

Enhancing nutritional security through biofortified rice varieties in India

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Rice biofortification is a sustainable approach to alleviate nutrient and micronutrient malnutrition. Research efforts have led to the development and release of more than 25 biofortified rice varieties in India with enhanced grain zinc (Zn) and protein along with high yield and good quality. The efficacy of biofortified rice varieties in animal models is encouraging. The adoption of these varieties by target consumers can translate the benefits of these varieties to address nation's nutritional security.

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Rice (*Oryza sativa* L.) is one of the most prominent cereal crops and serves as a staple food for more than half of the world's population. However, polished rice lacks certain essential nutrients like protein and micronutrients like zinc leading to various health issues. Nearly 80% of Indian population found to be protein deficient and ~40% are suffering from zinc deficiency. While proteins are the building blocks of life, zinc is essential for growth, and immune response,

especially in children and women. Under Government of India efforts towards food fortification, zinc was also included. Biofortification is a proven strategy for increasing the nutrient content of food crops through genetic selection *via* plant breeding and biotechnology. This strategy considers five criteria, *viz.* maintaining or increasing crop yield similar to the popular rice varieties, ensuring appropriate amount of nutrients, establishing the relative stability of the increased

nutrient/micronutrients across locations, conducting consumer acceptance tests for the taste and cooking quality, and testing the bioavailability of nutrients and micronutrients in humans.

Indian Council of Agricultural Research (ICAR), HarvestPlus and Department of Biotechnology (DBT) are supporting development of biofortified varieties, especially rice. ICAR-Indian Institute of Rice Research (IIRR) plays a pivotal role in this effort by coordinating the



Field view of DRR Dhan 45 (India's first Zn biofortified rice) released by ICAR-IIRR during 2016



Field view of DRR Dhan 63, Zn biofortified rice released by ICAR-IIRR during 2021

release of rice varieties through the All-India Coordinated Research Project on Rice (AICRP-R) since 2013 and by leading the rice biofortification programme. Normal milled or polished rice consists of 6-7% protein and 13 to 16 ppm zinc. Through conventional plant breeding, several rice varieties with increased zinc (>20-24 ppm) and protein (>10%) in polished rice have been released through Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural/Horticulture Crops/Central Varietal Rice Committee and by states. These varieties have been released after three years of multi-locational evaluation for their yield performance, zinc or protein content in polished rice, desirable plant height and good cooking quality.

Biofortified rice varieties (CVRC)

DRR Dhan 45 (IET 23832): DRR Dhan 45, India's first zinc biofortified and high-yielding rice variety developed at ICAR-IIRR, in association with HarvestPlus and released in 2016 for irrigated areas of Tamil Nadu, Karnataka and Andhra Pradesh. It can yield upto 5.5 t/ha and has an average zinc content of 22.6 ppm. It has medium duration maturity of 125-130 days with long slender grains and moderate resistance to leaf blast. The bioavailability of DRR Dhan 45 was reported to be twice that of a popular variety IR 64.

CR Dhan 310 (IET 24780): CR Dhan 310, the world's first protein-rich rice variety was released by

ICAR-National Rice Research Institute (NRRI) in 2016 for cultivation in irrigated and shallow rainfed areas of Odisha, Uttar Pradesh and Madhya Pradesh. It was also released for Assam state in 2022 under area extension. This variety can yield upto 4.5 t/ha and has zinc content of 20 ppm and 10.3% protein. It has medium duration maturity (120-125 days) and medium slender grains.

DRR Dhan 48 (IET 24555): DRR Dhan 48, a high yielding, zinc biofortified and bacterial blight-resistant rice variety was released by ICAR-IIRR in 2018 for cultivation in irrigated areas of Andhra Pradesh, Telangana, Karnataka, Tamil Nadu and Kerala. This variety can yield upto 5.5 t/ha and possesses zinc content of 23.3 ppm. With 135 to 140 days of crop duration and medium slender grains and three major bacterial blight resistance genes

(*xa5*, *xa13* and *Xa21*), this variety has become quite popular.

DRR Dhan 49 (IET 24557): DRR Dhan 49 is a zinc biofortified rice variety released by ICAR-IIRR in 2018 for irrigated areas of Gujarat, Maharashtra and Kerala. It can yield 4.8 - 5.0 t/ha with zinc content of 25.2 ppm. The crop duration is 125-130 days and is resistant to bacterial blight with genes *xa5*, *xa13* and *Xa21*; moderate resistance to rice tungro disease, sheath rot, neck blast and brown spot. The variety also has medium slender grains and exhibits moderate tolerance to soil sodic conditions.

Zinco Rice MS (IET 25477): Zinco Rice MS is a zinc biofortified rice variety developed by Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur in 2019 for irrigated and rainfed areas of Chhattisgarh, West Bengal and Odisha. It can yield upto 5.8 t/ha and has an average zinc content of 27.4 ppm with medium slender grains.

Surabhi (IET 24760): Surabhi is a zinc biofortified rice variety developed by Nuziveedu Seeds Pvt Ltd., Hyderabad and ICAR-IIRR in 2018 for Maharashtra and Gujarat. It can yield up to 4.5 - 5.0 t/ha with an average zinc content of 22.84 ppm. It has duration of 130-135 days with medium slender grains and moderate resistance to bacterial leaf blight, sheath blight and brown spot.

CR Dhan 311 (Mukul) (IET 24772): CR Dhan 311 is a nutrient rich rice variety released by ICAR-NRRI in



Spoorthi, a high Zn biofortified rice variety jointly released by ICAR-IIRR and Agricultural Research Station, Gangavathi during 2024



Paddy and polished rice of Zinco rice developed by IGKV during 2019

2019 for cultivation in irrigated and shallow rainfed areas of Odisha and was released for Assam state in 2022 under area extension. This variety can yield upto 5.5 t/ha and holds 10.1% protein and 20 ppm zinc. It has medium duration (120-125 days) with long bold grains. It exhibits resistance to leaf blast, glume discoloration and bacterial leaf blight.

DRR Dhan 63 (IET 26383): DRR Dhan 63 is a zinc biofortified rice variety released by ICAR-IIRR in 2021 for irrigated areas of Uttar Pradesh, Odisha and Kerala. It can yield 5.5 - 6.0 t/ha with zinc content of 24.2 ppm. The crop duration is 127-130 days and has short bold grains with moderate resistance to leaf blast and neck blast, bacterial leaf blight and plant hoppers.

CR Dhan 315 (IET 27179): CR Dhan 315 is a zinc biofortified rice variety released by ICAR-NRRI in 2021 for Gujarat and Maharashtra. It

can yield 5.0 t/ha with zinc content of 25 ppm in polished rice. The crop duration is 125-135 days with moderate resistance to leaf blast and neck blast, bacterial leaf blight and plant hoppers. The variety features medium slender grains and has resistance to leaf folder and moderate resistance to stem borer, leaf blast, neck blast and brown spot.

CR Dhan 411 (Swaranjali) (IET 26398): Swaranjali is a protein rich biofortified rice variety (known as "high protein Swarna") developed by ICAR-NRRI in 2021 for Odisha. It can yield 5.6 t/ha with protein content of 10.01%. The crop duration is 140 days and has resistance to leaf folder and moderate resistance against stem borer, leaf blast, neck blast, brown spot, rice tungro disease and bacterial leaf blight.

DRR Dhan 67 [BRR Dhan 84 (BR7831): DRR Dhan 67 is a zinc biofortified rice variety developed by

Bangladesh Rice Research Institute (BRRI) and released by ICAR-IIRR in India during 2022 for boro-irrigated, transplanted areas of Assam, West Bengal and Tripura. It was released under Seed without Borders, a regional seed policy agreement for the distribution of modern rice varieties across countries in South and Southeast Asia. This variety can yield 6.0-6.5 t/ha with zinc content of 27.6 ppm. The key character of this variety is reddish colour grain.

DRR Dhan 69 (BRR Dhan 100): DRR Dhan 69 is a zinc biofortified rice variety developed by BRRI and released by ICAR-IIRR in India during 2022 for boro-irrigated, transplanted areas of Assam, West Bengal and Tripura under Seed without Borders agreement. This variety can yield 7.7 t/ha with zinc content of 25.7 ppm and duration of 148 days.

Spoorthi (GNV 1906; IET 28694): Spoorthi is a high zinc biofortified rice variety jointly released by ICAR-IIRR and Agricultural Research Station, Gangavathi in 2024 for Andhra Pradesh, Telangana, Tamil Nadu and Karnataka. It can yield 5.3 t/ha and possess zinc content of 20.05 ppm. It has duration of 125-130 days with long bold grains.

Biofortified rice varieties released through states

CGZR-1 (IET 23824): Chhattisgarh zinc Rice-1 (CGZR-1) is a zinc biofortified rice variety developed by IGKV for Chhattisgarh. It can yield upto 4.5 t/ha and features with an average zinc content of 24 ppm. It has duration of 110 days and long bold grains.

Bauna Kalanamak 101 (UPCAR-KN-2-19-14) (IET 24753): Bauna Kalanamak 101 is a semi-dwarf, high-yielding variety of heritage rice Kalanamak. This aromatic variety was released by Department of Agriculture, Uttar Pradesh in 2016 and contains 14.61 ppm of zinc. It has duration of 135 days with semi-dwarf plant type and shows resistance to bacterial leaf streak and brown spot and moderate resistance to bacterial blight and blast.

GNR-4 (Gujarat Navsari Rice –



Paddy and polished rice of CR Dhan 310, the world's first protein-rich rice variety released by ICAR-NRRI during 2016

4) (IET 23815): GNR4 is a biofortified rice variety released by MRRC, Navsari for Gujarat in 2016. It can yield up to 4.8 t/ha, contains 17.63 ppm zinc and has a duration of 135 days.

Paustic-1: Paustic-1 is a zinc biofortified rice variety released by ZARS, GKVK, Bengaluru in 2016 for Karnataka. This variety can yield 5.0 t/ha, contains more than 24 ppm zinc and has a duration of 120-125 days with fine grain type.

Paustic-9: Paustic-9 is a protein rich biofortified rice variety released by ZARS, GKVK, Bengaluru in 2016 for Karnataka. This variety can yield 5.0 t/ha and contains more than 10% protein content. It has a duration of 120-125 days with fine grain type and has resistance to blast disease.

CGZR-2 (IET 23829): Chhattisgarh zinc Rice-2 (CGZR-2) is a zinc biofortified rice variety developed by IGKV, Raipur in 2019 for Chhattisgarh. It can yield 4.5 t/ha and features with an average zinc content of 24 ppm in polished grains. The variety has a duration of 135 days, good cooking quality and moderate resistance to green leafhoppers, stem borer and plant hoppers.

Ratnagiri 7 (IET 25448): Ratnagiri 7 is a biofortified variety released by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth for Konkan region of Maharashtra in 2019. This variety can yield up to 4.8 t/ha and zinc content of 15.4 ppm. It has a medium duration (122-125 days), short bold red kernel and good cooking quality. It showed a resistant reaction to stem borer, leaf folder and gall midge and is moderately resistant to leaf blast and bacterial leaf blight.

Kalanamak Kiran (PRDF-2-14-10): Kalanamak Kiran is a biofortified protein rich rice variety released in 2019 for Uttar Pradesh. This variety can yield 3.7 t/ha and possess 10.4% protein content. It has a duration of 125-130 days, medium slender grain type, good aroma and has resistance to bacterial leaf streak, tungro, root weevil and brown spot and moderate resistance to bacterial blight, blast, brown plant hopper, green leafhopper and case worm.

Protezin (IET 25470): Protezin

is a high zinc and protein rich biofortified rice variety released by IGKV, Raipur in 2020 for Chhattisgarh. It can yield up to 4.5 t/ha and features with an average zinc content of 22 ppm and protein content of 9.50%. It has a duration of 130 days with good cooking quality and shows tolerance to bacterial leaf blight and rice tungro virus.

PDKV Sakoli Red Rice (IET 28710): PDKV Sakoli red rice is a protein rich rice variety released in 2021 for Maharashtra. This variety can yield 4.3 t/ha and possess zinc content of 16.25 ppm and 9.04% protein content. The crop duration is 125-130 days with short slender grain type and has moderate resistance to stem borer.

CR Dhan 324 (Abhaya Paustik) (IET 28698): CR Dhan 324 is a biofortified rice variety released by ICAR-NRRI in 2023 for Odisha state. It can yield 4.5 t/ha with zinc content of 23.20 ppm and protein 11.68% in polished rice. The crop duration is 115-120 days with moderate resistance to gall midge and leaf folder under natural screening conditions. In addition, it was moderately tolerant to leaf blast, neck blast, brown spot, grain discoloration and false smut. This variety features long slender grains.

GR 23 (Navsari Paushtik) (IET 27167): GR 23 is a biofortified rice variety released by MRRC, Navsari in 2024 for irrigated transplanted areas of Gujarat. This variety can yield 5.6 t/ha and possess zinc content of 20.40 ppm and protein content of 12.18%. It has a medium slender grain with good cooking quality. It is moderately resistant against bacterial leaf blight, grain discoloration and leaf blast diseases and tolerant reaction against brown plant hopper and leaf folder pests.

While the targeted breeding programme for biofortified rice varieties has accelerated since 2015, some of the earlier released varieties have also shown high grain zinc through serendipitous selection.

HPR 2720 (Palam Lal Dhan 1): Palam Lal Dhan-I is a red rice variety developed by CSKHPKV, Palampur in 2013. This variety is

suitable for irrigated areas of mid hills of Himachal Pradesh and has a duration of more than 40 days after transplanting and an average yield 4.0-4.5 t/ha. This variety possesses zinc content of 17.00 ppm.

Akutphou (IET 9305): Akutphou is released for irrigated hills ecologies in 1999 for Manipur state. This variety can yield up to 5 t/ha with a crop duration of 120-125 days. It has long bold grains with good cooking quality and moderate resistance to blast. This variety possesses zinc content of 17.00 ppm.

Kasturi (IET 8580): Kasturi is an aromatic rice variety released by ICAR-IIRR in 1989 yielding 4.0 – 4.5 t/ha with a crop duration of 125-130 days. It has long slender grains with good cooking quality and moderate resistance to blast. This variety possesses zinc content of 19.20 ppm.

In addition to rice varieties biofortified for zinc and protein, Paustic-7 variety with high grain iron was released by ZARS, GKVK, Bengaluru. Among the released biofortified varieties, DRR Dhan 48 was identified with low Glycaemic Index (GI). Laboratory studies at National Institute of Nutrition (NIN), Hyderabad and Indian Institute of Technology, Roorkee have demonstrated significant zinc uptake in human Caco-2 cells from rice varieties biofortified with zinc. Feeding trials of rats with zinc biofortified rice at NIN also have shown significant improved growth and zinc status in zinc deficient rats.

CONCLUSION

The effective translation of the benefits from these biofortified varieties as their adoption can be made possible by converging the extensive efforts being made by the researchers and government policies. The integration of biofortified rice varieties into the existing food systems could be one of the potential interventions to address the nutrient and micronutrient malnutrition of the country.

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