of the researchers for crop improvement in the future. To eradicate micronutrient malnutrition, biofortification is a promising and potential crop-based approach at present. Still, some essential exploration gap is present in existing biofortification technique, and currently it is a challenging venture (Singh et al. 2016).

- A wide knowledge gap exists between the bioavailability of micronutrients in food grain and mineral distribution pattern in plant system.
- The comprehensive perceptiveness of the mineral translocation mechanisms from soil to seed is missing in most of the edible crops.
- Before making the biofortified crops available to the customers, a detailed examination of its safety concerns is necessary.
- Some micronutrient loss that occurs during the processing of crops has not been analysed in majority of the crops which need to be investigated.
- Presently, the biofortification procedure is limited to a few important crops only and in some crops which have local significance. But to cope up with the micronutrient malnutrition, it is necessary to investigate all the crops which are related with the micronutrient deficiencies.
- Sometimes, enhancement of vitamins and micronutrient causes a negative impact on the colour and flavour of the finished product which was often not up to the standard of consumer expectations. Therefore, for greater adoption biofortified crops will be in acceptable form.
- The most important factor for malnutrition is the high cost of nutrient-rich food, so the biofortified crop has to be economically viable to common people.

Some of the important strategies to deal with these problems of biofortified crops would lie in molecular cytogenetics, in which through gene transfer, zinc and iron contents can be increased (Nestel et al. 2006). The drop-down in the micronutrient content during postharvest processing can be minimised by uniform allocation of minerals in the grain. To improve the bioavailability of micronutrients, manipulation of phytic acid level should be done during biofortification of crops (Nestel et al. 2006). The accomplishment of biofortification programme is directly related with the introduction of improved policies which must include agricultural policies, nutrition education, marketing and public awareness. Therefore, to completely eradicate the micronutrient malnutrition in human and further to ensure the food and nutritional safety, more organised steps towards the progress of biofortified crops together with appropriate alternatives for agronomic management are needed in the future.

4.8 Nutrient Biofortification and Abiotic Stress Tolerance

Productivity of crops and their quality have been adversely affected by several abiotic stress factors such as drought, frost heat, salinity and ion toxicities (Hasanuzzaman et al. 2012, 2017). Lack of micronutrients in agricultural soils is a fast-growing trend and is also an ever-increasing abiotic stress in agricultural world. Increasing the essential micronutrients by biofortification approach could be a significant alternative in enhancing the nutritional value and stress tolerance capability of crop plants. There are many evidences which showed that biofortification of nutrients in crops improved their resistance to abiotic stresses. Sufficient amount of silicon present in a large variety of plant provides them ability to resist in a stress environment (Ashraf et al. 2010). The benefits related with the increased content of vitamin B6, for instance, higher biomass and greater tolerance level to stress, suggest that improvement in the concentration of vitamin B6 could be a significant alternative for crop plants to improve the nutritional status and also to cope up with the abiotic stress (Vanderschuren et al. 2013). Some studies showed that biofortification of iodine leads to increased tolerance in some plants against specific type of abiotic stresses like heavy metal and salinity stress (Leyva et al. 2011; Gupta et al. 2015). Calcium is a crucial macronutrient for both plants and animals, associated with important structural and signalling function, deficiency of which can affect the crop quality and yield and also result in reduced resistance towards biotic and abiotic stresses.

To alleviate the stresses caused by several stress-inducing factors, concentration of reactive oxygen species increased in plants at their cellular level. Hence, the stimulation of antioxidants is acknowledged as a significant aspect of the adaptive response of plants leading to tolerance against stress (Gill and Tuteja 2010). Iodine was found to be the first inorganic antioxidants which give the ability to organism to mitigate stress level after the origin of oxygenic photosynthesis (Crockford 2009; Küpper et al. 2011; Venturi 2011). The treatment of temperature- and humidity-affected seeds of sunflower and soybean with calcium carbonate and iodine decreases the physiological deterioration rate and provides stress tolerance (Macias et al. 2016). Similar observations were also found with peanut seeds where pretreatment of seeds with zinc resulted in the increased tolerance of seeds to the fungal pathogen *Aspergillus niger* (Jajda and Thakkar 2012). Further investigations are needed on the prospective of micronutrients to increase the stress tolerance in plants. The advantage of biofortification is that it is more feasible from an economic perspective, accomplishing dual functions as a micronutrient enhancer and stress defender.

4.9 Conclusion

This chapter has tried to tackle the role of agricultural solutions and biofortification in addressing micronutrient malnutrition. In the future, mineral and vitamin deficiencies are likely to be more menacing, but the biofortification approach is emerging as a promising means to deal with this problem. Biofortification is a simple, cost-effective, crop-based strategy; that's why it gives assurance for coping up with the micronutrient malnutrition crisis and is best suitable method in the developing countries. But, the scientific approach alone is not sufficient, although a holistic approach is needed to cope up with the problem of micronutrient malnutrition. There is a need to generate awareness among people about the advantage of food diversity and suggesting them feasible solutions how they can improve their dietary requirement. Remarkable improvements have been already going on in this area; further suitable strategies and potential planned studies could result in biofortification's immense accomplishment in the near future.

Acknowledgement The author Sonal Dixit is grateful to DSKPDF Cell, Pune, India, and University Grant Commission, New Delhi, India, for the award of the D.S. Kothari Postdoctoral Fellowship (F4-2/2006 (BSR)/BL/15-16/0156).

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