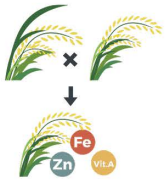
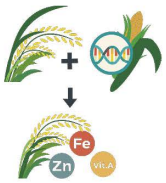
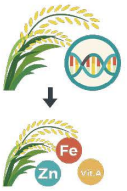
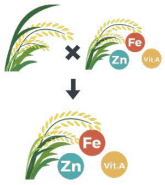
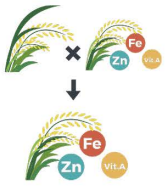
RICE BIOFORTIFICATION:

Complementary pathways to improved human nutrition

IRRI's extensive genetic resources and technical expertise enables the exploration of multiple pathways to biofortification, the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology (WHO, 2019). Together with our national research partners, the IRRI Healthier Rice Program aims to develop and deploy biofortified rice varieties that can help address micronutrient deficiencies by providing 30-50% of the estimated average requirement for vitamin A, iron, and zinc to micronutrient-deficient women and children. Rice biofortification is intended as a complementary food-based solution to existing nutritional interventions.

	CONVENTIONAL BREEDING	TRANSGENIC BIOFORTIFICATION	GENE EDITING BIOFORTIFICATION
WHEN IS THIS USED	 When target micronutrients are naturally occurring in rice varieties, and can be improved in selected rice varieties through cross-breeding.	 When target micronutrients are not naturally occurring in rice grains, or cannot be significantly improved through conventional breeding methods.	 When an existing gene present in any rice variety can be tweaked to achieve the desired micronutrient content, without the need to introduce any additional genes to the rice.
HOW DOES IT WORK	 Existing rice varieties are cross-bred for multiple generations until the desired micronutrient content is improved to target levels. IRRI breeders use molecular markers to identify and tag desirable traits in the rice genome. This enables them to pick the best varieties for breeding.	 A gene from another organism with a desirable trait is transferred to the rice genome through genetic modification (GM). Numerous tests and independent assessments are conducted to ensure that the added gene does not introduce any unintended effects. IRRI has its own Institutional Biosafety Committee to oversee the biosafety aspect of its GM research, which adheres strictly to nationally and internationally accepted standards.	 Molecular "scissors" like CrisprCAS9 make precise edits to the rice genome in order to trigger the desired trait. The "scissors" and its guide leave no trace in the next generation, only the desired changes remain.
PATHWAY ADVANTAGE	 Universally accepted method of varietal improvement, with less restrictive regulatory processes, marketing, and trade requirements.	 More precise method of improving micro-nutrient content, including those not previously found in rice varieties. Once the desired trait is present in the rice variety, this can be transferred to other varieties through conventional breeding methods.	 Once the desired trait is present in the rice variety, this can be transferred to other varieties through marker-assisted conventional breeding methods.
PATHWAY CHALLENGE	 Less precise and limited to traits already existing in rice varieties. Can take up to 30 years before the desired trait is improved and passed on to succeeding generations.	 Long review periods for regulatory applications may delay market release.	 More precise but limited to traits that can be obtained through editing single or multiple rice genes. Lack of clarity in regulations surrounding gene editing techniques at this time limits development of marketable varieties.

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STATUS UPDATES

CONVENTIONAL BREEDING

Bangladesh:
With support from IRRI and Harvestplus, the Bangladesh Rice Research Institute (BRRI) released the world's first conventionally bred high zinc rice, **BRRI dhan 62**, in 2013. Other high zinc varieties have since been released.

Philippines:
NSIC 2016 Rc 460 high zinc rice was registered by Philippine Rice Research Institute (PhilRice) with the National Seed Industry Council in 2016.

TRANSGENIC BIOFORTIFICATION

Bangladesh:
Golden Rice regulatory application, submitted by BRRI, is currently under review.

Philippines:
Golden Rice regulatory application, submitted by PhilRice, is currently under review.

PhilRice aims to develop a Golden Rice 3-in-1 variety, which combines Golden Rice with resistance to bacterial blight and tungro.

High iron and zinc rice (HIZR) recently completed confined trials, in partnership with PhilRice.

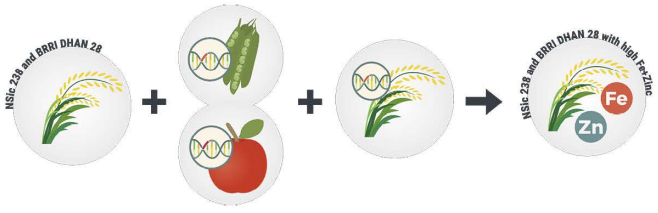
Indonesia:
Early research on Golden Rice was conducted in partnership with the Indonesian Center for Rice Research.

IRRI: The Healthier Rice Program's end goal is a stacked rice variety biofortified with beta-carotene, iron, and zinc.

GENE EDITING BIOFORTIFICATION

IRRI: Proof of concept underway for high zinc rice developed through CrisprCAS9 gene editing.

HIGH IRON AND ZINC RICE PROCESS



GOLDEN RICE PROCESS

IRRI International Rice Research Institute