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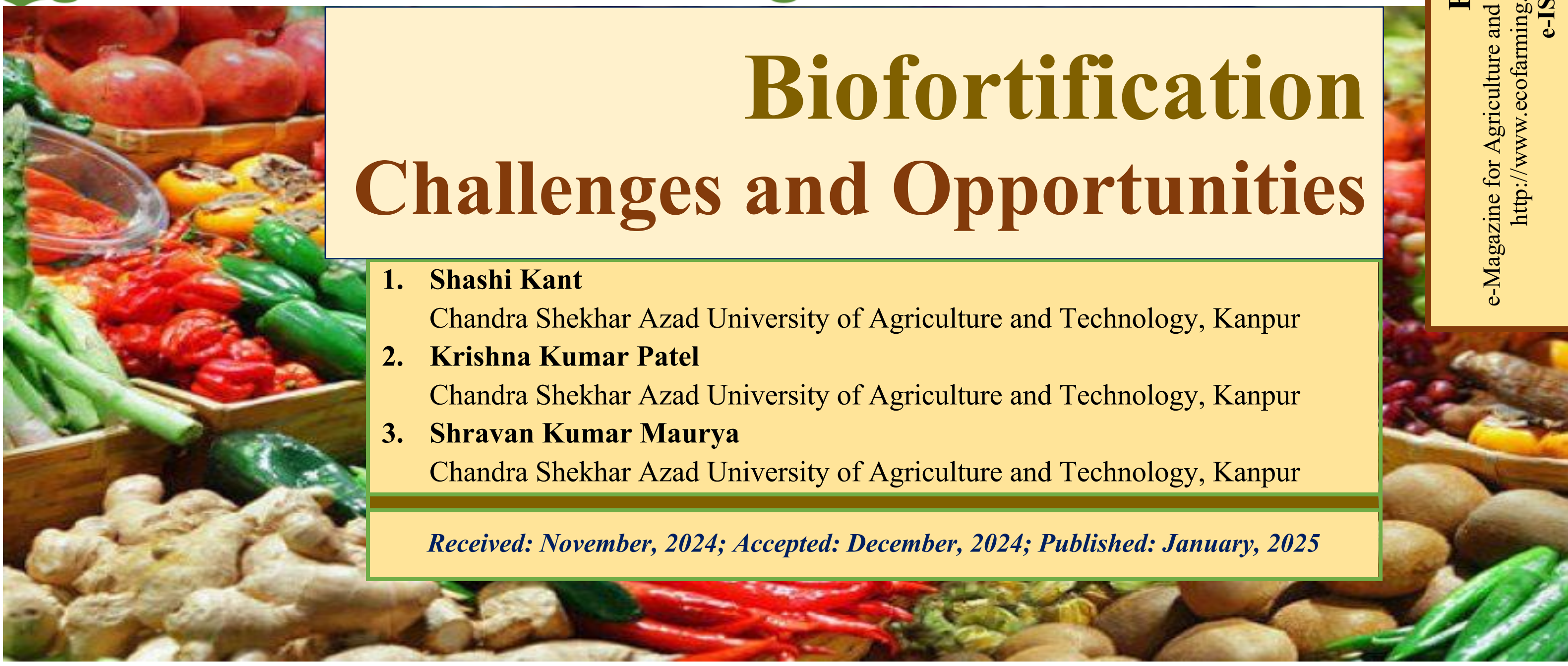

Biofortification
Challenges and Opportunities

1. **Shashi Kant**
Chandra Shekhar Azad University of Agriculture and Technology, Kanpur
2. **Krishna Kumar Patel**
Chandra Shekhar Azad University of Agriculture and Technology, Kanpur
3. **Shravan Kumar Maurya**
Chandra Shekhar Azad University of Agriculture and Technology, Kanpur

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What is Biofortification?

Biofortification is the development of nutrient-dense staple crops using the best conventional breeding practices and modern biotechnology, without sacrificing agronomic performance and important consumer-preferred traits. (Nestel *et al.,2006.)*

Kinds of biofortification:

1. ***Conventional Breeding:*** Traditional breeding methods involve selecting and crossbreeding plants with desirable traits, such as higher nutrient content. This process is time-consuming but has been successful in developing biofortified varieties of crops.
2. ***Genetic Modification (GM) or Genetic Engineering:*** Genetic modification involves the direct manipulation of an organism's genes to introduce or enhance specific traits. In biofortification, genetic engineering can be used to insert genes responsible for increased nutrient uptake or synthesis into the crop's genome.
3. ***Marker-Assisted Selection (MAS):*** MAS is a breeding technique that utilizes molecular markers to identify and select plants with specific desired traits. This method expedites the breeding process by allowing researchers to identify and select plants with the desired biofortification characteristics more efficiently.
4. ***Hybridization:*** Hybridization involves crossing different varieties or species to produce offspring with improved traits. This technique is often used to combine beneficial traits from different parent plants, including higher nutritional content.
5. ***Mutagenesis:*** Mutagenesis involves inducing mutations in the plant's DNA to generate genetic diversity. Mutagenesis can occur naturally or be induced through chemical or radiation treatments.
6. ***Cross-Breeding with Wild Relatives:*** Wild relatives of crops often have traits that can be beneficial for biofortification.

Example of biofortification for different nutritional elements

Iron Biofortification: Targeted at addressing iron deficiency, iron biofortification involves increasing the iron content in staple crops such as rice, wheat, beans, and lentils. This can be achieved through conventional breeding or genetic engineering to enhance iron uptake and accumulation in plant tissues.

Zinc Biofortification: Zinc is essential for various physiological functions, and its deficiency is a significant health concern. Zinc biofortification focuses on increasing the zinc content in crops like wheat, rice, and maize. Breeding programs aim to develop varieties with improved zinc absorption and transport mechanisms.

***Vitamin A Biofortification**:* Vitamin A deficiency can lead to vision problems and impaired immune function. Biofortification targets crops like sweet potatoes, maize, and cassava to increase the levels of provitamin A carotenoids, which the body can convert into vitamin A. This can be achieved through conventional breeding or genetic modification.

Amino Acid Biofortification: Amino acids are the building blocks of proteins, and their balance is essential for human health. Biofortification programs may target crops to increase specific amino acids, addressing nutritional imbalances and promoting better protein utilization.

Multi-nutrient Biofortification: Rather than focusing on a single nutrient, some biofortification initiatives aim to enhance multiple nutrients simultaneously. This holistic approach targets crops like millets, which are nutrient-dense and can be biofortified to address various deficiencies.

Iodine Biofortification: Iodine is crucial for thyroid function, and its deficiency can lead to disorders such as goiter. Biofortification targets crops like potatoes and rice to increase iodine content, addressing iodine deficiency in regions where soil lacks sufficient iodine.

Some examples of minerals and vitamins targeted in biofortification efforts:

Minerals:

- Iron
- Zinc
- Selenium
- Calcium

Vitamins:

- Vitamin A (Beta-carotene)
- Vitamin C
- Vitamin D
- Vitamin E

Some crops developed through biofortification

High Fe & Zn wheat WB2 Wheat:

WB2:High Zn (42 ppm) and Fe (40 ppm) with 12.4% protein and average seed yield is 51.6 q/ha and maturity142 days, Resistant to yellow rust, brown rust and highly resistant mildew to powdery mildew. Recommended for irrigated timely sown conditions of North Western Plains Zone

Golden rice: Golden rice, a rice variety produced using genetic engineering, is an epitome of scientific innovation! It is ingeniously designed to syn beta-carotene, a precursor of vitamin A, in the parts of rice that are meant to be eaten by us, humans. Golden rice rich in β-carotene (vitamin A) and produce β-carotene in green tissues - not in endosperm

Maize: Pusa Vivek QPM Improved (Hybrid): Country's first provitamin- A rich maize, High provitamin- A (8.15ppm), lysine (2.67%) and tryptophan (0.745%) as compared to 1.4-2.0 ppm provitamin –A, 1.5- 2.0 % lysine and 0.3-0.4% tryptophan content in popular hybrids and Grain yield 55.9 q/ha [Northern Hills Zone (NHZ) and 59.2 q/ha (Peninsular Zone).

Mustard: Pusa Mustard 30 (Pure line variety): Contains low erucic acid (<2.0%) in oils as compared to > 40% erucic acid in popular varieties. Oil Contents 37.7%, Seed yield 18.2 q/ha and Suitable for timely sown irrigated condition. Adaptation in Uttar Pradesh, Uttarakhand, Madhya Pradesh and Rajasthan and developed by ICAR New Delhi.

Advantages of Biofortification

- **Targets the poor-** who eat high levels of food staples. A food-based intervention biofortification uses the very staples that the poor are already eating, to deliver the micronutrients to them. Therefore, biofortified foods are more easily integrated into the livelihood and diets of the poor.
- **Rural-based**-it is an agriculture intervention targeted at rural area where more 75% of the poor live and where access to supplements, fortified foods and other urban-based interventions are limited.

- **Cost-effective-** A onetime investment in breeding biofortified crops would provide micronutrients far more cost-effectively than through conventional means that have high recurring costs. The biofortified crops are self-sustainable in that the biofortified seeds can be grown year after year.

Future challenges in biofortification:

While biofortification holds great promise in addressing malnutrition and hidden hunger, several challenges must be overcome to ensure its widespread success in the future. Some key challenges include:

- Genetic Diversity and Adaptation
- Acceptance and Consumer Preferences
- Regulatory and Policy Frameworks
- Seed Systems and Distribution
- Integration with Existing Agricultural Practices
- Collaboration and Knowledge Transfer
- Long-Term Impact Assessment
- Climate Change Adaptation
- Ethical Considerations

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