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BIOFORTIFIED RICE VARIETIES IN INDIA :

Key to Nutritional Security

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PREFACE

To combat serious malnutrition problems and fulfil the sustainable development goals fixed by the United Nation, the cultivation of nutritionally rich crop varieties with elevated levels of micronutrients, proteins, lysine, vitamins, coupled with reduced levels of anti-nutritional factors has been given priority in India in recent years. Biofortification in rice is an innovative agricultural approach aimed at enhancing the nutritional quality of staple food. As rice is primary source of calories of a large section of population, improving its nutritional content can have profound implications for public health and food and nutritional security. In the past decade, along with other crops around 11 biofortified rice varieties have been developed under the umbrella of the Indian Council of Agricultural Research (ICAR). Biofortified varieties typically do not impact ecological conditions, soil, or water requirements differently from traditional varieties. Additionally, they do not incur extra cultivation costs, and their economic output is comparable to traditional produce, leading to their widespread adoption. In India, the scale-up of biofortified varieties has gained momentum, with substantial quantities of breeder seeds being produced and distributed to public and private seed agencies for further multiplication and dissemination to farmers.

This document depicts the malnutritional status and scope of elevating it through biofortification in rice. Biofortified rice varieties are elaborated with general and special characteristics and information on suitable ecology where growers can cultivate. Potential impact of biofortified rice on growers along with consumers and scope of reduction of malnutrition through spreading biofortified rice cultivars in India is suggested in this document.

Authors

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Introduction

INTRODUCTION

Biofortification refers to the genetic enhancement of major food crops with grain nutrients such as micronutrients (Fe, Zn, etc.) along with protein, essential amino acids, vitamins, etc. Rice is one of the most important staple foods among all cereals and considered the major caloric supplement for two thirds of Indian population with a consumption of around 220 g per day. Rice grain as a whole is edible with 6.8 g of protein, 0.5 g of fat, 78.2 g of carbohydrate and 345 K cal of energy per hundred grams of rice. However, the grain is considered nutrionally poor after milling and polishing as the majority of the essential micronutrients *viz*. iron (Fe), zinc (Zn) and important vitamins are lost during the process. Since the poorer section of the worldwide population are often at the maximum risk of micronutrients deficiencies, they mainly depend on rice with rich in micronutrients. Rice is also relatively low in protein content (7-8%) as compared to other cereals such as wheat, barley and millets. Protein-energy malnutrition is prevalent among children those with the dietary intake of predominantly rice. The only possible solution for such malnutrition is to have nutritionally enriched food in the daily foodstuff. Biofortification in rice could be a game changer for those people who have very limited choices of dietary resources.

Indian Council of Agricultural Research (ICAR) has improved the nutritional quality in high yielding varieties of important crops including rice using conventional and modern breeding methods. Special efforts were initiated during 12th Plan with the launching of a special project on Consortium Research Platform on Biofortification. As a result, a number of high yielding biofortified rice varieties with promising yield and stable zinc content (>24 ppm in milled rice) and/or high protein content (>10%) have been identified through AICRIP programme and released by CVRC and SVRC since 2015-16. Some of the high zinc rich varieties include Chhattisgarh Zinc Rice-1, DRR Dhan 45, Surabhi, DRR Dhan 48, DRR Dhan 49, Zinco Rice MS, Chhattisgarh Zinc Rice-2, CR Dhan 315 and DRR Dhan 63. CR Dhan 310 has been released as the first high protein rice variety in India followed by release of CR Dhan 411 (Swarnanjali) in Odisha as 'high protein Swarna' with 10% protein content. Besides, nutrient-rich variety, CR Dhan 311 (Mukul) in the high yielding background of var. Naveen has been released by SVRC, Odisha and Assam for high protein content (10.1%) and moderately high zinc content (20 ppm) in milled rice. Higher content of glutelin and some of the essential amino acids such as lysine was found in high protein varieties. Subsequently, in 2023, CR Dhan 324 (Abhaya Paustik) developed through Doubled Haploid approach was released in SVRC, Odisha which possesses ~11% protein and ~23 ppm zinc. All these biofortified rice varieties with high zinc and protein in either brown rice or milled rice have enormous potential to alleviate malnutrition among rice consuming population and to increase productivity, profitability and sustainability of rice. In this present compilation, features of biofortified rice varieties developed and notified in India, their present status in breeder seed chain and potential contribution in alleviating malnutrition are discussed. ■■■

Malnutrition : Various aspects

Malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients. Malnutrition is a condition that results from eating an unhealthy diet. It means not having enough of the right nutrients for the body to function properly and grow as it should. This can mean not getting enough nutrients like protein, calories, vitamins, or minerals. It can also mean getting too much of certain nutrients. Malnutrition can affect people of all ages. It often affects babies and young children most seriously.

Types of malnutrition

Malnutrition is classified as undernutrition, micronutrient-related malnutrition, Protein-energy malnutrition and also overweight or obesity.

Undernutrition

Wasting, stunting, underweight and, vitamin and mineral deficiencies are the four categories of undernutrition. Undernourished children are more prone to diseases and death. Less weight-for-height is termed as wasting. It indicates sudden and severe weight loss, as a person would not have had enough food to eat or would have had an infectious disease, like diarrhoea, causing them to lose weight. Less height-for-age is known as stunting which occurs due to chronic undernutrition, associated with poor socio-economic conditions, poor maternal health and nutrition, frequent illness, and inappropriate feeding and early care. Children with less weight-for-age are termed to be underweight. An underweight child may be stunted, wasted, or both.

Micronutrient-related malnutrition

India faces a severe deficiency of micronutrients and also known as hidden hunger. This deficiency can be caused by inadequate nutrition during pregnancy and lactation. Inadequate intake of vitamins and minerals can also be categorized in this group. Micronutrients help the body to produce enzymes, hormones, and substances that are essential for proper growth and development. Moreover, vitamin A, iron, and iodine deficiency represent a principal threat to the health and development of children and pregnant women populations across the globe.

Protein-energy malnutrition

The term protein-energy malnutrition (PEM) applies to a group of related disorders that include marasmus, kwashiorkor, and intermediate states of marasmus-kwashiorkor. Children with kwashiorkor have nutritional edema and metabolic disturbances, including hypoalbuminemia and hepatic steatosis, whereas marasmus is characterized by severe wasting.

Body mass index – BMI

Overweight and obesity are defined as abnormal or excessive fat accumulation that can impair health. Body mass index (BMI) is a simple index of weight-for-height commonly used to classify overweight and obesity in adults. People are divided into healthy or unhealthy weight categories based on a universally adopted measurement called body mass index (BMI), which is the ratio of weight to height squared. A healthy BMI comes between 18.5 and 24.9.

Malnutrition status in India

Malnutrition in India is one of the most serious issues resulting in bottleneck in its overall growth and development on the social and economic front. As per the National Family Health Survey-5 (2019-21), Ministry of Health and Family Welfare, Govt. of India, the following scenario of malnutrition was found.

- Neonatal mortality rate (NNMR): 24.9 per 1,000 births
- Infant mortality rate (IMR): 35.2 per 1,000 births
- Child (< 5 years) mortality rate (U5MR): 41.9 per 1,000 live births
- 35.5 % of the children (<5 years) are stunted, 19.3 % wasted and 7.7 %severely wasted
- 32.1 % of the children (<5 years) are under-weight
- 3.4 % of the children (<5 years) are over-weight
- 18.7 % women and 16.2 % men possess BMI below normal (<18.5)
- 24.0 % of women and 22.9 % of men are overweight or obese (BMI≥25.0)
- 67.1 % of the children (6-59 months) are anemic
- 57.2 % of non-pregnant, 52.2 % pregnant and 57.0 % of all women (15-49 years) are anemic
- 59.1 % of all women (15-19 years) are anemic
- 25.0 % of men (15-49 years) are anemic
- 31.1 % of men (15-19 years) are anemic
- 13.5 % of women and 15.6 % of men possess high or very high blood sugar
- 21.3 % women and 24.0 % men possess elevated blood pressure

Ways to alleviate malnutrition

- ***Fortification of rice:*** **Fortification** is defined by WHO as the "*practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements) in food, so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk*

to health". Food Safety and Standards Authority of India (FSSAI) has formulated a comprehensive regulation on fortification of foods namely 'Food Safety and Standards (Fortification of Foods) Regulations, 2016'. Iron and folate fortified rice grain or flour is one of the important example in some of the states in India. It can be introduced quickly and can produce nutritional benefits for populations in a short period of time.

- ***Medical supplementation:*** It is a process of providing vital nutrients through pills. For example, Govt. sponsored programmes, (i) Weekly Iron Folic Acid Supplementation (WIFS) programme for school adolescent boys and girls (10-19 years) and out of school girls (10–19 years) in urban and rural areas, and (ii) Vitamin-A Supplementation (VAS) programme for children under five, are in place India.
- ***Diversification in dietary items:*** It is a process of including diverse cereals, pulses, oilseeds, vegetables and fruits in the diet in order to enhance the nutritional status. Introduction of millets as 'nutri-cereals' in combination of rice and rice based-products can significantly enhance public nutrition and reduce malnutrition.
- ***Biofortification in rice:*** The breeding and genetic modification of plants to improve their nutrient content and/or absorption is termed as Bio-fortification. A number of protein and zinc rich high yielding rice varieties in India are developed through biofortification breeding programme.

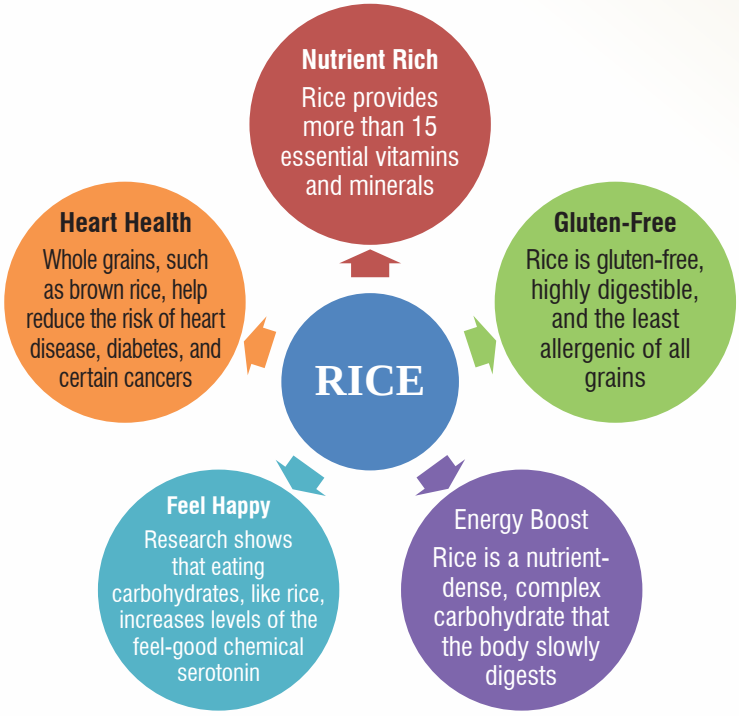
Fortification Vs Biofortification

Significant costs associated with the food fortification process. Nature of the food vehicle or the fortificant, sometimes limit the amount of fortificantion. For example, some iron fortificants change the colour and flavour of many foods, and can cause the *destruction of fortificant vitamin A and iodine.* Biofortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops, as is the case of standard fortification. The biofortificantion is cost effective as compared to fortification.

Nutritional status of rice and scope of improvement

Rice is most important crop of India from the nutritional point of view for more than half of the Indian population. It provides more than 25% dietary protein for the population depends on rice for their nutrition. Quality of Rice protein is promising due to balanced amino acid profiling and higher digestibility with higherProtein Digestibility-Corrected Amino Acid Scores (PDCAAS) as compared to other cereals. Rice is The nutrient rich rice free from gluten can reduce heart disease.

However, as compared to other cereals, rice contains lower quantity of micronutrients and protein. Protein calory can be considered the best option for the malnutrition where rice is predominantly grown in region of this country and taken as the staple food.



Crop	Protein (%)	Zinc (ppm)
Rice	6-7	10-15
Wheat	13-14	25-65
Maize	8-11	13-58
Sorghum	10-15	14-55
Pearl millet	6-21	25-85
Small millet	8-20	5-60

Biofortification in rice fixing minimum threshold limit:

All India Coordinated Rice Research Programme initiated Biofortification trials for identification and release of high yielding biofortified varieties rich in zinc and protein since 2013-2014. Identification of biofortified promising lines was based on minimum threshold limit of zinc content of 24 ppm and protein content of 10% in milled rice. In those promising lines the grain yield should not be less that the yield check (high yielding varieties).

High yielding biofortified rice varieties released

Biofortification for grain protein content

ICAR-NRRI, Cuttack identified a few landraces with high protein content in grains and used one of the land race, ARC10075 as high GPC donor and exercised backcrossing with high yielding recurrent parents, Swarna and Naveen for developing backcross populations. Backcross derived high-protein lines had identified with significantly higher glutelin content than the recurrent high yielding parents. Higher accumulation of glutelin ensured better protein quality. Moreover, high-protein lines had similar or slightly lower values in prolamin/ glutelin ratio than the parents which safeguarded the cooking quality of these introgression lines (Chattopadhyay et al. 2019). Those lines were also detected with considerably higher levels of lysine, threonine, leucine, isoleucine, valine, phenylalanine, alanine, proline, glutamate, arginine and total amino acid as compared to recurrent high-yielding parents. Among those selected lines, CR Dhan 310 and CR Dhan 311 (Mukul) in the background of Naveen and CR Dhan 411 (Swarnanjali) in the background of Swarna were released and notified. Besides, double haploid approach also found effective in development and released of nutrient rich rice variety, CR Dhan 324.

Biofortification for grain zinc content

High zinc donors are generally found low in yielding. In past few years high Zn donors with acceptable yield level were used in crossing with high yielding varieties and selection of suitable high yielding high Zn segregants for developing high yielding biofortified variety with high Zn (Swamy et al. 2016). Advanced backcross breeding also suggested to transfer high Zn trait from un-adapted donors to high yielding rice varieties. Recently through exercising backcross, pedigree and bulk-pedigree breeding methods combining high yield with high Zn content in rice was found successful and few number of varieties such as CR Dhan 311, DRR Dhan 45, DRR Dhan 48, DRR Dhan 49, DRR Dhan 63, CR Dhan 315, Chhattisgarh Zinc Rice-1, Chhattisgarh Zinc Rice-II, Zinco Rice MS, etc. under National biofortification breeding programme were released and notified.

CR DHAN 310

Special nutritional traits	:	High grain protein content (10.2%)
Ecology	:	Irrigated and rainfed shallow
Developed and released by	:	ICAR-National Rice Research Institute, Cuttack
Year of release (notification)	:	2016 and 2022 (Assam)
IET Number and Institute ID	:	IET 24780, CR 2829-PLN-37
Pedigree details and breeding method	:	HP-2 (ARC 10075)/ Naveen; Backcross breeding
Zone/s the variety identified for	:	Eastern , Central
State/s the variety identified for	:	Odisha, UP, MP, Assam
Grain yield for Zone/s	:	4483 kg/ha
Maturity duration	:	125 days
Plant height	:	109 cm
1000 grain weight	:	23 g
Resistance to insect-pests and diseases	:	Moderately resistant against Stem borer, Gall midge Biotype 1, Leaf folder, Whorl Maggot, Moderately tolerant to leaf blast, brown spot, sheath rot, leaf scald and glume discoloration
Grain type	:	Medium slender
Amylose content	:	25 %
GC	:	37 mm
HRR	:	69 %
Breeder seed (quintals) indent (upto 2024)	:	211.6 q

MUKUL (CR DHAN 311)

Special nutritional traits	:	High grain protein (10.1%) and moderate zinc (20 ppm)
Ecology	:	Irrigated and rainfed shallow
Developed and released by	:	ICAR-National Rice Research Institute, Cuttack
Year of release (notification)	:	2019 (Odisha), 2022 (Assam)
IET Number and Institute ID	:	IET 24772; CR 2829-PLN-100
Pedigree details and breeding method	:	HP-2 (ARC 10075)/ Naveen; Backcross
Zone/s the variety identified for	:	Eastern
State/s the variety identified for	:	Odisha and Assam
Grain yield for Zone/s	:	5542 kg/ha
Maturity duration	:	125 days
Plant height	:	117 cm
1000 grain weight	:	22 g
Resistance to insect-pests and diseases	:	Moderately tolerant to Stem borer, Gall midge, Tolerance to leaf blast, glume discoloration, brown Spot, RTD and bacterial leaf blight
Grain type	:	Long bold
Amylose content	:	23.6 %
GC	:	24 mm
HRR	:	60%
Breeder seed (quintals) indent (upto 2024)	:	70.63 q

CR DHAN 315

Special nutritional traits	:	High zinc content in grains (25 ppm)
Ecology	:	Irrigated and rainfed shallow
Developed and released by	:	ICAR-National Rice Research Institute, Cuttack
Year of release (notification)	:	2021
IET Number and Institute ID	:	IET 27179; CR 2826-1-1-2-4B-2-1
Pedigree details	:	Swarna/ARC 10075; Bulk-pedigree breeding
Zone/s the variety identified for	:	Western
State/s the variety identified for	:	Maharashtra, Gujarat
Grain yield for Zone/s	:	5054 kg/ha
Maturity duration	:	130 days
Plant height	:	110 cm
1000 grain weight	:	23 g
Resistance to insect-pests and diseases	:	Resistant to leaf folder, moderately resistant to stem borer, Moderately tolerant to leaf blast, neck blast and brown spot
Grain type	:	Medium slender
Amylose content	:	25 %
GC	:	22 mm
HRR	:	65.7 %
Breeder seed indent (quintals) (till 2024)	:	11.15 q

CR DHAN 411 (SWARNANJALI)

Special nutritional traits	:	High grain protein content (10.01%)
Ecology	:	Rainfed shallow lowland
Developed and released by	:	ICAR-National Rice Research Institute, Cuttack
Year of release (notification)	:	2022
IET Number and Institute ID	:	IET 26398; CR 2830-PLS-17
Pedigree details and breeding method	:	ARC10075/Swarna; Backcross
Zone/s the variety identified for	:	Eastern
State/s the variety identified for	:	Odisha
Grain yield for Zone/s	:	5621 kg/ha
Maturity duration	:	140 days
Plant height	:	95 cm
1000 grain weight	:	21 g
Resistance to insect-pests and diseases	:	Resistant to leaf folder, moderately resistant against stem borer Moderately tolerant to leaf blast, neck blast, brown spot, RTD and bacterial leaf blight
Grain type	:	Short bold
Amylose content	:	25.9 %
GC	:	43 mm
HRR	:	55.3 %
Breeder seed indent till 2024	:	4.1 q

CR Dhan 324 (Abhaya Paushtik)

Special nutritional traits	:	High grain protein (11% and zinc (23 ppm)
Ecology	:	Irrigated condition
Developed and released by	:	ICAR-National Rice Research Institute, Cuttack
Year of release (notification)	:	2023
IET Number and Institute ID	:	IET28698, CRAC 3994-2-5
Pedigree details and breeding method	:	CRHR 32 (CRMS 31A/CRL 22R); Doubled haploid breeding through androgenesis
Zone/s the variety identified for	:	Central
State/s the variety identified for	:	Odisha
Grain yield for Zone/s	:	3838 kg/ha
Maturity duration	:	115-120 days
Plant height	:	105-110 cm
1000 grain weight	:	24.0 g
Resistance to insect-pests and diseases	:	IET 28698 recorded moderately resistant against gall midge and leaf folder under natural screening condition IET 28698 was moderately tolerant to leaf blast, neck blast, brown spot, grain discoloration and false smut
Grain type	:	Long slender
Amylose content	:	25.66 %
GC	:	33 mm
HRR	:	67.9 %
Breeder seed indent till 2024	:	2 q

Field view of CR Dhan 324

DRR Dhan 45

Special nutritional traits	:	High grain zinc content (22.6 ppm)
Ecology	:	Irrigated ecology
Developed and released by	:	ICAR-Indian Institute of Rice Research, Hyderabad
Year of release (notification)	:	2016
IET Number and Institute ID	:	IET 23832
Pedigree details and breeding method	:	IR 73707-45-3-2-3/ IR 77080-B-34-3
Zone/s the variety identified for	:	Southern
State/s the variety identified for	:	Karnataka, Tamil Nadu, Andhra Pradesh and Telangana
Grain yield for Zone/s	:	5000 kg/ha
Maturity duration	:	125 days
Plant height	:	105 cm
1000 grain weight	:	26.4 g
Resistance to insect-pests and diseases	:	Moderately resistant to blast, sheath rot and rice tungro virus
Grain type	:	Long slender
Amylose content	:	21.1 %
GC	:	54 mm
HRR	:	55.6 %
Breeder seed indent till 2024	:	80.72 q

Source: https://www.icar-iirr.org & Dr. CN Neeraja, IIRR, Hyderabad

DRR Dhan 48

Special nutritional traits	:	High grain zinc content (24 ppm)
Ecology	:	Irrigated ecology in *kharif* season
Developed and released by	:	ICAR-Indian Institute of Rice Research, Hyderabad
Year of release (notification)	:	2018
IET Number and Institute ID	:	IET 24555, RP 5898-182-22-4-3-2-1
Pedigree details and breeding method	:	RPBio226*1/CSR27, backcross followed by pedigree
State/s the variety identified for	:	Telangana, Andhra Pradesh, Karnataka, Tamilnadu and Kerala.
Grain yield for Zone/s	:	5200 kg/ha
Maturity duration	:	138 days
Plant height	:	92 cm
1000 grain weight	:	-
Resistance to insect-pests and diseases	:	It has Xa21+xa13+xa5 genes introgressed for bacterial leaf blight (BLB) and hence is resistant to BB, also moderatelyresistant to RTD, sheath rot, neck blast and brown spot.
Grain type	:	Medium slender
Amylose content	:	24 %
GC	:	28 mm
HRR	:	60.9 %
Breeder seed indent till 2024	:	7.52 q

Source: https://www.icar-iirr.org

DRR Dhan 49

Special nutritional traits	:	High grain zinc content (25.2 ppm)
Ecology	:	Irrigated ecology for kharif and rabi
Developed and released by	:	ICAR-Indian Institute of Rice Research, Hyderabad
Year of release (notification)	:	2018
IET Number and Institute ID	:	IET 24557, RP 5898-38-7-2-1-1
Pedigree details and breeding method	:	Bio226*1/CSR27, backcross followed by pedigree
Zone/s the variety identified for	:	Southern and Western
State/s the variety identified for	:	Gujarat, Maharashtra and Kerala
Grain yield for Zone/s	:	5000 kg/ha
Maturity duration	:	130 days
Plant height	:	100 cm
1000 grain weight	:	-
Resistance to insect-pests and diseases	:	BLB resistant having genes of xa21+xa13 and moderately tolerant to Blast.
Grain type	:	Medium slender
Amylose content	:	24.49 %
GC	:	22 mm
HRR	:	63.1 %
Breeder seed indent till 2024	:	2.92 q

Courtesy: Dr. CN Neeraja, IIRR, Hyderabad

DRR Dhan 63

Special nutritional traits	:	High grain zinc content (24.2 ppm)
Ecology	:	Irrigated ecology for kharif and rabi
Developed and released by	:	ICAR-Indian Institute of Rice Research, Hyderabad
Year of release (notification)	:	2021
IET Number and Institute ID	:	IET 26383, RP 5115-111-24-3-1-1
Pedigree details and breeding method	:	IET 17280/Pusa Basmati 1
Zone/s the variety identified for	:	Southern and eastern
State/s the variety identified for	:	Uttar Pradesh, Odisha, Kerala
Grain yield for Zone/s	:	6000 kg/ha
Maturity duration	:	130 days
Plant height	:	101 cm
1000 grain weight	:	-
Resistance to insect-pests and diseases	:	moderately resistant to leaf and neck blasts, bacterial leaf blight, and planthoppers
Grain type	:	Short bold
Amylose content	:	24.66 %
GC	:	22 mm
HRR	:	68.2 %
Breeder seed indent till 2024	:	0.1 q

Source: https://www.icar-iirr.org

Chhattisgarh Zinc Rice-1

Special nutritional traits	:	High grain zinc content (22 ppm)
Ecology	:	Rainfed upland, irrigated and Aerobic condition
Developed and released by	:	Indira Gandhi Krishi Viswavidyalaya (IGKV), Raipur
Year of release (notification)	:	2015
IET Number and Institute ID	:	IET 23824, R-RHZ-2, R-1033-968-2-1
Pedigree details and breeding method	:	Poornima / Annada, Pedigree selection
Zone/s the variety identified for	:	Central
State/s the variety identified for	:	Chhattisgarh
Grain yield for Zone/s	:	3787 kg/ha
Maturity duration	:	112 days
Plant height	:	114 cm
1000 grain weight	:	26.4
Resistance to insect-pests and diseases	:	Moderately resistant to leaf blast, neck blast and sheath blight
Grain type	:	Long bold
Amylose content	:	24.77 %
GC	:	43 mm
HRR	:	58.1 %
Breeder seed indent till 2024	:	78.63 q

Courtesy: IGKV, Raipur

Zinco Rice-MS

Special nutritional traits	:	High grain zinc content (27.4 ppm)
Ecology	:	Rainfed and irrigated condition in *kharif*
Developed and released by	:	IGKV, Raipur
Year of release (notification)	:	2018
IET Number and Institute ID	:	IET 25477, R-RHZ-LI-23
Pedigree details and breeding method	:	Lalmati / IR 681444B-13-2-1-1, Pedigree selection
Zone/s the variety identified for	:	Central and eastern
State/s the variety identified for	:	Chhattisgarh, West Bengal and Odisha
Grain yield for Zone/s	:	5800 kg/ha
Maturity duration	:	135 days
Plant height	:	99 cm
1000 grain weight	:	-
Resistance to insect-pests and diseases	:	Moderately tolerance to leaf blast, brown spot, sheath rot and rice tungro disease
Grain type	:	Medium slender
Amylose content	:	24.2 %
GC	:	71 mm
HRR	:	52 %
Breeder seed indent till 2024	:	121.3 q

Courtesy: IGKV, Raipur

Chhattisgarh Zinc Rice-2

Special nutritional traits	:	High grain zinc content (22 ppm)
Ecology	:	Rainfed and irrigated condition
Developed and released by	:	IGKV, Raipur
Year of release (notification)	:	2018
IET Number and Institute ID	:	IET 23829, R- RHZIH-7
Pedigree details and breeding method	:	IR 681444/HMT, Pedigree selection
Zone/s the variety identified for	:	Central
State/s the variety identified for	:	Chhattisgarh
Grain yield for Zone/s	:	4500 kg/ha
Maturity duration	:	105 days
Plant height	:	91 cm
1000 grain weight	:	-
Resistance to insect-pests and diseases	:	-
Grain type	:	Short slender
Amylose content	:	22.93 %
GC	:	25 mm
HRR	:	63.5 %
Breeder seed indent till 2024	:	85 q

Courtesy: IGKV, Raipur

Way forward and future thrust areas of biofortification in rice

- Understanding the variation of phytic acid and genetic factors governing the low phytic acid in rice grain with the view of higher bioavailability of micronutrients.
- Strengthening the in-vitro and in-vivo analysis of bioavailability of the micronutrient and integrated with micronutrient-biofortification programme.
- Optimization of phytic acid content for best trade-off between the micronutrient bioavailability and seed viability as well as, agronomic performance.
- Strengthening the biofortified research on development of Fe and folate biofortified rice through conventional as well as genome editing approaches..
- Identification of suitable standard processing techniques to reduce the loss of Fe, Zn and protein content during processing.
- Exploring innovative approach to create awareness and suitable policy prescription to integrate biofortified rice in our food system.

Popularization of Biofortified varieties : A case study

Around 18 Memorendum of understanding (MoUs) signed between ICAR-NRRI and private companies, NGOs and Faarmers' producer companies (FPCs) for large scale commencial seed production and marketing in India of the biofortified rice varieties CR Dhan 310, CR Dhan 311 (Mukul) and CR Dhan 411.

Success story

ICAR-NRRI signed MoUs for commercialization of Biofortified rice variety (CR Dhan 310) with 7 FPCs in Uttar Pradesh in 2022. Grameen Foundation India collaborated with National Rice Research Institute (NRRI) Cuttack Odisha and facilitated signing of MoU between NRRI and 7 FPCs in April 2022 to commercialize biofortified paddy seed production of CR Dhan 310 - a protein-rich variety of paddy. Total members of these FPCs were 7444 and among them 57% was female members.

Impact

- CR Dhan 310 has been included in the UP-Seed Certification Management Information System portal
- This integration allowed the variety to be added to the seed supply system of GoUP.
- The department added variety to the portal, enabling farmers to register their FPCs for seed certification and market their produce.
- 200 quintals of seeds, costing INR 2 Lakh, harvested by 7 FPCs, marketed to FPC shareholders to boost biofortified paddy cultivation.
- The production of 900 quintals of biofortified rice in the upcoming season is expected for consumption.

Potential contribution and impact analysis of biofortified rice varieties

Potential contribution of biofortified varieties

- **Replacement of high yielding varieties**: CR Dhan 310 and CR Dhan 311 (Mukul) are in the background of Naveen, whereas CR Dhan 411 (Swarnanjali) is in the background of Swarna and DRR Dhan 48 is in the background of Samba Mahsuri. Swarna, Naveen and Samba Mahsuri are well adopted popular rice varieties in India for irrigated and rainfed ecologies. The high protein and zinc varieties have been well accepted by the farmers due to their resemblance for grain and plant type to their respective recurrent parents. They are the valid replacement of more than 10 years old varieties like Naveen, Swarna and Samba Mahsuri. Apart from that all other biofortified rice varieties with high yielding potentiality have abilities to replace high yielding varieties, resulting in increased productivity, profitability and sustainability of rice system.
- **Better nourishment to rice-consumers:** Rice based food and feed industry is growing very fast. High protein and high zinc rice varieties can significantly contribute in this industry. Moreover, high yielding rice varieties with high nutritional values developed through biofortication breeding intervention have significant potentiality to contribute towards the better nourishment of millions of poor who depend mainly on rice for their nutrition and also in improving the economic level of the farming community. Protein energy malnutrition is frequent among children in villages of India. High protein rice in mid-day meal programme can give benefits to underprivileged school-going children in villages of India.

Breeder seed indent of biofortified rice varieties

Breeder seed indent is a direct indicator of commercialization and population of a released variety. The biofortified varieties of rice were first time released for cultivation in the year 2016. Today, about a dozen of biofortified rice varieties are popular among the farmers. Since 2016-17 the breeder seed indent through DAC, Govt. of India of these biofortified varieties is 673.87 quintals (Table 1). The estimated area covered by using certified seeds produced from breeder seeds is around 144 lakh ha. Among the different biofortified rice varieties, CR Dhan 310, Zinco Rice-MS, CG-Zinc Rice-2, CR Dhan 311, DR Dhan 45 and CG Zinc Rice-1 are most popular among the farmers. The direct cumulative area under these varieties after their release was highest for high protein rice CR Dhan 310 while the newly released varieties like DRR Dhan 63 and Surabhi have minimum spread (Fig 1).

It should be noted that the product by private firms through licensing and farmers to farmers spread has not been taken into account, while estimating the total yield, area and production of biofortified rice varieties.

Table 1. Breeder seed indent (q) of the biofortified rice varieties in India

Variety	Year of notification	Breeder seed indent (q)								
		2017	2018	2019	2020	2021	2022	2023	2024	Total (q)
Chhattisgarh Zinc rice-1	2015	-	10.1	1	5	22.13	30	0.4	10	78.63
CR Dhan 310	2016	22.9	-	7.45	44.1	23.35	70.6	26.7	16.5	211.6
DRR Dhan 45	2016	25.9	0.65	4.25	5.95	14.8	12.2	7.85	9.12	80.72
DRR Dhan 48	2017	-	-	4	-	2.1	1.2	0.2	0.02	7.52
DRR Dhan 49	2017	-	-	2.5		0.1	0.1	0.2	0.02	2.92
Surabhi	2017	-	-	-	-	-	-	-	0.2	0.2
Zinco-Rice-MS	2018	-	-	-	-	51	50	15.3	5	121.3
Chhattisgarh Zinc Rice-2	2018	-	-	-	-	30	30	15	10	85
CR Dhan 311 (Mukul)	2019		1.2	-	3	11.1	25.51	14.3	15.52	70.63
CR Dhan 315	2020	-	-	-	-	-	3	3.05	5.1	11.15
CR Dhan 411	2021	-	-	-	-	-	-	1	3.1	4.1
DRR Dhan 63	2021	-	-	-	-	-	-	-	0.1	0.1
Total		48.8	11.95	19.2	58.05	154.58	222.61	84	74.68	673.87

Source: https://seednet.gov.in

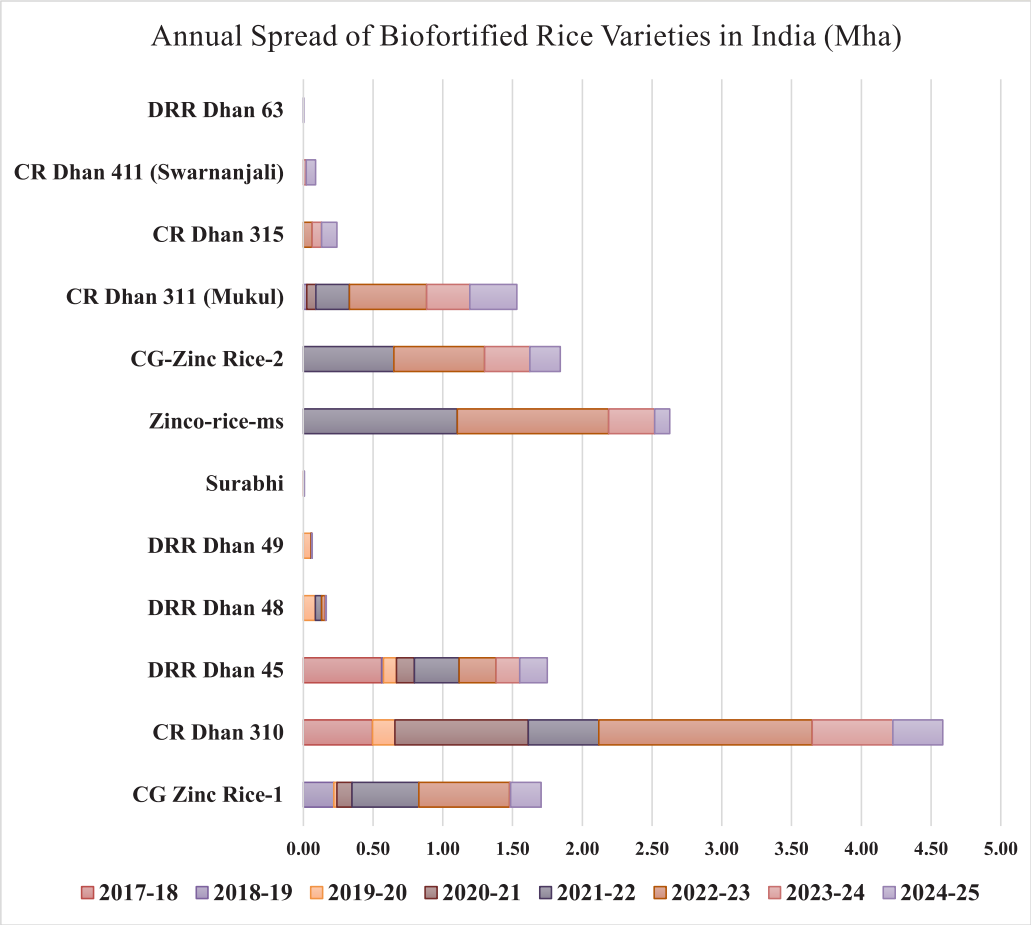


Fig. 1. Annual Spread of Biofortified rice varieties in India (Mha)

Cumulative areas coverage of biofortified rice varieties

The annual cumulative area under all the biofortified rice varieties follow an increasing trend over the years. However, the year 2022-23 and 2021-22 have witnessed maximum spread of area under biofortified rice varieties. On observing the share of different biofortified rice varieties on farmers field in the year 2024-25, CR Dhan 310, CR Dhan 311, DRR Dhan 45, CG Zinc-Rice-2 cumulatively covers significantly larger areas as compared to others under biofortified rice in India (Fig. 2).

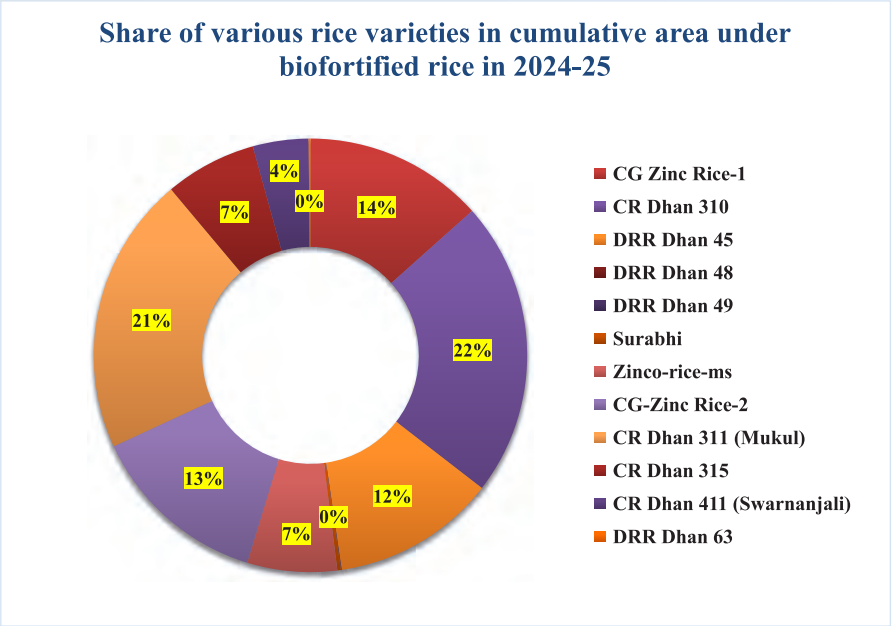


Fig. 2. Share of biofortified rice varieties in cumulative area covered in 2024

Production of biofortified rice

- Considering the domain yield of each biofortified rice varieties, the production of all the biofortified rice varieties after 2017-18 could be around 10 million tonnes. Among all biofortified varieties, the estimated higher production of the high protein variety, CR Dhan 310 and high zinc variety, Zinco Rice MS as compared to others is noted which is around 20 million tonnes and 15 million tonnes over the years, respectively (Fig. 3).

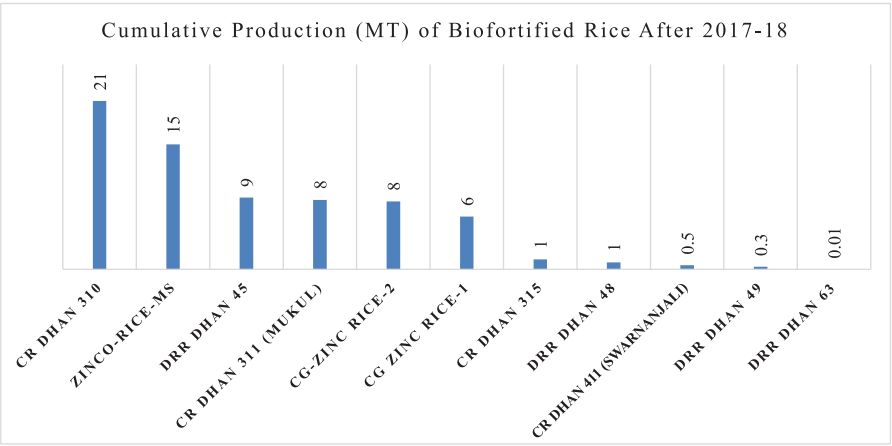


Fig. 3. Cumulative production (MT) of Biofortified rice since 2017-2018

Impact of Government intervention and new initiatives

Extension Division of the ICAR has also launched two special programmes viz. Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) for up-scaling the biofortified varieties through its Krishi Vigyan Kendras (KVKs).

Data on nutritional indicators in the country are captured periodically under the National Family Health Survey (NFHS) conducted by the Ministry of Health and Family Welfare. As per the recent NFHS-5 (2019-21) report, the nutrition indicators for children under 5 years have improved as compared with NFHS-4 (2015-16).

- Stunting has reduced from 38.4% to 35.5%
- Wasting has reduced from 21.0% to 19.3%
- Underweight prevalence has reduced from 35.8% to 32.1%.

Government has accorded high priority to the issue of malnutrition and is making serious efforts to address this issue. The efforts under the Supplementary Nutrition Programme under Anganwadi Services and POSHAN Abhiyaan have been rejuvenated and converged as 'SakshamAnganwadi and POSHAN 2.0' (Mission Poshan 2.0). It seeks to address the challenges of malnutrition in children, adolescent girls, pregnant women and lactating mothers through a strategic shift in nutrition content and delivery and by creation of a convergent eco-system to develop and promote practices that nurture health, wellness and immunity.

Highlights

- Biofortified rice varieties with high grain yield is established as a proven approach to alleviate malnutrition
- Around a dozen of biofortified rice varieties have been released in India through ICAR -AICRIP platform with elevated level of grain protein and zinc content in rice grain.
- Biofortified rice varieties are accepted widely as realized from a fairly good amount of breeder seed indent since 2017.
- The estimated area covered by using certified seeds produced from breeder seeds is around 144 lakh ha since 2017-18.
- The cumulative production of CR Dhan 310 and Zinco Rice-MS over the years is estimated around 20 million tonnes and 15 million tonnes, respectively.
- Substantial consumption of biofortified rice varieties is estimated based on biofortified rice production in this country.

Suggested Readings

Chattopadhyay K, Sharma S, Bagchi T B, Mohanty B, Sardar S S, Sarkar S and Singh O N (2019). High-protein rice in high-yielding background, cv. Naveen. Current Science. 117 (10) 1722-1726.

Swamy BPM, Rahman MA, Inabangan-Asilo MA, Amprado A, Manito C, Chada-Mohanty P, Reinike R, Slamet-Loedin IH (2016). Advances in breeding for high grain Zinc in rice. Rice 9:49. https://doi.org/10.1186/s12284- 016- 0122- 5

International Institute for Population Sciences (IIPS) and ICF (2021). National Family Health Survey (NFHS-5), 2019-2021: India, Vol-I, Mumbai, IIPS.

Yadava DK, Roy Choudhury P, Hossain F, Kumar D, Sharma TR, Mohapatra T (2022). Biofortified Varieties: Sustainable Way to Alleviate Malnutrition (Fourth Edition). Indian Council of Agricultural Research, New Delhi. 106 p.

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