Nutritious Grains for Health and Wellness

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Grains – Cereals in Gm / 100Gm

Grain	Protein	Total Fat	T Fiber	Energy K Cals
Bajra	11	5	12	373
Jowar	10	2	10	350
Maize dry	9	4	12	350
Quinoa	13	6	15	344
Ragi	7	2	11	336
Rice raw	8	.5	3	373
Rice Brown	9	1	5	370
Maida	10	.75	2.8	368
Atta	11	1.5	11.5	335

Source: IFCT ICMR NIN 2017

Grains – Legumes gm/ 100 gms

Legume	Protein	Fat	Fiber	Energy -Kcals
Bengal Gram Dhal	22	5	15	344
Black Gram	23	2	12	339
Lentil Dhal	24	1	10	337
Soya bean	37	19	23	395

Source IFCT ICMR NIN 2017

Minerals in grains mg/ Kg

Mineral	Millet	Wheat	Maize	Rice	Sorghum
Phosphorus	2400	1170	990	1030	350
Potassium	2200	1550	1200	1500	240
Magnesium	1000	250	470	350	188
Calcium	100	170	60	60	27
Zinc	34	8	5	17	3
Iron	48	12	11	12	11

Source : Cereal Grains ed AK Goyal, Intech open ebook, 2021

Nutritional Impact of Global warming

Iron and Zn deficiency in crops up to 20%

Additional 175 million Zn def and 122 million protein deficient

About 4% decrease in iron intakes of vulnerable

Shifting Crops C3 to C4 pathways

- C3 crops = Rice, Wheat, high water needs, lower temperature tolerance, slower carbon di oxide fixation
- C4 better photosynthesis in high temp and drought tolerant- faster carbon di oxide fixation
- C4 better nitrogen use
- C4 have twice as much photosynthetic capacity
- Eg C3- Rice, Wheat, oats
- Eg C4 – Maize, Pearl millets, Sorghum

Biofortification

- Select climate resilient crops
- Select nutrient rich crop varieties
- Develop natural hybrids by selective breeding
- Select hybrids with climate resilience and enhanced nutrients
- Biofortification makes food crop varieties more nutritious and more stable under a variety of challenging environmental conditions. (Harvest Plus)

Millet varieties (Source Harvest Plus CGIAR)

- Pearl Millet Biofortified – 80% RDA of iron
- Survives 40C temp and less than 40 cm annual rainfall
- Finger Millet (Ragi)- Highest Calcium content

- Pro Vitamin A biofortified Maize
- Bio fortified Quality Protein Maize- Higher amino acid content
- High heat tolerant

Bioavailability studies

- The Journal of Nutrition (2013)

Biofortification of Pearl Millet with Iron and Zinc in a Randomized Controlled Trial Increases Absorption of These Minerals above Physiologic Requirements in Young Children1–3

Bhalchandra S. Kodkany, Roopa M. Bellad, Niranjana S. Mahantshetti, Jamie E. Westcott,

Nancy F. Krebs,5 Jennifer F. Kemp,5 and K. Michael Hambidge

- A Randomized Trial of Iron-Biofortified Pearl Millet in School Children in India

Julia L Finkelstein, Saurabh Mehta, Shobha A Udipi, Padmini S Ghugre,Sarah V Luna,

Michael J Wenger, Laura E Murray-Kolb, Eric M Przybyszewski, and Jere D Haas

This study demonstrated that feeding Fe-PM is an efficacious approach to improve iron status in school-age children: The Journal of Nutrition, 2014

Biofortified Crops: Climate-smart Traits and Productivity Advantages

BIOFORTIFIED CROP	NUTRITION TRAIT	CLIMATE-SMART TRAITS	SAMPLE VARIETIES	YIELD, TONS PER HECTARE (MATURITY TIME)
Rice	High zinc	Extra early maturity	BRRI Dhan 62	4 t/ha (Extra early: 100 days)
Wheat	High zinc	Stem rust resistance Drought tolerance	Akhbar-2019	4.47 t/ha (Intermediate: 140 – 145 days)
Maize	High vitamin A	Drought tolerance Early maturity	SAMMAZ 60	5 t/ha (Early to medium: 110 – 120 days)
Pearl Millet	High iron	Downy mildew resistance High temperature and drought tolerance Extra early maturity	Dhanshakti	2.5 t/ha (Extra early: 70 – 75 days)
			HHB299	3.3 t/ha (Intermediate: 80 – 85 days)
Beans	High iron	High temperature tolerance (up to 4°C higher than the range normally tolerated by bean varieties grown in drought conditions in Latin America and the Caribbean)	ICTA Peten ACM	4.2 t/ha
			CENTA Ferromas	2.3 t/ha
			ICTA Superchiva	4.2 t/ha
			Corpoica Rojo 43	1.2 t/ha

Source: Harvest Plus program of CGIAR) harvestplus@cigar.org

Biofortification Through Genetic Engineering

- **Insertion of iron-binding protein gene- Lacto ferrin / ferritin gene**
- **Insertion of an iron-chelator gene**
- The Ferritin gene co-expressed with the nicotianamine synthase (NAS) gene in rice is reported to show a 6-fold increase in Fe content, which is higher when compared to the single gene approach (Wirth et al., 2009). Rice and Pearl Millet
- **Overexpression of the iron reductase gene**

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Biofortification Through Genetic Engineering

- **Over-expression of already present proteins for iron-binding and accumulation**
- **Insertion of transporter gene**
- **Decreasing Fe-inhibitor/antinutrient- reduce phytate content**
- **Increasing the synthesis of enhancers that enhance Fe absorption**

 - Over express ascorbic acid gene

Beta Carotene in rice- Golden rice

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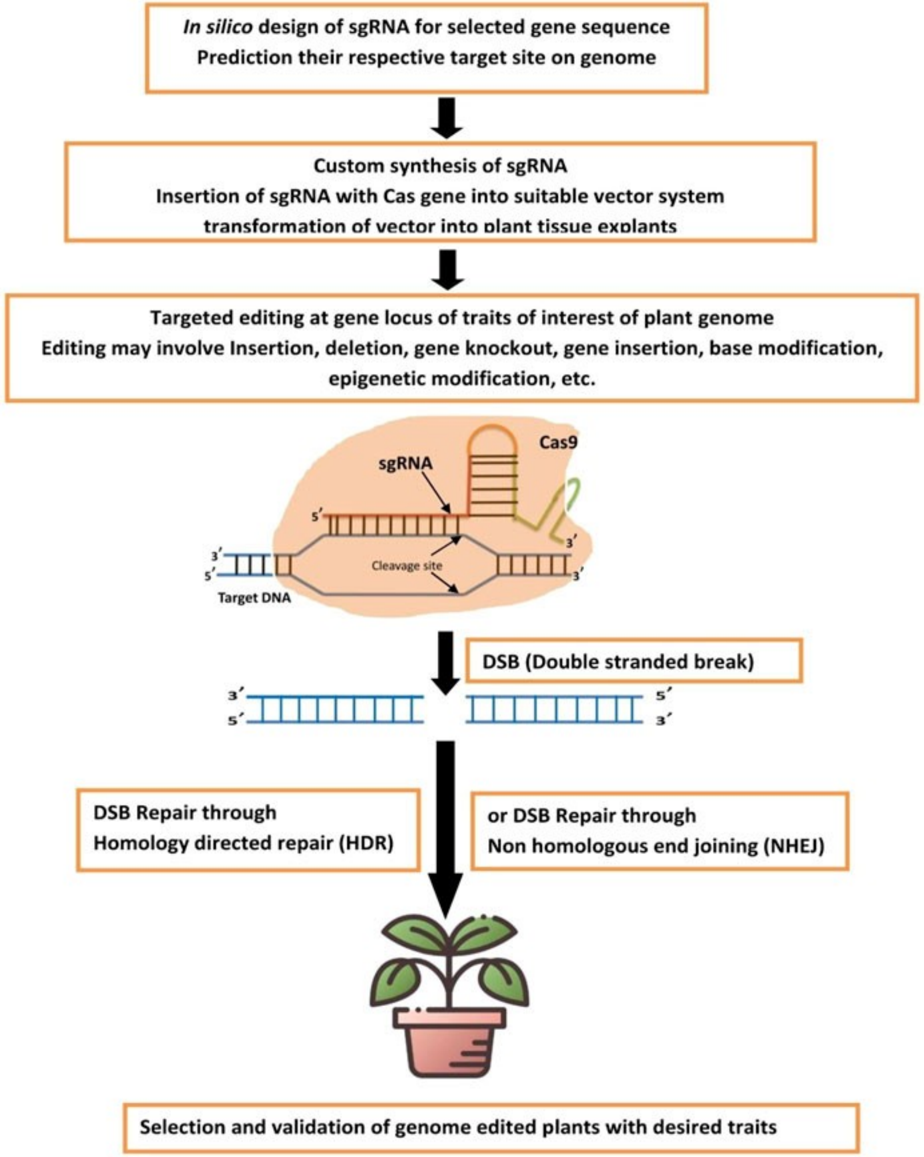
Development of Biofortified Crops Through CRISPR-Cas Genome Editing Approach



REVIEW article
Dileep Kumar et al Front. Genet., 14 July 2022
Sec. Plant Genomics
Volume 13 - 2022 | https://doi.org/10.3389/fgene.2022.932859

Gene editing technologies in biofortification

CRISPR-Cas9 is responsible for the latter type of biofortification. This system has been reported to disrupt the *Inositol pentakisphosphate 2- kinase 1* (*IPK1*) gene causing iron biofortification in wheat (Ibrahim et al., 2021).

CRISPR-Cas system disrupts *Triticum aestivum Inositol Pentakisphosphate 2-kinase 1 (TaIPK1)* that reduces phytic acid to cause improvement in zinc accumulation in wheat grains (Ibrahim et al., 2021).

Genetically edited plants have been developed with indigenously lowered cytokinin levels that favour enrichment of P, Ca, S, Cu, Mn, Fe, and Zn in plant biomass (Ramireddy et al., 2018a)

Thank You for your attention