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Biofortification of Major Vegetable Crops to Alleviate Malnutrition

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INTRODUCTION

Mineral nutrition present in the food play significant role in the improvement of human health and prevention of various kinds of illness and diseases. Micronutrient deficiency is the major cause of malnutrition in children and poor peoples. The micronutrients like iron, zinc, calcium, iodine, magnesium, selenium and vitamins are very essential for human health (Lucca, *et al.*, 2006). More than 2 billion people are affected by iron, zinc, beta-carotene and folic acid deficiencies across the world. In most of the countries, cereals, vegetables, milk and meat are the major source of caloric intake (Dosman, et al. 2012). Biofortification of vegetable with vitamins and micronutrients is the present need of an hour to fight different health issues faced by the developing countries (Gomathi, *et al.*, 2017). For biofortification of vegetable and other staple crops, three major techniques are used, viz. conventional breeding, agronomic approach (use of mineral fertilizer), and genetic engineering. These approaches have enormous potential to address this vitamin and micronutrient malnutrition. Many genes are available for the target traits by which it will be possible to improve micronutrient in vegetables (Goicoechea and Antolin, 2017). These tools can be very much helpful in improving the level of micronutrients and vitamins by several-fold in staple cereals and vegetables. However, fortification of fruits and vegetables including cassava, banana, beans, orange sweet potato, potato, pumpkin, cowpea, and cauliflower has been successfully achieved and other crop varieties are under pipeline.

Biofortification

Biofortification is the process of the development of nutri-dense crops employing agronomical practices, plant breeding practices, and biotechnological approaches (Perez-Massot, et al. 2013).

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Biofortification is important aspects of micronutrient and vitamins fortification in food crops to provide high nutritional food to the large population by using small land area. The aim of vegetable crop fortification to increase the essential nutrient contents in the major vegetable crops during plant growth rather than through manual means during processing of the crops (White, et al., 2012). However, plant breeding; biofortification can enhance the nutritional content of the staple food contributing a comparatively economical, cost-effective, sustainable, long-term means of providing more micronutrients to the poor.

Important minerals and nutrients to be fortified

Micronutrients like Fe, Zn, Se, Mg, Ca, Iodine, and vitamins like pro-vitamin A, vitamin C, vitamin, B, vitamin E, vitamin K and folate are an important component of the biofortification program (Lyu, et al. 2020).

Biofortification strategies of vegetable crops

Biofortification of mineral nutrients and vitamins into vegetable crops can be achieved by agronomical practices, conventional breeding approaches, molecular breeding and biotechnological approaches.

Agronomic biofortification: Agronomical approaches for improvement in the micronutrients in the vegetable crops are one of the important practices that can be achieved by application of fertilizers and micronutrients in the soil and on the crop plants. The relevant micronutrients like selenium in form of selenite, iodine in the form of iodate, Zn in the form ZnSO4 can be applied for increase of these micronutrients in the vegetable crops (Wood, et al.2018). In the foliar vegetable crops, the foliar application of ZnSO4 can improve the Zn content in foliage. Furthermore, several bio-fertilizers and some fungi species can enhance the micronutrient uptake from soil into plant is also a type of agronomical practices of biofortification (Jena, et al., 2018). Several vegetable crops like tomato, potato, and amaranths have been fortified using agronomical practices. Use of next-generation organic fertilizer like *Riverm* potentially increases the Zn content in solanaceous vegetables (Bouis, *et al.*, 2011). Furthermore, *Amaranthus gangeticus* leaves are a rich source of Zn, Fe, Ca, Mg and Cu. *Spirulina platensis*, a microbial inoculant was used as a biofortifying agent to enhance the iron level of crop (Kalpana, *et al.*, 2014).

Conventional approaches: Conventional breeding in another practice for incorporation of traits from one to other cultivars (Garg, *et al.*, 2018). The known cultivars having good amount micronutrients can be used as donor parent for breeding purpose to develop biofortified vegetable cultivars with significant quantity of vitamins and minerals (Hare, 2015). Conventional breeding practices have been applied in the development of beta-carotene, carotenoids, amino acids, amylase, carbohydrates and other minerals through making proper selection of breeding material to increase nutritional efficiency (Gregorio, *et al.*, 2000).

Molecular breeding approaches: Marker assisted selection is one of the robust systems of crop improvement in which gene of interest on the various chromosomal locations is identified using molecular marker and introgressed into commercial cultivation (Parulekar, et al., 2019). Number of gens and QTLs has been identified from various vegetable germplasm and introgressed into cultivars for increasing micronutrients and vitamins (Azmach, et al. 2013).

Genetic engineering approaches: Transgenic approaches of biofortification have been successfully achieved in some vegetable crops. Particularly in the case of transgenic tomato, increased quantity of antioxidants, carotene, anthocyanin, flavones, and folate have been achieved (Perez-Massot, *et al.*, 2013). The desirable transgenes associated to minerals and vitamins have also been introgressed in to potato for increased starch content, protein, amino acid and beta-carotene (Haynes, *et al.*, 2012).

Biofortified vegetables in India

In India, numbers of vegetable crops have been fortified for increased content of beta-carotene, Fe, I, Cu, Zn, Mn, Co, Cr, Se, Mo, F, Sn, Si, V and other beneficial plant pigments (Grotz, et al. 1998). Bio-available of calcium content in modified carrots was found to increase by the Arabidopsis H^{+}/Ca^{2+} transporter CAX1 thus Ca content reduce the incidence of osteoporosis (Gerber, et al. 1999). Other achievements of fortified crop for significant increase in lycopene, anthocyanin, flavones and antioxidant have also been achieved in tomato and potato. Other crops like cauliflower, sweet potato, and radish are also fortified.

CONCLUSION

Strategic biofortification of vegetable crops using multi aspects of plant breeding and biotechnological approach provides easy means to reaching malnourished populations. Biofortified vegetable crops have good source of mineral nutritions like Fe, I, Cu, Zn, Mn, Co, Cr, Se, Mo, F, Sn, Si, and V. It is indeed a challenging endeavour to enhance the micronutrient concentration in a sufficient amount and the acceptance of fortified crop plants by consumers. After a single investment in developing seeds that fortify themselves, further costs are low and germplasm may be shared internationally. This multiplication aspect of plant breeding programme across distance and time makes it economical. Once production and consumption of nutritionally efficient varieties is highly sustainable, international funding for micronutrient and government attention issues fade.

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