Bio- fortification in vegetables crops

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The Green Revolution solely concentrated on increasing the output of food crops;nevertheless, the populati on's nutritional needs were not satisfied well, which resulted in a problem with hunger, especially in developing countries (Chaudhary et al., 2021). In order to deliver, enhanced nutrition within a food based system, it is necessary to increase nutritionvalue of the food. A sustainable, economical, and food-based method of providing the entire population with minerals and vitamins is bio-fortification of stable foods. It is the process of improving food crops' nutritional value. Agronomic techniques, conventional breeding, and biotechnology-based methods can all be used to achieve this. Agronomic bio-fortification is the process of adopting appropriate agronomic measures to increase the density of nutrients, vitamins, and minerals in a crop. Transgenic techniques have been used to target a large number of crops, although breeding techniques are more commonly used to really use bio fortification (Garg et al., 2018). Bio-fortification is different from conventional fortification and supplementation because it concentrates on making plant foods more nutrient-dense as the plants grow rather than adding nutrients to the foods when they are processed, and it is easier for people in developing countries to access and accept. Consuming bio-fortified veggies may be a better solution to address hidden hunger. Through bio-fortification programmes, there is potential to increase micronutrients and vitamins in vegetables on a wide scale. The production of wholesome, safe food that is produced in a sufficient and-sustainable manner is bio-ultimate fortification's goal.

What is Bio-fortification?

- The term "bio-fortification" is derived from the Latin word "fortificare," which means "to make strong," and the Greek word "bios," which means "life."
- Bio-fortification of stable food is an environmentally friendly, economically viable, and food-based method of providing the general populace with minerals and vitamins.
- Delivering micronutrients to a population with limited access to varied meals and other micronutrient therapies, bio-fortification is an emerging, promising, and sustainable technology.

Long-term alternatives to boosting mineral nutrition include bio-fortication. It is a technique that raises both the mineral content and bio-availability. There are three primary ways to accomplish bio-fortification: transgenic method, traditional breeding, and agronomic bio fortication. Transgenic techniques have been used to target more crops, while breeding techniques have increased the practical application of bio-fortification. All three methods have targeted vegetables because they are a staple crop.

Agricultural methods: It involves the purposeful application of mineral fertilisers to boost the concentration of a desired mineral. In order to temporarily increase the nutritional and health condition of crops using agronomic methods for bio-fortification, physical application of nutrients is necessary. Consuming such foods also improves human nutritional status. As a result, agronomic bio-fortification the method of boosting the micronutrient content in food crops was developed. Organic matter, synthetic fertiliser, micronutrient applications, PGPRs, balanced and integrated nutrient management, fungi, cynobacteria, and actinomycetes can all be used to achieve this.

The following vegetables have been agronomically biofortified to boost human nutrient intake:

Tomato: When grown with iron fertiliser, tomatoes are a great crop for iodine bio-fortication programmes.

Sweet potato: Treatments with irrigation and chemical fertilisers have been seen to increase the beta-carotene content of orange-fleshed sweet potatoes.

Carrot: I and Se have been added to carrot leaves and storage roots by using both of them as fertilisers. According to reports, 100g of fresh carrots that have been fertilised with I and Se can provide the entire recommended daily amount.

Lettuce: By using KIO3 and Na2Se04 as foliar spray and nutrient medium lettuce, lettuce I and Se biofortification has been obtained. After soil agronomic bio-fortification with an inorganic form of selenium, se bio-fertilizer in the leaves has been successfully implemented.

Potato: Using foliar zinc fertilisers, field tests were conducted to raise zinc concentrations in potato tubers, which considerably raised tuber zinc concentration. After selenium selenite and selenite were applied topically to potatoes, there have been reports of an increase in the selenium content of the tubers.

Lantini et al., 2011 carried out a research to perform iodine bio-fortification in tomato the main objective was to evaluate iodine uptake in tomato (Solanum lycopersicum L.) whether it is possible to increase the iodine concentration in its fruits. Iodine translocation and storage inside tomato tissues were studied using radioactive iodine. Tomato plants was grown both in soil as well as hydroponics were treated with radioactive iodine starting from age of 2 week, 1 month, and 2 month after germination. So, 3 iodine feeding were done both as leaf and root treatments. After the treatment, iodine was clearly detectable in all the treated plants. Regardless of the age, the amount of iodine accumulated by root treatment was higher thanleaf treated. 2 week plants accumulated max. iodine. They found that hydroponics was more effective than soil in promoting iodine absorption the overall amount of iodine taken up by tomato plants was generally higher when iodine was supplied to the roots rather than onto the leaf blade. Hydroponic culture, with iodine added to the nutrient solution, thus, gives excellent possibility for tomato bio-fortification.

2. Bio-fortification through conventional breeding:

An affordable, sustainable alternative to transgenic and agronomic-based solutions is conventional breeding. For conventional breeding to be successful, the trait of interest must have enough genotypic diversity. Only when genetic variety is acccessible is it done. In order to develop plants with ideal nutritional and agronomic qualities, parent lines with high nutrient content are crossed with recipient lines with desirable agronomic traits over a number of generations. However, the limited genetic diversity that exists in the gene pool must occasionally be taken into account in breeding methods. This can often be avoided by breeding with distant relatives, which gradually introduces the qualities into the commercial variety. Alternately, mutagenesis can be used to add novel features directly into commercial types.

- Nassar et al., 2009 worked on improving carotenoids and amino-acids in cassava. The main objective of the study was to assess lycopene content and amino-acid profiles of cassava landraces and inter-specific hybrid respectively. The amino acid profiles of a common cassava cultivar and an interspecific hybrid namely ICB-300 was determined. The inter-specific hybrid was developed by crossing UNB 01 and Manihot oligantha. It was found the inter-specific hybrid has 10 fold lysine and 3 fold methionine than common cassava cultivar. The result of the study found that Inter-specific hybridizations provides materials that could be more interesting sources for breeding nutritious cassava for human consumption. Among 6 samples analyzed in this study, the ICB-300 showed highest amount of protein (1.654 g/100g sample) and the cassava landrace UnB 400 had a high content of beta-carotene (up to 4 mg/kg). The cassava cultivar rich in essential amino acids and carotenoids will be important for enhancing the nutritional quality of the crop.

3. Transgenic method:

When there is little to no genetic variation in nutrient content among plant varieties, transgenic strategy may be a viable alternative for the production of bio fortified crops. The only practical method to fortify crops with a certain micronutrient when it doesn't occur naturally in them is through transgenic methods. The creation of transgenic crops has relied heavily on the capacity to characterise gene function and then use these genes to alter plant metabolism.

In the long run, developing transgenically bio-fortified crops is a cost-effective and sustainable technique even though it initially requires a significant amount of time, effort, and expense.

Transgenic vegetables:

Transgenic lettuce: Compared to spinach, lettuce has a lower iron level. By expressing a soybean ferritin gene, the lettuce's iron content, yield, and growth rate have all enhanced.

Carrots that are genetically modified are high in the vitamin and mineral beta-carotene, but poor in calcium. Arabidopsis H+/ Ca++ transporter expression has enhanced the bio-available calcium content in transgenic carrot.

Kalia et al., 2018 studied marker assisted introgression of the Or gene for enhancing beta carotene content in Indian cauliflower. The main objective of the study was Interogression of the β-carotene (pro-vitamin a). -enhancing or gene from donor inbred line EC625883 into Indian cauliflower Pusa sharad (DC309) and the parents of Pusa hybrid-2 (CC-35 and DC-18 19) through marker-assisted backcross breeding (MABB) approach. SCAR marker was utilized for forehead selection in the BC1F1 cross of Pusa sharad and EC625883.

EC625883 has 3.35-5.62 (μg g/g fresh curd weight) beta-carotene content. The first cauliflower cultivar bred for β-carotene biofortification, 'Pusa KesariVitA-1'was recently developed in the background of DC18-19 and selected for release to farmers for cultivation. It contains 8-10 µg g-1 β-carotene (HPLC eluted) and matures ready for harvesting during December-January, hence belonging to the mid-late maturity group of Indian cauliflower. Or gene introgression in early and late maturity groups is in progress, which will prolong the availability of cauliflower rich in β-carotene and go a long way to tackling the VAD malnutrition problem in India.

Fiqure 1 represents Pusa Kesari VitA-1 rich in Beta carotene 8-10 µg g/g

Folate rich tomato: Folates are synthesized from pteridine, p-aminobenzoate (PABA), and glutamate precursors. Pteridine production was increased upto 140 folds by overexpressing GTP cyclohydrolase. Then, the PABA synthesis was increased upto 19 by overexpression of aminodeoxychorismate synthatase. When transgenic PABA- and pteridine-overproduction traits were combined by crossing, vine-ripened fruit accumulated up to 25-fold more folate than controls.

Fiqure 2 represents folic acid rich tomatoes

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