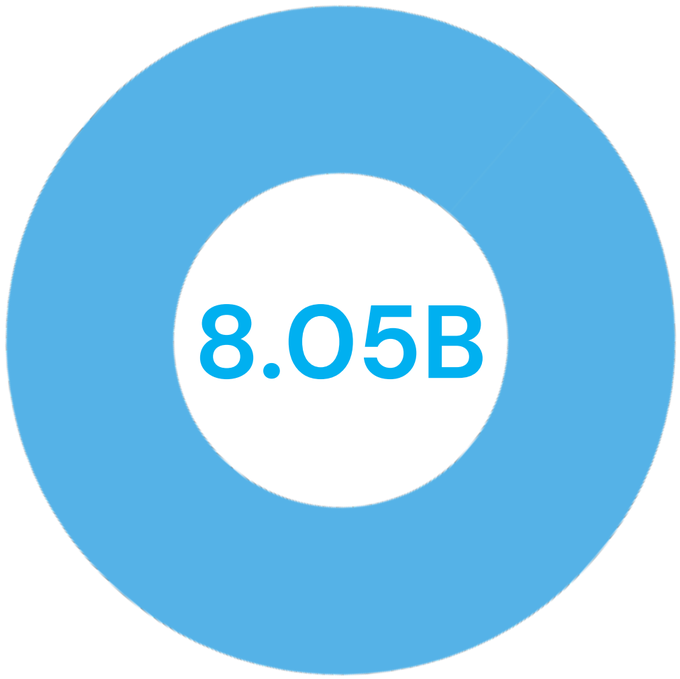
Genome Editing in Rice

Erwin Arcillas
Assistant Scientist
Genome Engineering and Transformation Laboratory (GETL)
International Rice Research Institute (IRRI)

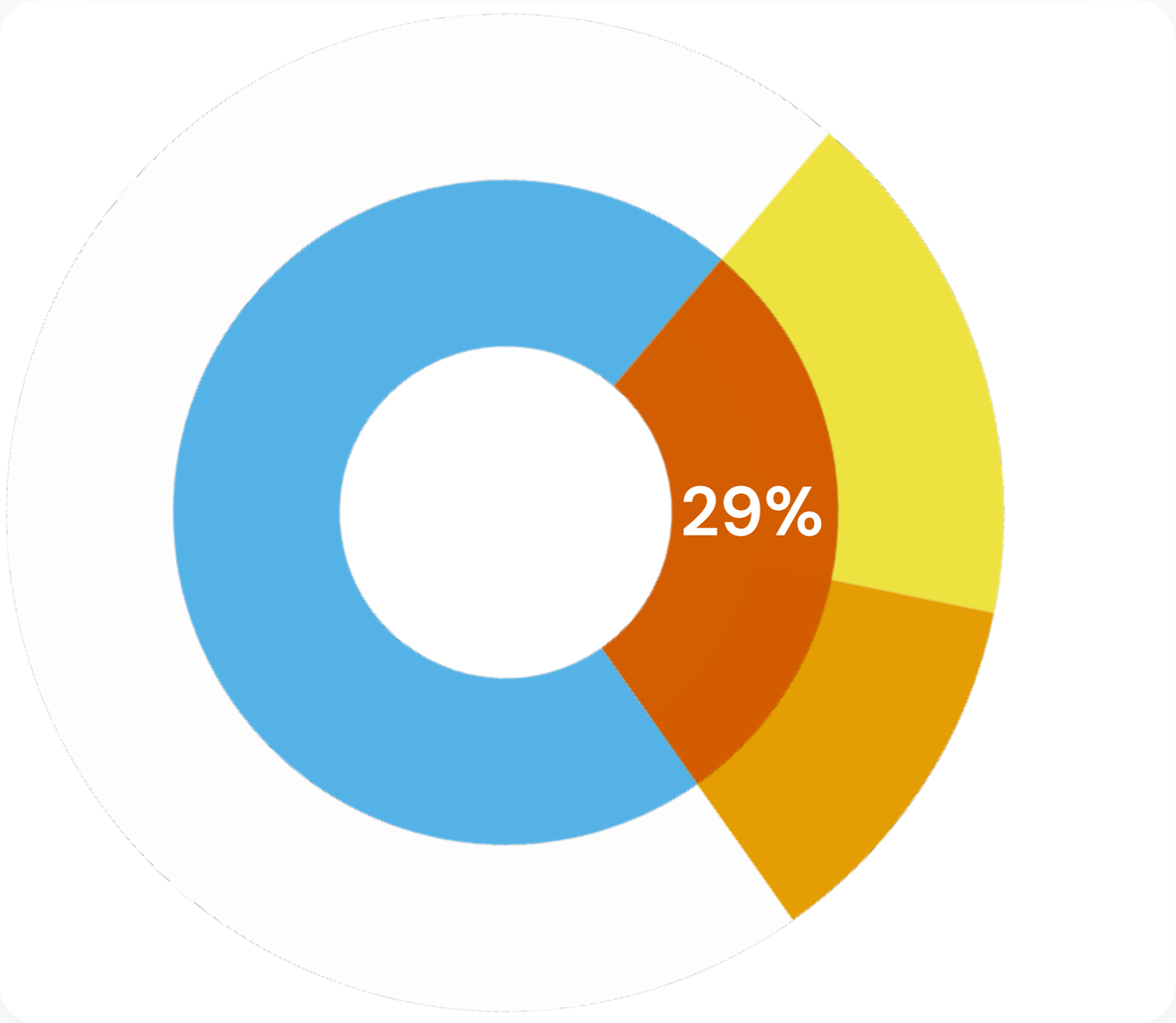
Food security › Genome Editing › IRRI's GE Work



2023

World population

UN. 2024; FAO, IFAD, UNICEF, WFP and WHO. 2024



2023

Prevalence of Food Insecurity

The percentage of the population facing challenges in accessing enough safe and nutritious food for normal growth and development.

1.4B Moderate

8.6M Severe

UN. 2024; FAO, IFAD, UNICEF, WFP and WHO. 2024

2023

Prevalence of Undernourishment

The percentage of the population whose usual food intake does not provide enough energy for a healthy and active life.

9.1%

733M
Total

370M
Asia-Pacific

UN. 2024; FAO, IFAD, UNICEF, WFP and WHO. 2024; FAO. 2023

IRRI CGIAR

6.8%

580M

Projected undernourished population

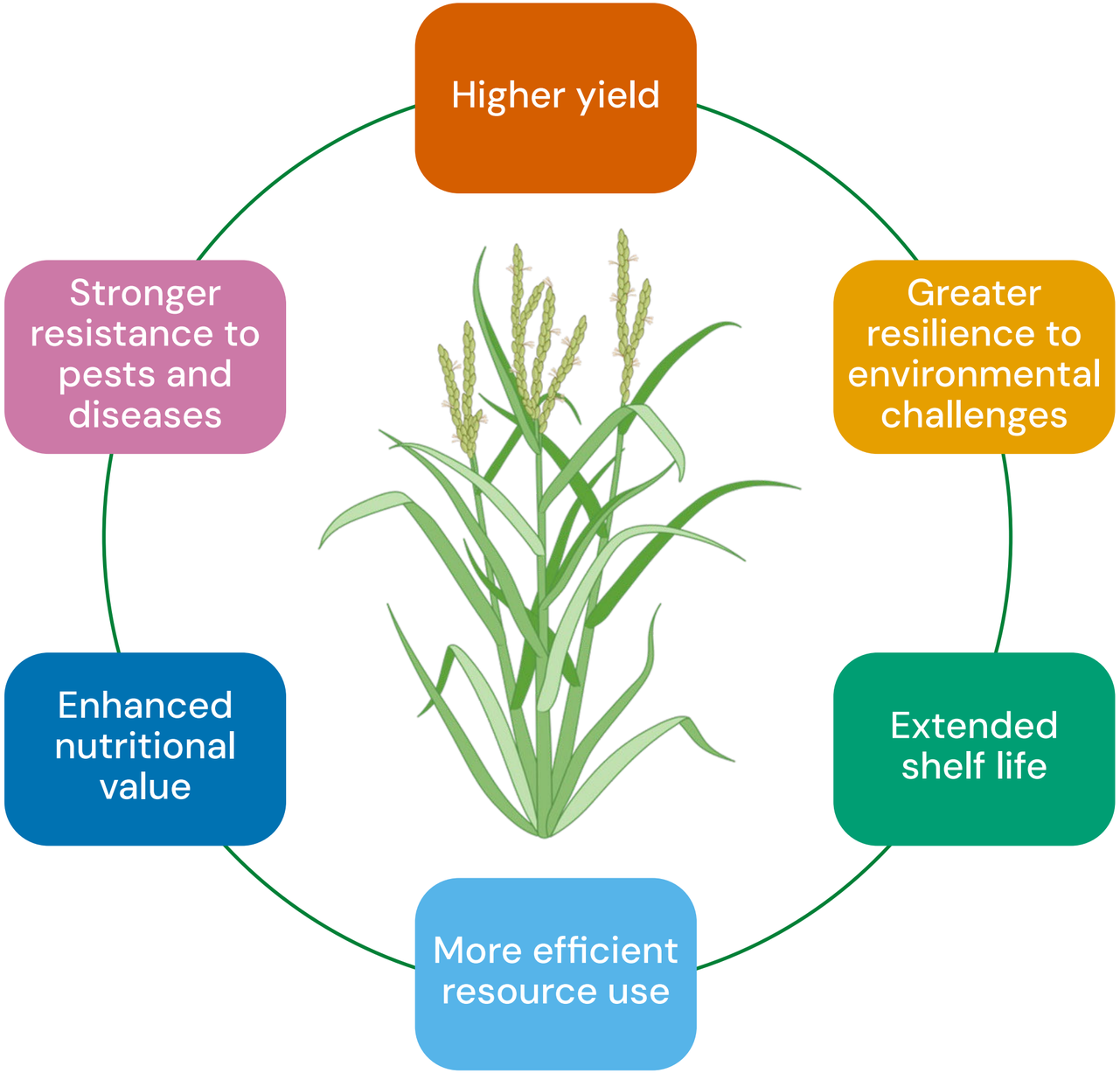
2030

Prevalence of Undernourishment

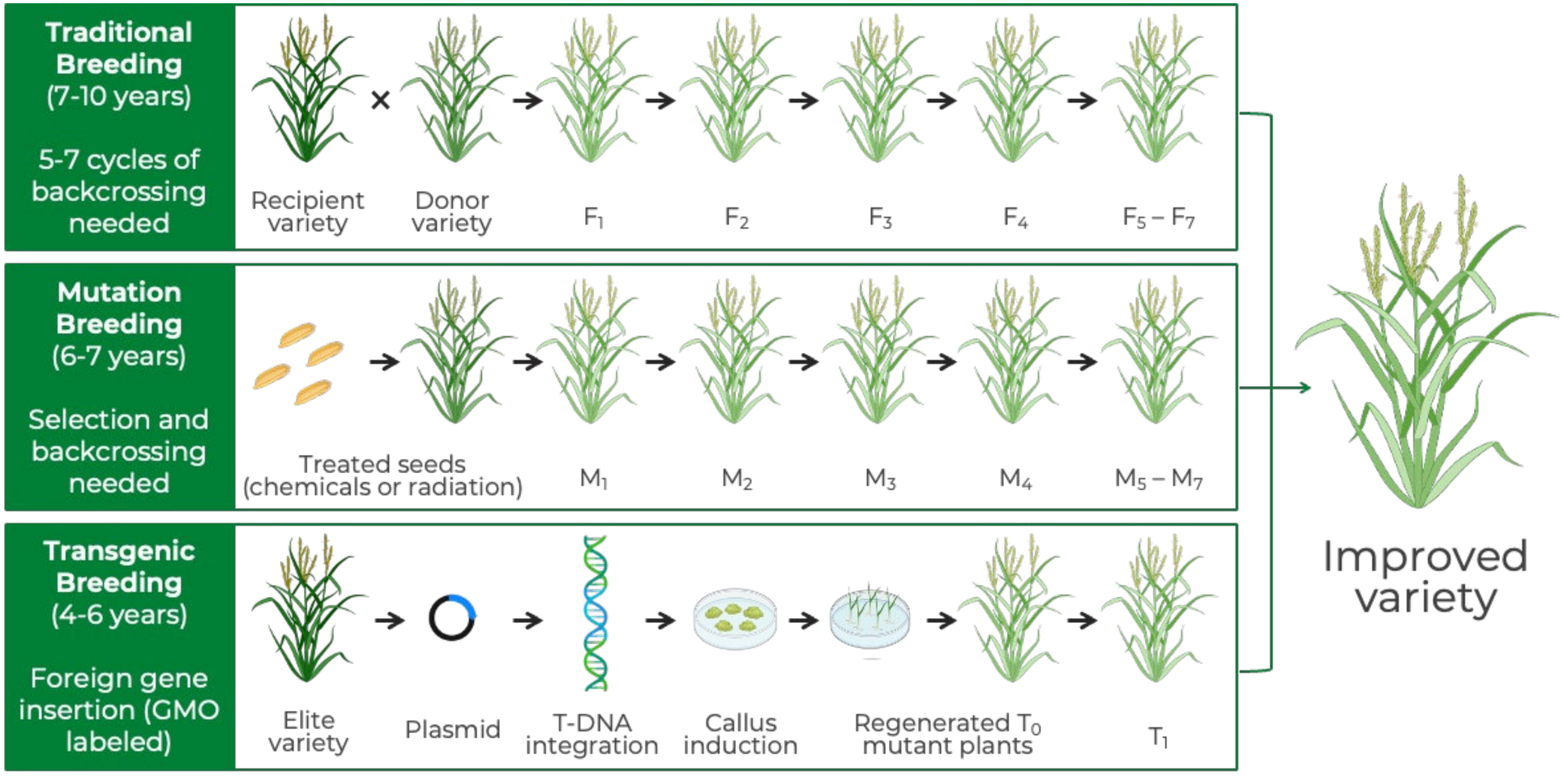
The percentage of the population whose usual food intake does not provide enough energy for a healthy and active life.

FAO, IFAD, UNICEF, WFP and WHO. 2024

Crop traits for food and nutrition security amidst climate change



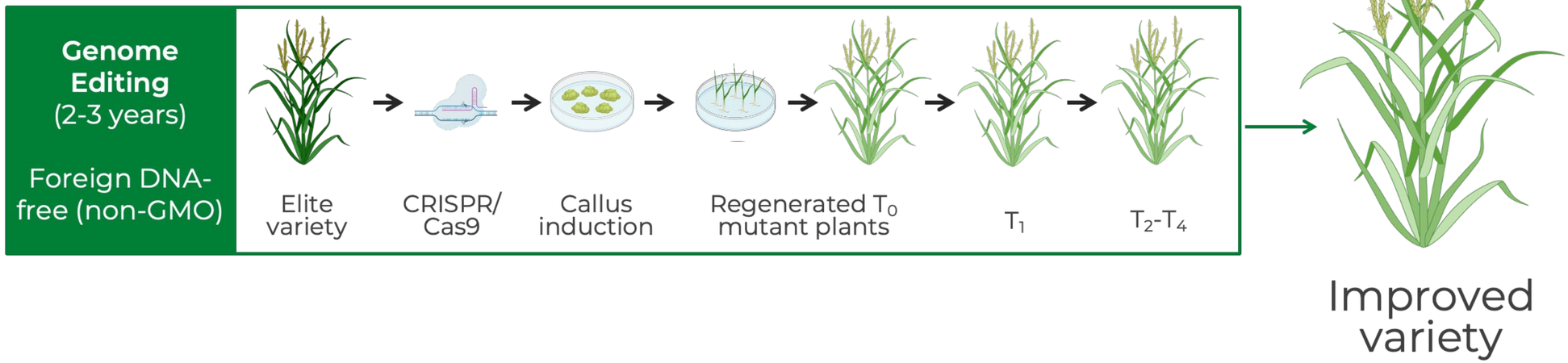
Conventional crop improvement methods



Genome Editing in Rice

Adapted from Ahmar et al. (2021)

Genome editing

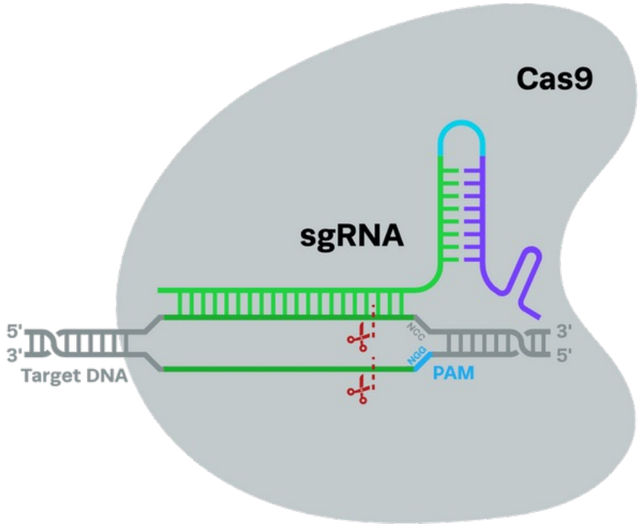


Genome Editing in Rice

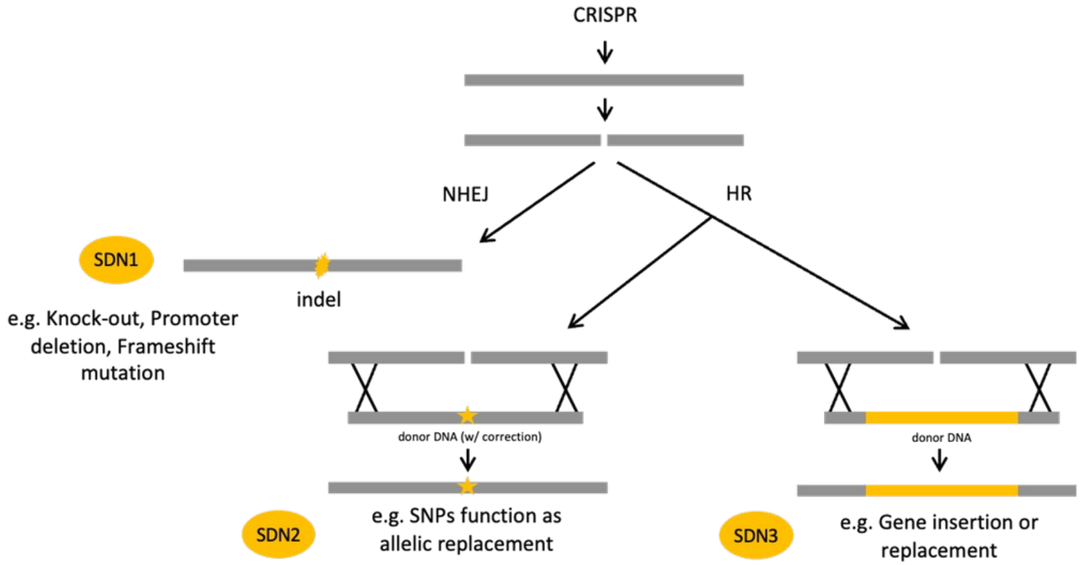
Adapted from Ahmar et al. (2021)

Genome editing

CRISPR-Cas9 System

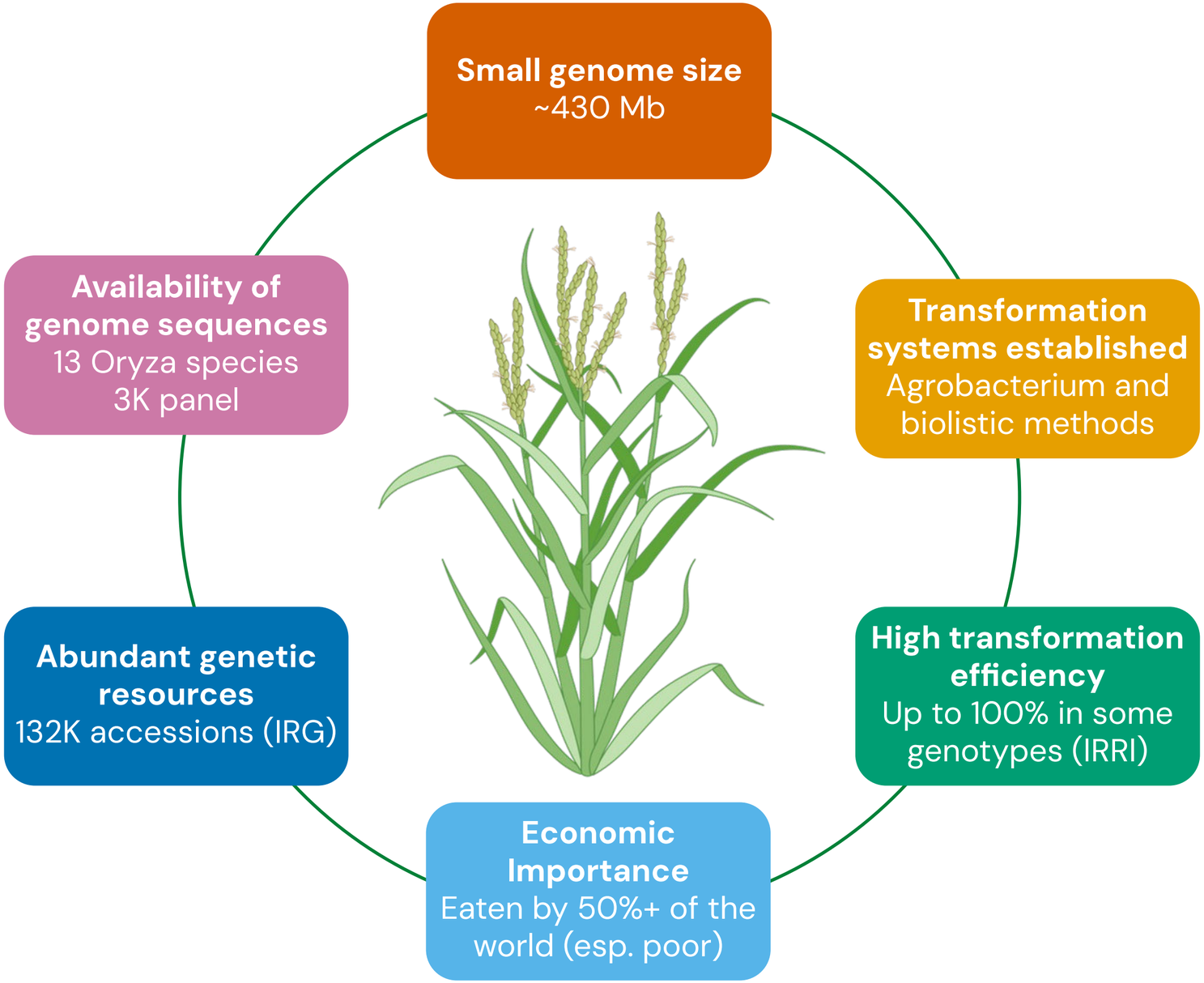


SDN Types



IDT Technologies; Belgian Biosafety Server

Rice's suitability to genome editing



Song, et al. 2019; GETL, IRRI; International Rice Genebank (IRG)

GE Product Development Pipeline

Gene construct design | Construct delivery | Tissue culture | Genotyping and phenotyping of generated events | Production of transgene-free lines | Field testing and performance trials | Varietal release

Molecular Biology Laboratory

Tissue Culture Laboratory

Glasshouse

Screenhouse

Confined Field (To be constructed)

Stewardship Practices

DOST-BC permit
Quality management system

Policies, procedures and instructions
Incident response management

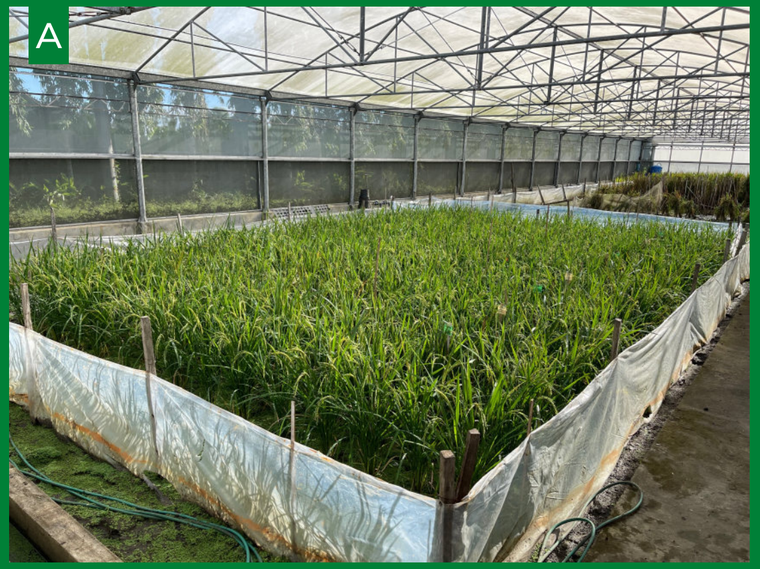
Inventories, records and databases
Personnel training and documentation

excellence through STEWARDSHIP

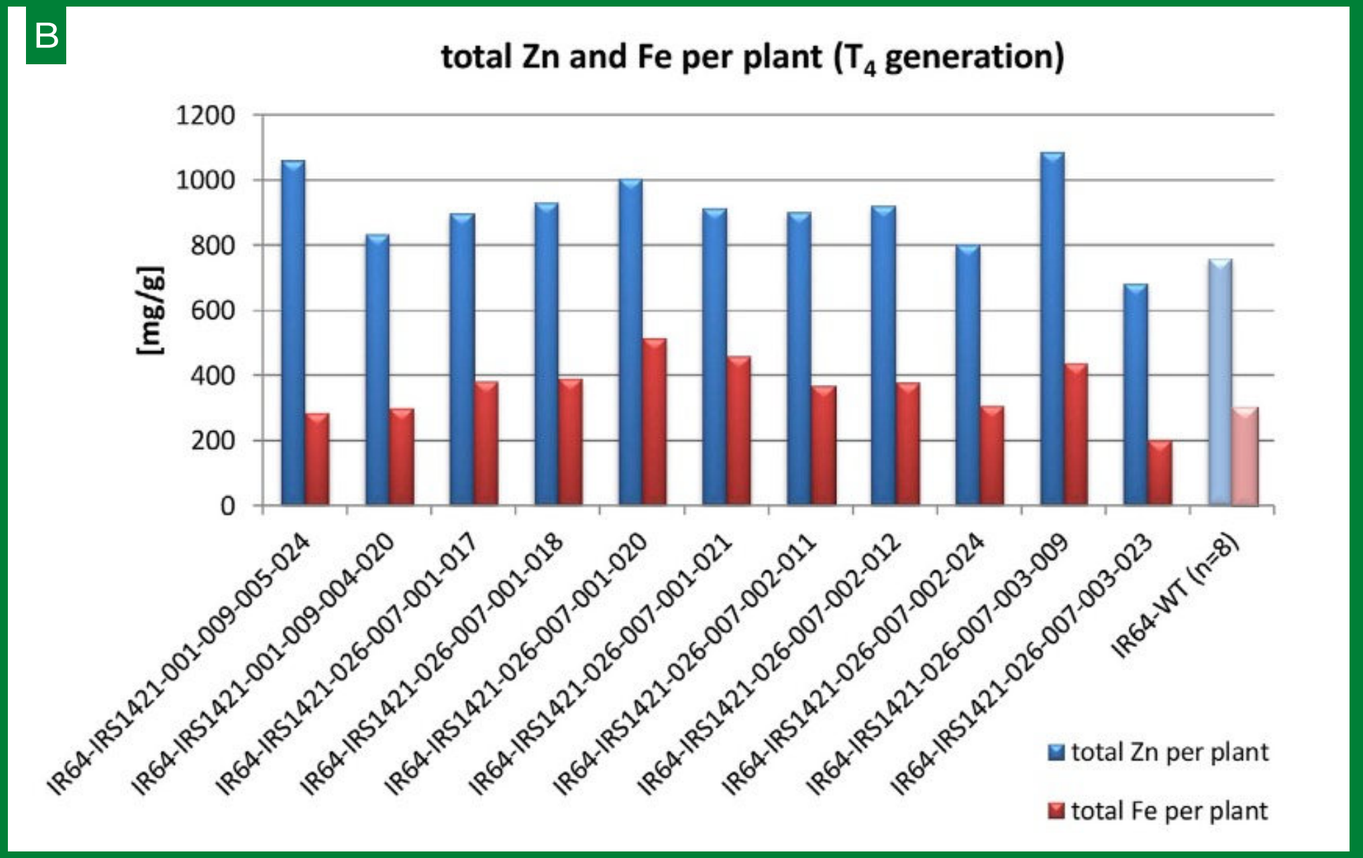
Enhanced grain nutrient content

OsNAS2 promoter-motif editing (SDN1)

A



B



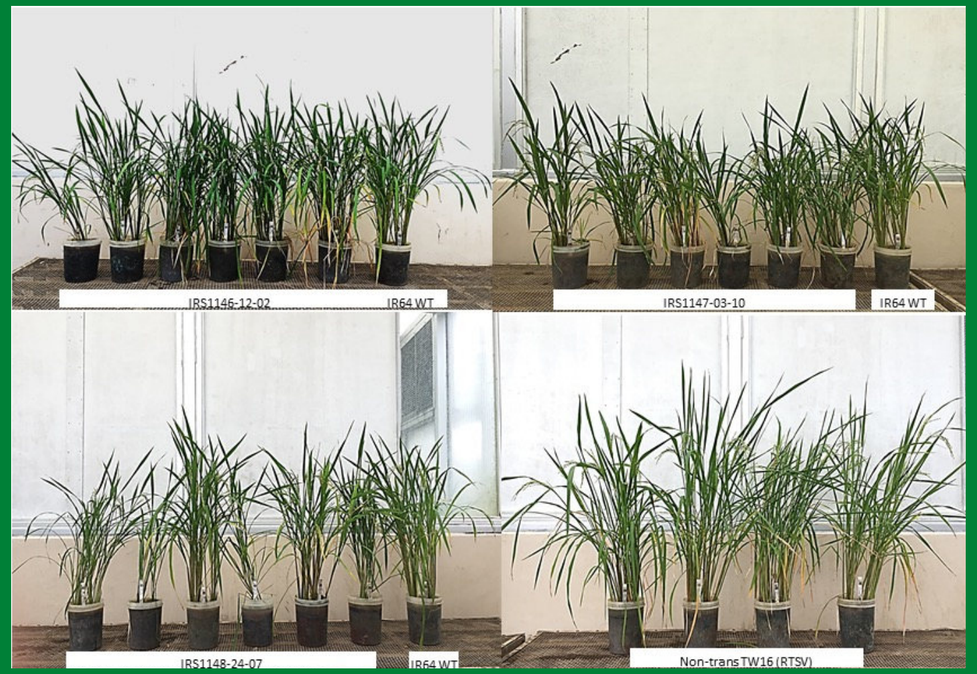
A) Experimental set-up, and B) estimated Zn and Fe concentrations per plant of selected T_4 candidates compared to IR64 WT control: Zn and Fe concentrations were measured via XRF, and the total Zn and Fe concentration per plant was calculated based on the total plant yield.

Ludwig, et al. (2024)

Resistance to Tungro spherical virus

eIF4G mutagenesis (SDN1)

A



B

Event	*eIF4G* allele		eIF4G protein		Zygosity		Reaction to RTSV
1146	A	→	Substitutions/deletions far upstream of YVV	→	A/A or A/D	→	Inconclusive (Resistant or susceptible)
	D	→	Truncated				
1147	B	→	Substitutions/deletions immediate upstream of YVV	→	B/B or B/D	→	Resistant
	D	→	Truncated				
1148	C	→	Substitutions/deletions downstream of YVV	→	C/C or C/D	→	Inconclusive (Resistant or susceptible)
	D	→	Truncated				
1146 1147 1148	D	→	Truncated	→	D/D	→	Plant not viable or infertile

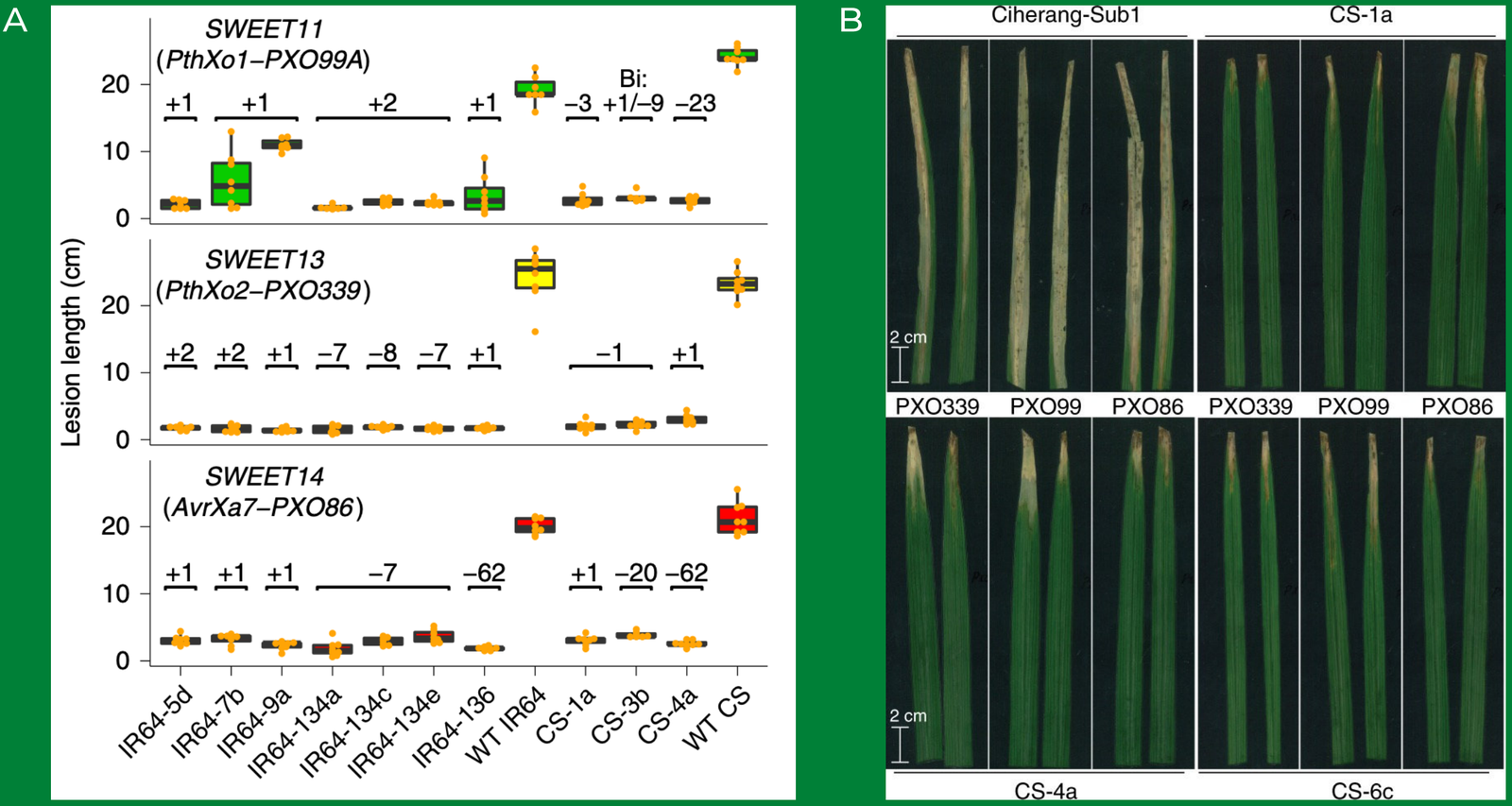
A) Selected 90-day-old T_2 plants at 80-days post-inoculation with *RTSV* and B) Reactions of the edited plants to *RTSV* depending on the type and zygosity of mutations.

Macovei, et al. (2018)

Broad-spectrum resistance to Bacterial blight

SWEET11, *SWEET13* and *SWEET14* promoter mutagenesis (SDN1)

Healthy Crops Consortium



A) Resistance of SWEET promoter edited IR64 and Ciherang-Sub1 lines, and B) resistance of three genome-edited Ciherang-Sub1 lines to three representative Xoo strains.

Oliva et. al (2019)

Low glycemic index phenotype

Target gene editing (SDN1); gene validation

A

B

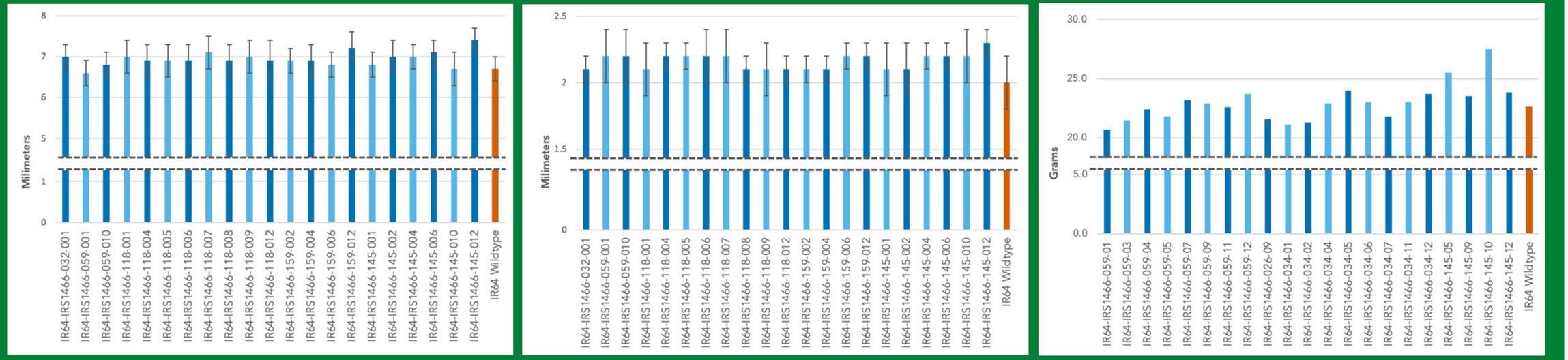
Event	Allele 1	Allele 2	Mutation	GI	RS%
WT	-	-	-	59	0.18
#35	A ins	A ins	Knock-out	55	2.50
#46	A ins	G ins	Knock-out	54	2.35

A) Morphology of the T_1 seeds harvested from the two KO T_0 plants, and B) analyses of in-vitro GI and resistance starch (RS) with T_1 seeds.

Badoni et. al (2024)

Increase in yield

Target gene Exon 1 editing (SDN1)

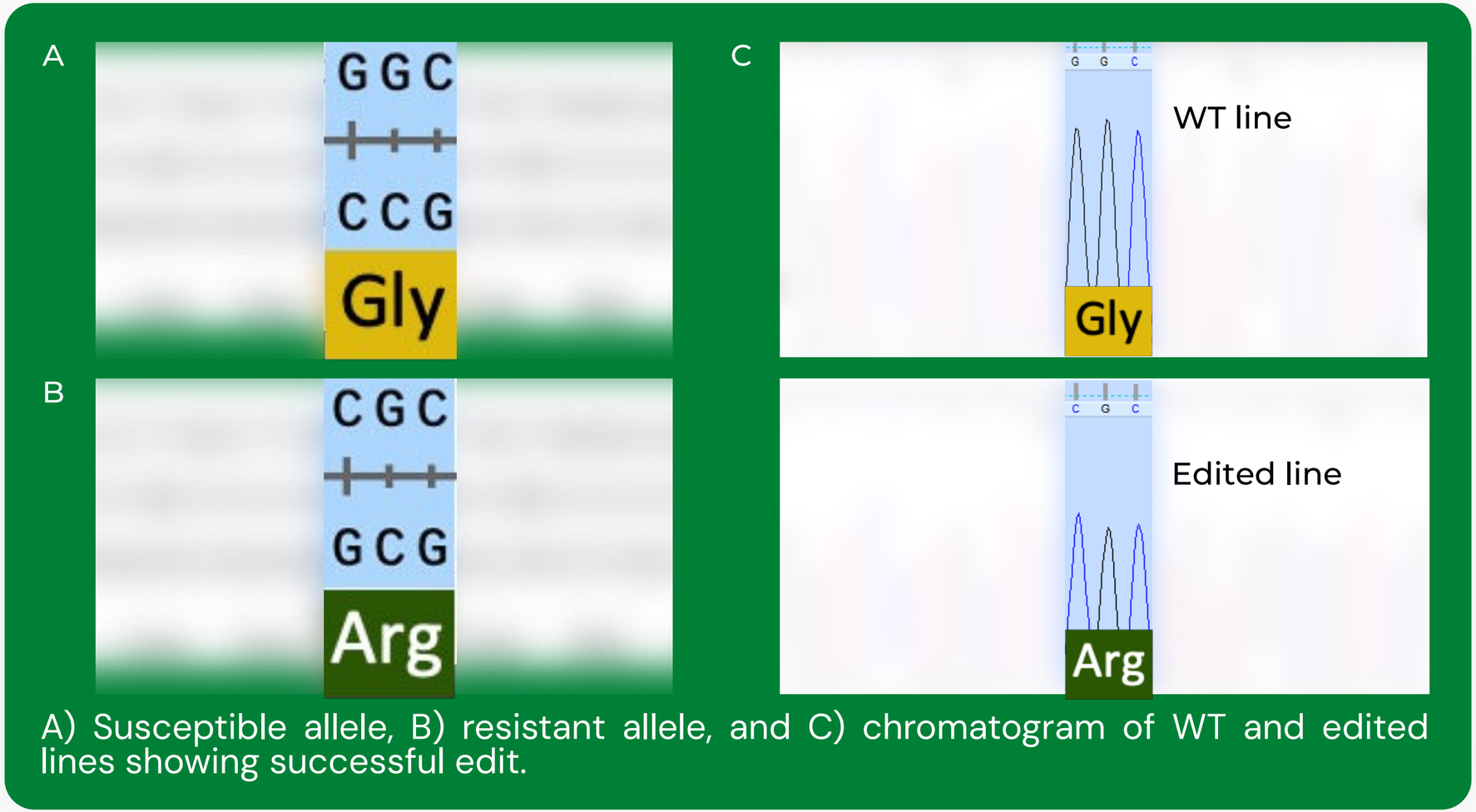


A) Average grain length, B) average grain width, and C) estimated 1000 grain weight of T_2 seeds of gene-edited IR64 lines.

Ludwig, et al. [Unpublished manuscript]

Broad-spectrum resistance to fungal pathogens

Target gene prime editing (SDN1)

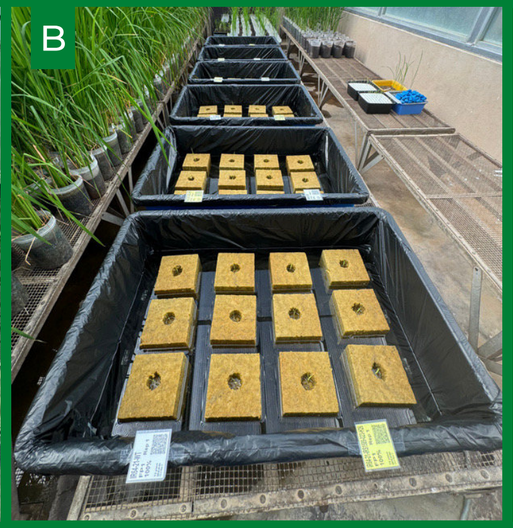


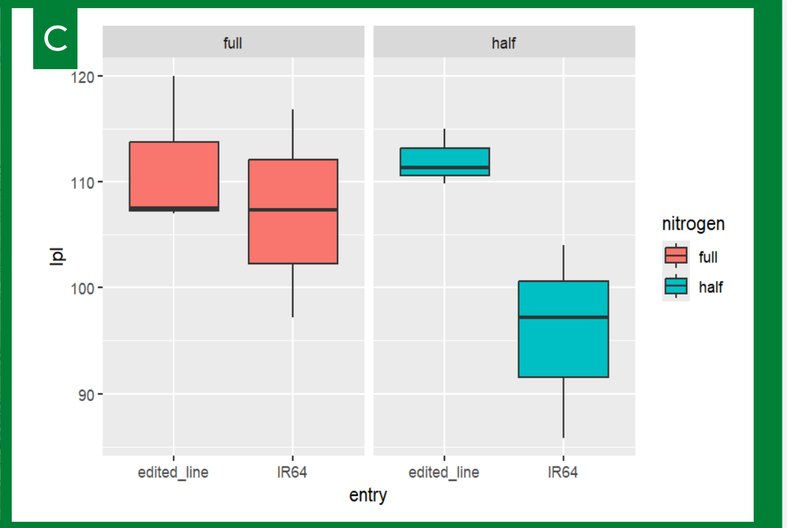
A) Susceptible allele, B) resistant allele, and C) chromatogram of WT and edited lines showing successful edit.

CP Bahaladia, G Magalit, Y Ludwig, V Luu, E Lagudah, I Slamet-Loedin [Unpublished manuscript]

Improved nitrogen remobilization

Target gene editing (SDN1)





Ongoing A) soil, and B) hydroponic experiments, and C) number of leaves per plant of selected HPT-free homozygous IR64-IRS1589 T_2 lines, and WT controls in full-strength and half-strength nitrogen in the soil set-up.

Trijatmiko, et al. [Unpublished manuscript]

Traits for Future Consideration*

1 Enhanced head rice recovery

Increase proportion of paddy rice retaining 75% of its length after milling

2 Improved resistance to pest and diseases

E.g. stem borer, brown plant hopper, leaf folder, gall midge, RYMV, bacterial blight, sheath blight and blast

3 Increased tolerance to abiotic stress

E.g. submergence and salinity

4 Traits related to hybrid rice

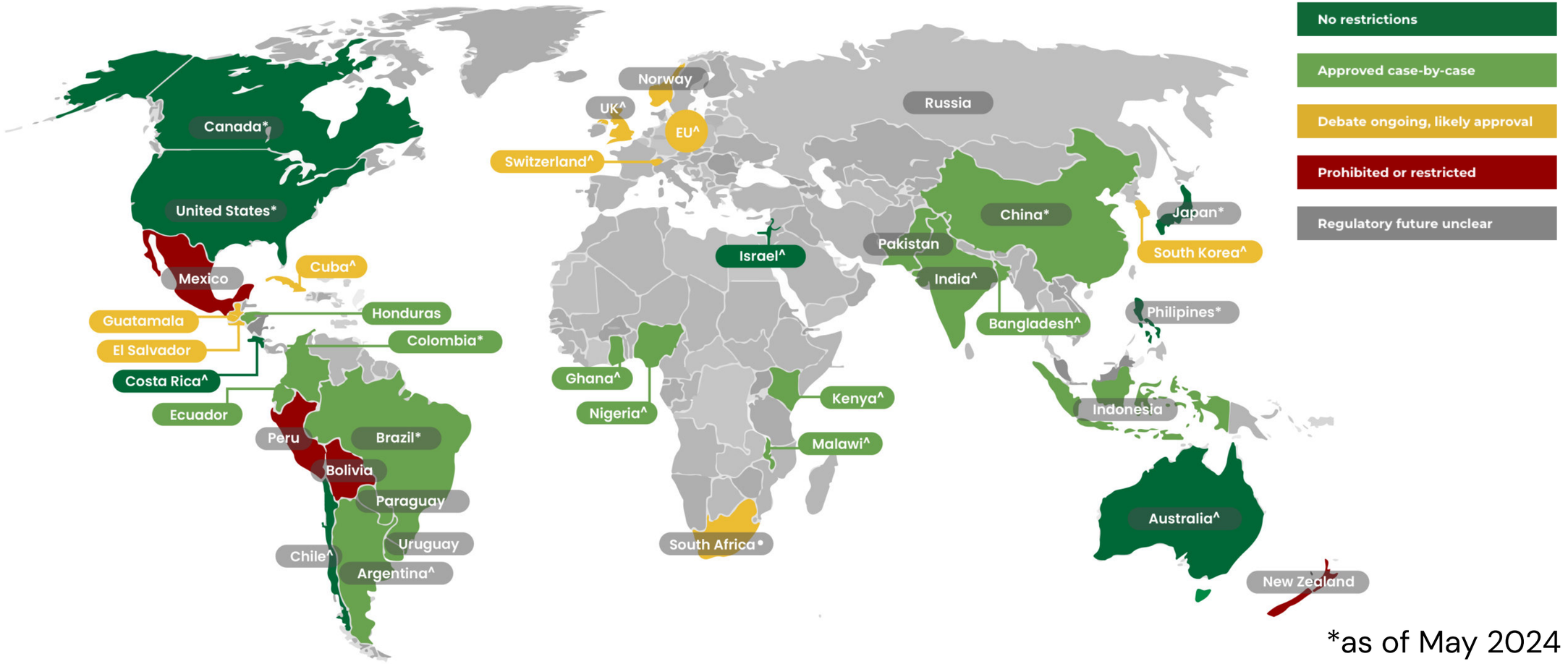
E.g. improved recombination, higher outcrossing, and apomixis

5 Traits lacking in direct-seeded rice lines

E.g. anaerobic germination, harvest index

*Trait prioritization ongoing

Global regulatory landscape for GE crops*



Genome Editing in Rice

Global Gene Editing Regulation Tracker by the Genetic Literacy Project

Genome editing has the potential to address challenges in the rice industry, directly enhancing food and nutritional security in the Asia-Pacific region amidst climate change.

Acknowledgement

Yvonne Ludwig, Conrado Dueñas Jr., Reena Jesusa Macalalad-Cabral, Ajay Kohli, Russell Reinke, Anca Macovei, Neah R Sevilla, Christian Cantos, Gilda B Jonson, Tomáš Čermák, Daniel F Voytas, Il-Ryong Choi, Prabhjit Chadha-Mohanty, Ricardo Oliva, Chonghui Ji, Genelou Atienza-Grande, José C. Huguet-Tapia, Alvaro Perez-Quintero, Ting Li, Joon-Seob Eom, Chenhao Li, Hanna Nguyen, Bo Liu, Florence Auguy, Coline Sciallano, Van T. Luu, Gerbert S. Dossa, Sébastien Cunnac, Sarah M. Schmidt, Casiana Vera Cruz, Boris Szurek, Wolf B. Frommer, Frank F. White, Bing Yang, Saurabh Badoni, Erstelle Pasion-Uy, Sakshi Kor, SungRyul Kim, Gopal Misra, Rhowell Jr. N. Tiozon, Reuben James Q. Buenafe, Ana Rose Ramos-Castrosanto, Vipin Pratap, Julia von Steimker, Saleh Alseekh, Alisdair R. Fernie, Gurudev S. Khush, Nese Sreenivasulu, Precious Guevarra, Jerlie Mhay Matres, Christian Paolo Balahadia, Grace Angelique Magalit, Blesilda Enriquez, Kurniawan Rudi Trijatmiko and Inez H. Slamet-Loedin.

Thank you for listening!