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Biofortification in Vegetable Crops

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Increasing population, insufficient food and nutrition, hunger, vitamins, and micronutrient malnourishment, and so on are the most pressing issues confronting most countries throughout the world. In the developing countries Vitamin A deficiency (VAD) is very common among children and women, resulting in more than 600,000 deaths per year among children under the age of five. The population's micronutrient malnourishment is dominated by 60 percent iron, 30 percent zinc, 30 percent iodine, and 15 percent selenium. Insufficient availability of these essential vitamins and minerals led to a variety of health and physical problems in humans. Traditional agricultural practices can improve the nutritional content of plant foods to some extent, but biofortification is a practice of nutrient fortification into food crops using agronomic, conventional, and transgenic breeding methods to provide a long-term strategy to address the negative effects of vitamin and nutrient deficiencies. Biofortification has been used in most of horticultural crops, including banana, cassava, beans, potato, orange sweet potato (OSP), cowpea, pumpkin and others. In this area several conventional and transgenic varieties have been developed, and more are in the process. The findings of efficacy and effectiveness studies, as well as recent distribution achievements, demonstrate that biofortification is a potential technique for treating hidden hunger. The process of adding nutritional value to a crop is known as biofortification. It refers to the improvement of crops with nutrients to alleviate the negative economic and health consequences of vitamin and mineral deficiencies in people.

It is the process of increase the bioavailable mineral content of food crops by genetic modification. Producing bio-fortified crops improves their growth efficiency on soils with depleted or unavailable mineral composition. Plant breeding for augmented phytonutrients is most easily accomplished with crops that have short juvenile periods to reach the fruiting stage, such as vegetables, berries and melons but it is a much longer-term strategy for tree-fruit and nuts, which generally require a juvenile period of many years before fruit-set is possible. Discovering plant variations with increased phytonutrient content within germplasm collections or existing commercial cultivars is an alternative strategy.
This can identify lines that are already acceptable to consumers, or it can point out a prospective donor parent with the suitable phytonutrient background for transfer into a more edible plant variety.

Importance of Biofortification

Biofortification is a reasonably cost-effective, sustainable, and durable method of delivering additional micronutrients in distant rural regions, as well as giving naturally-fortified foods to people groups with limited access to commercially marketed fortified foods. Biofortified staple foods cannot make available as many minerals and vitamins per day as supplements or industrially fortified meals, but they can serve by boosting the daily adequacy of micronutrient intakes across individuals across the lifespan. Biofortification is not expected to treat micronutrient deficiencies or eliminate them in all people groups. No single intervention will solve the problem of micronutrient malnutrition, but biofortification complements existing interventions to sustainably provide micronutrients to the most vulnerable people in a comparatively inexpensive and cost-effective way. For instance, according to World Health Organization (WHO) evaluation, biofortification could help cure two billion people suffering from iron deficiency-induced anaemia.

Table 1 Sources of nutrients from vegetables

Nutrients	Vegetables
Carbohydrate	Sweet potato, potato, cassava
Protein	Pea, lima bean, French bean, cowpea
Vitamin A	Carrot, spinach, pumpkin
Vitamin B_1	Tomato, chilli, garlic, leek, pea
Vitamin C	Chilli, sweet pepper, cabbage, drumstick
Calcium	Hyacinth bean, amaranthus, palak
Iron	Amaranthus, palak, spinach, lettuce, bitter gourd
Phosphorous	Pea, lima bean, taro, drumstick leaves
Vitamin B_5	Palak, amaranthus, bitter gourd, pointed gourd
Iodine	Tomato, sweet pepper, carrot, garlic, okra
Sodium	Celery, green onion, Chinese cabbage, radish

Methods of Biofortification

Biofortification can be achieved through three strategies:

- Agronomic Biofortification
- Conventional plant breeding
- Genetic engineering

1. Agronomic Biofortification

Applications of fertilizers for enlarge the micronutrients in edible parts. The most appropriate micronutrients for agronomic biofortification are Zinc (foliar applications of $ZnSO_4$), Iodine (Soil application of iodide or iodate), and Selenium (as selenate). Foliar application is a quick and easy method of nutrient application to the fortification of micronutrients (Fe, Zn, Cu, etc.) in the plants. Numerous studies have found that the mycorrhizal associations enhance Fe, Se, Zn, and Cu concentrations in the crop plants. AM-fungi enhance the uptake and efficiency of micronutrients like Zn, Cu, Fe, etc. Sulphur oxidizing bacteria amplify the sulphur content in onion.

2. Biofortification of crops with Iron:

Tomato plants can tolerate high levels of iodine, stored both in the vegetative tissues and fruits at concentrations that are more than sufficient for the human diet, and conclude that tomato is an outstanding crop for iodine-biofortification programs. The fruit concentration of iodine detected in 5 mM iodide–treated plants was more than enough to cover a daily human intake of 150 µg. Increasing iron levels of Amaranthus plants by using S.platensis as microbial inoculants when compared with control and he also reported that Spirulina platensis has been used as a biofortifying agent to augment the iron status in Amaranthus genetics plant.

3. Biofortification of crops with Zinc

The relationship between tuber Zn concentration and foliar Zn application followed a saturation curve, reaching a highest at approx. 30 mg Zn kg–1 DM at foliar Zn application rate of 1.08 g per plant. Despite a 40-fold enlarge in shoot Zn concentration as compared to the unfertilized controls following foliar Zn fertilization with 2.16 g Zn per plant. The use of fertilizer "Riverm" in the cultivation of capsicum, brinjal, and tomatoes helps to be enriched by zinc. Biofortified vegetables contain 6.60-8.59 % of Zn more than control.

4. Biofortification of crops with Selenium

Onions and carrots were bio-fortified by foliar application of a solution of 77Se that was enriched to 99.7% as 77Se. Selenium application did not affect the yield or oil content in brassica vegetables. A high accumulation of Se in the seeds and meal of (1.92–1.96 µg Se g^{-1}) was detected.

5. Conventional plant breeding

Conventional breeding usually focused on yield attributes and resistance breeding from last four decades and lack of priority on nutritional aspects leads to decreased quantity of nutrient status in the existed varieties. Examples of minerals whose mean concentration in the dry matter have decrease in numerous plant-based foods are Fe, Zn, Cu, and Mg. Recent progress in conventional plant breeding has emphasized the fortification of important vitamins, antioxidants and micronutrients. The potential to improve the micronutrient density of staple foods by conventional breeding requires adequate genetic variation in concentrations of β-carotene, other functional carotenoids, iron, zinc and other minerals exists among cultivars, making a selection of nutritionally appropriate breeding materials possible.

Table 2 Examples of biofortification in vegetable crops

Crop	Biofortified element/mineral/vitamin
Tomato	Chlorogenic acid, stilbene, flavonoids, anthocyanin, Folate, phytoene, lycopene β-carotene, provitamin A Zinc, Iodine
Potato	Amino acid, protein, anthocyanin, starch, carbohydrate (fructan)
Onion, Broccoli	Selenium
Lettuce, Beans	Iron
Carrot	Calcium
Radish	Selenium
Brassica spp.	Selenium, carotene
Cassava	Protein, carotene, and mineral contents
	Zn, Se, Cu, I
Sweet potato	Protein
	Carotene
Broccoli	Selenium
Cucumber	Potassium
Spinach	Iodine
Pumpkin	Carotenoids

Conclusion

Biofortification is a feasible method of addressing malnourished populations in somewhat remote rural regions by distributing naturally fortified meals to those who do not have easy access to commercially promoted fortified foods, which are more commonly available in cities. As a result, biofortification and commercial fortification are extremely complimentary. Finally, effective nutrition is dependent on adequate intakes of a variety of nutrients and other chemicals, in combinations and quantities that are yet unknown. Thus, increasing the intake of a variety of non-staple foods is the greatest and final answer to eliminate under nutrition as a public health concern in developing nations. However, this will take decades to accomplish, as well as intelligent government policies and a relatively big investment in agricultural research and other public and on-farm infrastructure.

To sum up in the words of M.S. Swaminathan, "GM foods have the potential to solve many of the world's hunger and malnutrition problems and to help protect and preserve the environment by increasing yield, quality and reducing reliance upon chemical pesticides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, industrial policy, and food labeling."

Future Thrust

Crop biofortification is a complicated task. Many plant breeding initiatives aim to enhance production, tolerance to biotic and abiotic stresses and food palatability. In recent years, improving nutritional quality has been included as a new breeding goal. Collaboration between plant breeders and nutrition specialists is critical to achieving these goals. Furthermore, certain biofortification projects cannot be implemented due to a lack of adequate genetic variety for micronutrients in the germplasm. In such cases, genetic engineering methods must be used, and coordination between plant breeders and molecular scientists is vital. The regulatory approval procedure, which is both costly and time-consuming, is the most significant barrier to the commercial use of GM crops. Biofortification is a potential agriculturally based technique for improving the nutritional status of the world's starving populations. As a result, significant resources should be committed to biofortification efforts.