

AN INSIGHT INTO THE BIO-FORTIFICATION IN PULSES TOWARDS GLOBAL NUTRITIONAL SECURITY

Abstract

A sustainable method to enhance the nutritional makeup and the nutrient composition of food crops is biofortification through plant breeding. The bulk of the world's population relies on staple food crops, but most lack critical micronutrients. In several breeding projects during the past ten years, biofortification has gained relevance as a means of enhancing the nutritional makeup of pulse crops. Pulses and legumes, particularly chickpeas, mungbeans, soybeans, and peas, are members of the Fabaceae family and are high in nutrients. Many diets rely heavily on pulses and legumes as a source of plant protein. Due to the presence of several bioactive compounds—among which phenolic acids, flavonoids, and tannins make up the majority—pulses play a crucial role in metabolic and physiological processes. Despite being a good source of 15 vital minerals and vitamins, pulses and legumes have a limited bioavailability due to the presence of antinutrient agents. Breeding-based biofortification is a technique for improving the nutritional content of pulses and legumes. The key micronutrients that have been addressed include iron, zinc, selenium, iodine, carotenoids, and folates. The widely predicted improvement in crop productivity and yield has greatly increased with the extensive application of new technologies in agriculture. However, even an adequate amount of food cannot stop issues like hidden hunger or malnutrition, which are the root causes of many health issues around the world. Besides the challenges biofortified crops hold a bright future to address the malnutrition challenge.

Keywords: Biofortification, malnutrition, sustainable achievements, plant growth promoting organisms, transgenic, plant breeding

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I. INTRODUCTION

Malnutrition is a critical issue that impacts a large number of people in the majority of African and Asian nations. Due to the significant health issues it is associated with, it has attracted interest from throughout the world. Twenty million newborns are born every year with a low body weight. [1] Population increase is putting more strain on natural resources such as arable land, and this, combined with the environmental pressures brought on by climate change, is adversely affecting plant growth, productivity, and nutritional value. Additionally, the overuse of pesticides and fertilisers has a negative influence on the ecosystem, leading soil and water quality to decline [2 -5]. All of these challenges are reflected in human health, with malnutrition problems becoming more severe, not only in emerging economies but even in rich countries where food is plentiful but has low nutritional value.[6] The chemical residues in products are becoming a growing source of worry for consumers in industrialised nations, who are calling for more sustainable agriculture practises that prioritise safer products with no chemical residues. A quick response is required. In order to ensure the production of foods with a high nutritional value and a small environmental impact, society must find a sustainable way to address today's difficulties.

A promising approach to meet the requirements previously outlined is biofortification. The World Health Organisation (WHO) defines it as "the process by which food crops' nutritional value is improved through agricultural practices, conventional plant breeding, or modern biotechnology." [7] In this context, agronomical practices try to increase the solubilization and mobilization of nutrients in the soil by applying fertilizer, hence promoting mineral absorption [8]. In underdeveloped nations where cereals and legumes are the primary food sources, legumes are an excellent target for improving the nutritional value of diets. The combination of legumes and their naturally colonized bacteria appears to be a potent one for a sustainable and eco-friendly strategy to combat the effects of climate change on crops and enhance plant nutrition. Legumes have a high nutritional value in addition to being crucial for the environment [9].

II. PULSES AND LEGUMES

The Fabaceae family, which includes pulses and legumes, is rich in nutrients, particularly chickpeas, mungbeans, soybeans, and peas. In many diets, pulses and legumes provide a significant source of plant protein. They have a low GI (glycemic index) and are a great source of dietary fiber and complex carbs. Due to the presence of numerous bioactive chemicals, primarily phenolic acids, flavonoids, and tannins, pulses play a significant role in metabolic and physiological processes [14]. Legume is a type of plant that is described as a "fruit" that contain dry grains and has the propensity to nitrogen in soil is fixed. In 2021, approximately 88.97 million metric tonnes of pulses were produced in world wide [11]. The estimated production of pulses in 2021-22 as per the Department of Agriculture and Farmers' Welfare is 26.96 million tonnes [12]. In India 2021-22, 30.37 Mha area is under pulses with an average yield of 888 kg/ha [13].

The Contribution of Pulses to the Achievement of the Sustainable Development Goals Due to the climate change phenomena, which includes global warming and a rise in the frequency of extreme weather events (heavy rains and drought), the world is currently experiencing significant agricultural losses in terms of productivity and nutritious crop value.

As a result, over two billion individuals experience malnutrition issues as a result of food shortages (acute hunger) or inadequate intake of crucial micronutrients (hidden hunger) [16].

Even though they are crucial for human nutrition and health, the production of food legumes has only seen a slight annual increase of 0.95%, fluctuating only between 40.78 and 70 million tonnes. Pulses per capita availability has been under extreme strain due to the slow expansion in world pulses output, expanding population, diversifying end-uses, and people's improved purchasing power [17]. In order to increase the nutritious content of meals, fortification of foods during processing looks to be a promising method; nevertheless, not all populations can use this tactic [20].

With a focus on the most underprivileged people, biofortification looks to be a workable strategy to increase the nutritional value of meals [18]. Legumes in particular are superior to or on level with cereals in terms of their supplies of vitamins, minerals, and amino acids [21]. They have a wide range of possible health advantages when added to the human diet. Some specific chemicals in legumes, like soluble fibers, antioxidants, flavonoids, etc., appear to be linked to a decreased risk of diabetes, cardiovascular disease, and some types of cancer, among other conditions.[22] Legumes contribute to the symbiotic N fixation process in the environment, which lowers the requirement for nitrogen fertilizer, lowers agricultural CO₂ emissions, and improves soil quality [23]. In addition to providing the subsequent crops with pest and disease resistance [24], the introduction of legumes in crop rotation systems can cut greenhouse gas emissions by up to 25% [25].

III. NUTRIENT CONTENT OF MUNGBEAN, PEAS AND SOYABEAN

1. Mungbean : One of the most important pulse crops, mungbeans (*Vigna radiata*), are produced 90% of the world's supply in Asia. Indian is the greatest producer of mungbeans, accounting for 50% of global production, followed by China and Myanmar [26].

- **Protein:** Mungbean is a high proteinous food. Numerous storage proteins, including globulin (60%) and albumin (25%) are found in mungbean [27]. It contains significant amounts of the important amino acids phenylalanine (1.44%), leucine (1.85%), isoleucine (1.008%), valine (1.24%), tryptophan (0.26%), arginine (1.672%), methionine (0.286%), and lysine (1.66%). Histidine (0.7%) and threonine (0.78%) [28,29]. Mung bean protein has more in vitro digestibility than soybean protein (70%). (65%) [30].
- **Carbohydrates:** It has a high carbohydrate content of 55–65%. Because mungbeans contain starch, which is a significant carbohydrate, they can be used to make starchy noodles [31]. The starch granule is oval, circular, or bean-shaped, and it ranges in diameter from 7 to 26 m [32]. It has significant cross-linkage properties. Less common sugars including raffinose, stachyose, and verbascose are to blame for flatulence in the diet. The oligosaccharides in mungbean, however, can be easily reduced by soaking, germination, and fermentation because they are soluble in water. Compared to other legumes, mung bean carbohydrates are more easily digested and less likely to induce flatulence [33].

- **Lipids:** Mungbean contains just 2.1–2.5% oil, the majority of which is composed of linoleic acid (3.3–4.7 g/kg), palmitic acid (2.9–4 g/kg), oleic acid (2.2–2.9 g/kg), stearic acid (1.4–1.9 g/kg), and arachidic acid (0.23–0.3 g/kg) [34].
 - **Vitamins :** The amount of vitamins in one hundred grams of raw mungbean is ascorbic acid (4.9 mg), thiamin (0.62 mg), riboflavin (0.23 mg), niacin (2.25 mg), pantothenic acid (1.91 mg), vitamin B-6 (0.38 mg), folate (616 mg), choline (98 mg), beta-carotene (69 mg), vitamin A (115 IU), vitamin E (alpha-tocopherol) [35].
 - **Minerals:** The fact that it contains between 3.1 and 4 percent of ash [36,37 ,38] indicates that mungbean has a sizable amount of minerals. 3.5–4.5 mg/100g, 129–169 mg/100g, 8.9–13.2 mg/100g, 363–415 mg/100g, 80–114 mg/100g, and 1.3–2.1 mg/100g are the ranges for the minerals iron, magnesium, sodium, potassium, calcium, and zinc, respectively [39].
2. **Peas:** The pea (*Pisum sativum*), which is grown for both human and animal consumption, is one of the most significant crops ever produced. 17.5 million tonnes are produced worldwide each year of dry and green peas.
- **Protein:** A range of environmental and genetic factors influence the protein content of peas, which ranges from 21.4% to 33.1%. it contains the majority of the protein. The nutritional value of storage proteins or globulins is determined by the amino acid composition. Higher levels of arginine are present in it. Compared to soybeans and lupin, the lupin has less glutamic acid, cysteine, valine, and methionine. Despite having a lower in vitro digestibility than soybean and other pulses due to the presence of protease inhibitors, raw pea nevertheless has a better in vitro digestibility [42].
 - **Carbohydrates:** In whole peas, the range of carbohydrate content is 56.7–74.0%, and in the kernel, it is 62.7–78.7%. The two kinds of glucose that make up starch are amylose and amylopectin. Rough-cut peas compared to smooth peas' (44–46%) reduced level of starch (28–38%) the wrinkle peas, however, have a greater (60–75.2%) amylose concentration. comparative to smooth peas (22–38%). Additionally, discovered is that sucrose Content is greater in wrinkled peas than in smooth peas [43]. A desire- The ratio of amylose to glucose directly affects a starch's ability. the reaction of postprandial hyper glycemia to amylopectin [44].
 - **Lipids:** Peas have a low lipid content of 0.8–6.2%. The percentages of total lipids in wrinkle seeds and round seeds are 4.5–5.3% and 2.8–3.2%, respectively. Re-evaluated fatty acid composition of peas (g/100g total fatty acids) reported to be made up of oleic acid, stearic acid, and palmitic acid (8.5–19.5g). (6.5–13.5g), linolenic acid (14.3–23.3g), and linoleic acid (38–70g) [45].

- **Vitamins:** Ascorbic acid is one of the vitamins contained per kg in raw peas. Niacin (22-297 mg), thiamin (4.2–6.2 mg), and riboflavin (0.7–6.5 mg) Vitamin B-6 (1.2 mg), pyridoxine (10.5 mg), pantothenic acid (21.2 mg), and (1.1mg), beta-carotene (7.0g), biotin (8.3mg), and folic acid (0.7mg), among others. Inositol (1.6 mg), tocopherol (22–72 mg), and vitamin K (1.7 mg) [46].
 - **Minerals:** Peas contain many important minerals such as calcium (0.4–1.4 g/kg DM), potassium (7.6–12.6 g/kg DM), phosphorus (2.2–5.2 g/kg DM), Magnesium (1–2.5 g/kg DM), iron (22–500 mg/kg DM), zinc (20.5–67 mg/kg DM), sodium (30–1500 mg/kg DM), copper (5–10 mg/kg DM) and manganese (8.9–140 mg/kg DM). Most of these minerals are present between the testa and the kernel; the latter is richer in calcium and potassium [47]. Because of high phytate content in peas, the bioavailability of Zn, Fe, and Ca are very low [48].
- 3. Soyabean:** Soybean is recognized as one of the most important prospective protein sources for human nutrition under conditions of climate change and population growth. In 2021-22 the total world soyabean production goes to 385.524 million tonnes. With an annual production volume of 117,208,380 tonnes, the United States of America is the greatest soybean producer in the world. With 96,296,714 tonnes produced annually, Brazil comes in second. More than 60% of global production is produced jointly by the United States of America and Brazil. India is rated at #4 with 14,008,000 points [49-50].
- **Protein :** Soybean has a protein level of between (36 and 56%) [5]. big in soybean Numerous proteins, including globulin and other storage proteins, the primary globulin constituents are glycinin (11S) and -conglycinins (7S). Although soy protein has few amino acids that include sulfur, contains all the amino acids necessary for proper human body operation, including Leucine, lysine, methionine, cysteine, phenylalanine, isoleucine, tyrosine, threonine, tryptophan, valine, and histidine [51].
 - **Lipids and Carbohydrates:** About 17–20% of the dry weight of the soybeans are made up of oil. Linoleic and linolenic acids, which are found in abundance in soybean oil, make it appropriate for human consumption [5]. According to estimates, the fatty acid composition of soybean oil consists of the following: palmitic acid (10.5–25%), stearic acid (2.7–30%), oleic acid (20.8-85%), linoleic acid (58.6%), and linolenic acid (5–17%). About 33% of the carbs in soybeans are fiber, which makes up the majority of those carbs. The two main soluble carbohydrates, accounting for (4-6%) of the total, are raffinose and stachyose. Dry matter base ranges from 1.4% to 4.1%. The four main types of insoluble carbohydrates are starch, cellulose, hemicellulose, and pectin are present in the soybean [52].
 - **Vitamins:** Soyabean contains many type of vitamins such as fat soluble and fat insoluable. The quantity and the range of tocopherols in soybean is 10.9–28.5, 150–190, and on a dry matter basis, they are, respectively, 24.5-72.5 g/g [53].
 - **Minerals:** It has 5% ash in it. Significant minerals found in soybeans include potassium, the elements sodium, chloride, phosphorus, magnesium, calcium, and sulfur are present in from 0.2% and 2.1%, while the levels of silicon, iron, zinc,

magnesium, copper, cobalt, cadmium, lead, arsenic, and chromium are between 0.01–145 ppm [54- 55].

IV. APPROACHES FOR IMPROVEMENT OF NUTRITIONAL PROFILE

To improve the nutritional profile of crops and combat micronutrient insufficiency, many methods including dietary diversification, food supplements, food fortification, and biofortification are applied.

- 1. Dietary diversification:** It is a strategy that entails consuming a wide variety of foods, particularly varied plant-based meals including fruits, vegetables, and healthy grains. In order to increase the amount and bioavailability of micronutrients in food, dietary diversification also employs household-level tactics including food preparation that involves soaking, fermentation, and germination [56]. It is best to consume less foods high in anti-nutrients, which prevent the absorption of minerals, while consuming more fruits and vegetables high in promoter compounds . Foods high in ascorbic acid (a promoter of iron absorption) should be ingested, for instance, to boost iron absorption [57-58].
- 2. Food Fortification:** Fortification is the process of enhancing food's nutritional value by including vital micronutrients, such as vitamins and minerals. The World Food Programme (WFP) has several food aid programmes in place that use grains and pulses that have been partially pre-cooked, milled, and fortified with micronutrients overcome nutrient deficits and offer health advantages with little danger.
- 4. Biofortification:** The method of "biofortification" involves agronomic adjustments, genetic engineering, and traditional plant breeding to enhance the dietary profile of plant-based foods (Figure 1).

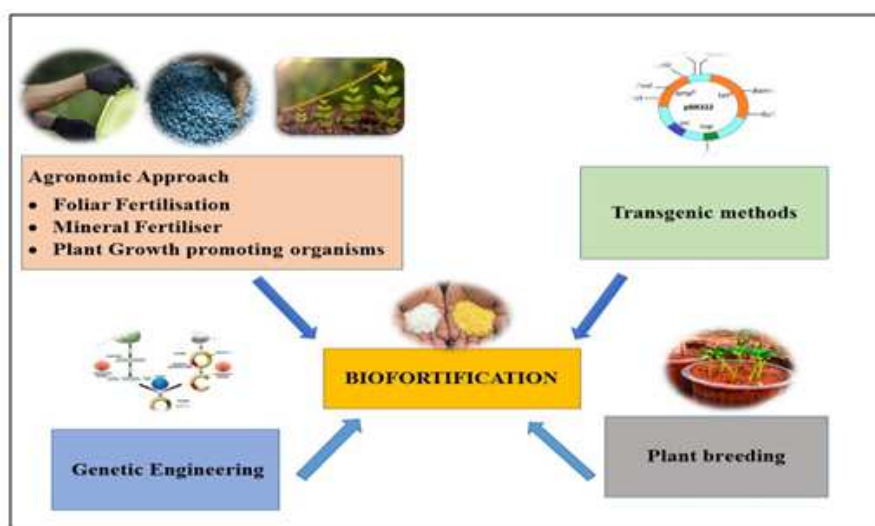


Figure 1: Different Methods used for Biofortification

V. AGRONOMIC APPROACHES

Through the use of agronomic methods, biofortification can be accomplished through foliar fertilisation [60], the application of mineral fertilisers to the soil, and the introduction of beneficial microbes into the soil.

- 1. Foliar fertilisation:** Application of fertilisers directly to leaves is known as foliar fertilisation. It might be successful when mineral elements are not instantly available in the soil or are not easily transported to edible tissues [60,61]. Micronutrients Fe, Zn, and Se were added as foliar fertilisers to pulse crops to biofortify them. Application in multiple trials led to enhanced levels of these micronutrients in the harvested Fe concentration in cowpea seeds was found to be higher (29–33%). [63]. After applying Fe to the leaves of mungbeans, [64] scientists have found that the Fe concentration had increased (46%). In a similar manner, foliar application of Fe and Zn considerably raised the content of these minerals along with protein in seeds of cowpeas and chickpeas [65,66].
- 2. Mineral Fertiliser :** Mineral fertilisers are inorganic substances that increase the mineral quantity in the soil and, consequently, the quality of the plants. Mineral fertilisers must be applied with increased mineral solubility and mobility [67]. Plants can be strengthened with minerals using this technique, but not with organic substances like vitamins, which the plant itself makes. For Se, this approach was successfully used. I, and Zn, as these elements are easily mobile in the soil as well as the plant tissue. [68].

Regular fertilisation is usually necessary for biofortification, although this could be bad for the environment's health and could reduce the amount of other minerals that are available. Furthermore, the soil type in a particular region, variations in mineral mobility, and the Successful mineral chelation may also be hampered by the potential for antinutrient molecules to restrict mineral bioavailability putting this strategy into practise [69, 70].

- 3. Plant growth promoting Organisms:** Beneficial soil microorganisms like rhizobia, mycorrhizal fungi, actinomycetes, and diazotrophic bacteria are symbiotically linked to plant roots and provide plants with a variety of benefits, including the availability and production of plant growth hormones and the promotion of nutrient mineralization. Although they occur naturally in the soil, inoculation or agricultural management methods can increase their numbers. To boost the phytoavailability of micronutrients, a variety of plant growth-promoting (PGP) soil microorganisms, such as *Enterobacter*, *Bacillus*, and *Pseudomonas*, can be utilised. These are mostly utilised as seed inoculants and promote plant growth by producing growth hormones, antibiotics, chitinases, siderophores, and inducing systemic resistance and mineralization [71].

Increased amounts of Fe, Se, and Zn have been seen in numerous experiments using microorganism inoculants via mycorrhizal connections [72,73].

In comparison to control (uninoculated) plants, chickpeas with PGP actinobacteria inoculation had higher seed mineral concentrations, including Fe (10–39%) and Zn (14–30%) [74]. Similar to this, the nutritional profile of chickpea grains was enhanced by arbuscular mycorrhizal fungi field inoculation by raising Fe and Zn concentration as well as yield and protein content [75]. Application of PGP rhizobacteria with Fe compound (FeSO₄) in soil enhanced iron concentration in chickpeas (up to 80%) when compared to a control, according to Khalid et al. [76]. They also speculated that microbes may play a part in the extra uptake of Fe from soil when supplemented with Fe.

VI. TRANSGENIC METHODS

This technique has been used to generate biofortified soybean (*Glycine max*), common beans (*Phaseolus vulgaris*), lupines (*Lupinus angustifolius*), and many other pulse crops. This approach could need a significant initial investment, but if a transgenic variety is created and commercialized, it becomes a more dependable and sustainable method. Regarding important micronutrients like iron, zinc, and folate, this approach is still in development for pulses. Several limitations in genomic technologies have been overcome by the introduction of modern technologies like CRISPR/CAS9, ZFN (zinc finger nucleases), and To improve the nutritional profile of pulses, TALENs (transcription activator like effector nucleases) have been used to circumvent a number of genomic technology limitations. Additionally, desired bacterial pathways can be added using these gene editing tools to benefit metabolic engineering.

The capacity to apply this approach for multigene transfer, micronutrient enrichment, and the removal of antinutrients from edible tissues is made possible by the availability of fully sequenced genomes of pulse crops. Despite the fact that single gene modifications have no impact of target micronutrients in the plants [77].

VII. GENETIC ENGINEERING

When any desirable micronutrients does not exist naturally, then modification can be achieved by the process of genetic engineering by putting the desirable genes. The recent availability of fully sequenced genomes in numerous crops encouraged this strategy. This strategy can simultaneously target the removal of antinutrients or the addition of promoters that can increase the bioavailability of micronutrients, in addition to boosting the concentration of micronutrients [12]. This method used genes from bacteria and other species in addition to those connected to several metabolic pathways used by plants [45].

Transgenic crop development demands a significant initial expenditure, however this could require a substantial investment during the initial stage and this is the best method to target the large populations especially in developing countries. Similar to this, cowpeas were successfully modified using CRISPR/Cas9-mediated genome editing technology to stop the activation of the SNF gene. These results pave the path for the use of gene editing technologies for numerous features of interest in legumes.

VIII. PLANT BREEDING

The most widely used form of biofortification is through traditional plant breeding. It provides a viable, economical substitute for agronomic- and transgenic-based techniques. For conventional breeding to be successful, the trait of interest must have sufficient genotypic variation. However, the low genetic diversity found in the gene pool must occasionally be taken into account in breeding techniques. In other instances, this can be avoided by crossing to distant cousins, which gradually introduces the characteristic into the commercial cultivars. A different method is to use mutagenesis to add new features directly into commercial cultivars.

IX. CHALLENGES IN BIOFORTIFICATION OF PULSES

Due to the adoption of all the aforementioned solutions, the process of pulse biofortification has been effective in many regions, but there are still certain obstacles to overcome. Plants include antinutrients that are naturally occurring, which decreases the ability of micronutrients to be absorbed. Phytic acid was found, according to Biel et al. This lowers the iron and zinc bioavailability in pulses and legumes. Other Saponins, lathyragens, protease inhibitors, and alpha-blockers are the inhibitors that are present. The presence of polyphenols as well as amylase inhibitors in legumes black bean seed coat's ability to absorb iron is hampered.

Another obstacle to bio-fortification is the limited genetic diversity of the plant gene pool and the lengthier period needed for research and cultivation. Due to poor marketing tactics and the low acceptance of transgenic pulses, the production of pulses has been viewed as a cashless crop, and many farmers have migrated to other crops. Yield and the nutritional composition of harvested pulses are also impacted by biotic and abiotic stress. The nutritional profile is further impacted by post-harvesting procedures since many micronutrients are removed during milling and polishing. Collaboration between plant breeders, nutritionists, genetic engineers, and marketing specialists is crucial to solving these issues. Both conventional and genetic engineering methods call for the expansion of germplasm conservation for better characterisation and screening of pulses varieties. A single locus multinutrient characteristic aids in the qualitative enhancement of pulses [45].

X. CURRENT STATUS OF BIOFORTIFICATION IN PULSES

Prof. M.S. Swaminathan, a great agriculturalist and visionary, has previously stated that nutritional security should be discussed instead of food security. He has also emphasised the importance of including all essential micronutrients in every person's diet as opposed to diets that are high in calories and protein. As a result, the idea of biofortification supported the need for a tool to combat malnutrition in the current situation.

Breeding-led biofortified crops have, among other methods of biofortification, improved crop nutrition profiles over time. With regard to biofortified crops developed through breeding, cereals account for 58.1% of the total, followed by legumes at 13.3%, vegetables at 19.8%, and fruits at 9%. In addition to this, an agronomic approach was used to distribute cereals at a rate of 69.5%, legumes at a rate of 14.5%, oilseeds at a rate of 3.2%, vegetables at a rate of 11.3%, and fruits at a rate of 1.6%.

By 2030, it is intended to provide more than one billion people with access to biofortified crops and the varieties of those crops so they can benefit from them in terms of nutrition and agronomy. Among the 12 biofortified crops, cowpea (Fe and Zn), lentils (Fe and Zn), and common beans (Fe) are frequently sold and consumed as biofortified crops under the category of pulses [1]. On October 16, 2020, in honour of the Food and Agriculture Organization's (FAO) 75th anniversary, the Indian Prime Minister dedicated one variety of lentil called “Pusa Ageti Masoor”.

XI. FUTURE PROSPECTS

Government policies governing food security vary from one nation to the next in order to secure the lives of those in need by giving them access to food grains. Despite this, nutritional security is now being discussed more than food security because it promotes a healthy lifestyle among the populace and serves as a weapon against malnutrition. In order to address that, the following strategies should be implemented in the future:

The implementation and strengthening of a fast-track breeding programme for the creation of nutritionally dense varieties in accordance with the agro-climatic conditions and dietary preferences of residents of particular areas and or regions.

Due to the presence of phytic acid, research should concentrate more on the bioavailability of micronutrients in pulses, particularly Fe and Zn.

Consumption of biofortified crops would be encouraged by the advancement of technological infrastructures and market chains from growers to consumers.

It would be very helpful to the breeder to identify such landraces or wild/primitive cultivars that have good micronutrient contents in order to create new varieties.

The creation of novel plant species that are incredibly effective at absorbing, transporting, and accumulating micronutrients in edible plant parts. Identification of target genes or pathways that promote the synthesis of micronutrients and improve the efficiency of their conversion in pulse crops is also important. Distribution of these developed varieties to farmers for commercialization.

A separate MSP should be implemented by the governments for the bio-fortified crops. By taking this action, farmers would be more likely to grow biofortified crops and make a greater profit from them

XII. CONCLUSION

One in three people worldwide lacks micronutrients, which are crucial for human growth and development. The most affordable and long-lasting method of addressing micronutrient deficiencies is thought to be biofortification through plant breeding. This strategy is widely accepted and has the potential to reach individuals living in Remote rural areas with little access to commercially marketed fortified foods. Further, Farmers can multiply seeds over years for practically nothing with a one-time investment. Marginal price. With the introduction of numerous biofortified products, significant

advancements have been made recently. Crop varieties that are assisting the target populations in overcoming micronutrient deficiencies. A better nutritional profile for pulse crops will lead to a significant increase in consumption because they are a significant source of protein and energy. The last ten years have seen a rise in biofortification efforts to enhance the nutritional profile of pulse crops. But if the use of biofortified foods is to be effectively maximised, there are a number of issues that must be resolved.

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