

The First International Symposium of the World Wild Rice Wiring: Conservation and utilization of global wild rice germplasm resources through international cooperation

Disna Ratnasekera^{1,2,4,13}, Jiayu Fan^{5,6,13}, Robert J. Henry⁷, Beng-Kah Song⁸, Peterson Wambugu⁹, Tonapha Pusadee¹⁰, Ohn Mar Aung¹¹, Koukham Vilayheuang¹², Xiaoming Zheng^{1,2,3,*} and Qian Qian^{1,2,5,*}

¹National Nanfan Research Institute, Chinese Academy of Agricultural Sciences, Sanya 572000, China

²State Key Laboratory of Crop Gene Resources and Breeding/Key Laboratory Grain Crop Genetic Resources Evaluation and Utilization Ministry of Agriculture and Rural Affairs, Institute of Crop Sciences, Chinese Academy of Agricultural Sciences, Beijing 100081, China

³International Rice Research Institute, Los Baños 4030, Philippines

⁴Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Matara 81000, Sri Lanka

⁵Yazhouwan National Laboratory, Sanya 572000, China

⁶Hainan University, Haikou 570228, China

⁷ARC Centre of Excellence for Plant Success in Nature and Agriculture, University of Queensland, Brisbane, QLD 4072, Australia

⁸School of Science, Monash University Malaysia, Selangor 47500, Malaysia

⁹Kenya Agricultural Research Institute, Nairobi 00100, Kenya

¹⁰Division of Agronomy, Department of Plant and Soil Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand

¹¹Department of Agricultural Research, Yezin 610213, Myanmar

¹²National Agriculture and Forestry Research Institute, Vientiane 0605, Lao

¹³These authors contributed equally to this article.

*Correspondence: Xiaoming Zheng (zhengxiaoming@caas.cn), Qian Qian (qianqian188@hotmail.com)

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As drastic climatic changes significantly impact global agriculture, the importance of conserving and utilizing wild germplasm has gained prominence. In this context, the conservation and sustainable utilization of wild rice germplasm resources have become a high priority. Although efforts to conserve and sustainably utilize wild rice germplasm are underway globally, they are fragmented and require international cooperation to advance climate-resilient rice breeding and ensure future food security.

The World Wild Rice Wiring (W-W-W) alliance was established in 2023 as a collaborative platform with a broad scope focused on the conservation, sustainable utilization, and sharing of knowledge, technology, and resources related to wild rice germplasm among countries and regions around the world. The alliance was officially announced through a publication of the concept in *Molecular Plant* (Zheng et al., 2024) and comprises 27 member countries at present. The W-W-W alliance proposed and organized the First International Symposium of the World Wild Rice Wiring and Academic Exchange Meeting of "Lancang-Mekong Granary" in Sanya, China, from September 5 to 8, 2024. The event was supported by the Yazhouwan National Laboratory, the Chinese Academy of Agricultural Sciences, the International Rice Research Institute (IRRI), and several other organizations, bringing together approximately 300 scientists, experts, and policymakers from more than 25 countries and organizations. The primary focus of the symposium was to discuss the strategies of

conserving, utilizing, and sharing the knowledge, technology, and resources within the W-W-W alliance in order to enhance rice production and improvements in the face of unpredictable climate change and future food security concerns.

The meeting addressed the need for consensus through international cooperation toward sharing science and technology, policy support, and mechanisms and platforms for the sharing and efficient usage of resources, empowering global food security and sustainable agricultural development. Discussions were held and decisions were made to analyze the present situation of the global wild rice germplasm resources, establish major scientific research and international cooperation, advance measures to safeguard global wild rice germplasm resources, and set policies for research, utilization, and international cooperation to provide a strategic direction.

THE MILESTONES OF WILD RICE GERmplasm RESOURCES IN THE DEVELOPMENT OF RICE INDUSTRY

As an ancient country with over 10 000 years of rice cultivation history, China has played a pivotal role in shaping human

agricultural civilization. With a vast cultivation area spanning 35° in latitude from north to south, China's diverse climate and environment support various rice cultivation practices, yielding a stable annual rice harvest of over 200 million tons.

China has driven two "Green Revolutions" in global rice production. Rice breeding in China has evolved from relying on natural variation and traditional optimization to adopting modern breeding technologies such as genetic recombination, mutagenesis, and precise selection. Professor Qian Qian from the Yazhouwan National Laboratory presented a review about the milestones of rice breeding in China and the role of key Chinese scientists in using wild rice to advance the rice industry.

In 1926, Professor Ding Ying discovered wild rice resources in Guangzhou. Then, in 1933, he bred "Zhongshan 1," initiating the utilization of wild rice resources. In 1959, Professor Huang Yaoxiang bred the first semi-dwarf *indica* rice variety, "Guangchang Ai," which had a significant impact on the international rice breeding industry. In 1970, Mr. Li Bihu discovered a male sterile wild rice individual plant (now known as "Ye Bai") in Hainan, providing crucial material for Professor Yuan Longping and his team to develop the three-line hybrid rice technology. Since its wide cultivation in 1976, the three-line hybrid rice has remarkably increased the rice yield per unit area, and this technological innovation is regarded as the second Green Revolution. The first hybrid rice, bred using wild abortive rice as the male parent, was further improved to super-hybrid rice through intelligent infertility technology, along with advancements in low-cadmium rice and mechanized seed production technology. These innovations focus on achieving high productivity, reducing seed costs, and ensuring food safety. As of today, hybrid rice has been globally cultivated over an area exceeding 600 million hectares, increasing grain production by more than 800 million tons, making a great contribution to global food security.

Moreover, Professor Qian introduced the recent research of his team about the genetic diversity of wild rice, which has provided a rich gene pool for rice breeding. By identifying important genes from wild rice, numerous hybrid rice varieties with high yield, disease resistance, and stress tolerance have been successfully bred. Professor Qian also introduced China's international collaboration regarding hybrid rice breeding. China has extensively worked with international organizations such as the Food and Agriculture Organization and the IRRI, to extend hybrid rice technology in more than 60 countries, especially developing countries. The extended area has reached 7 million hectares, and the average output has increased by more than 20%, effectively alleviating the food shortage. China has introduced about 34 800 rice germplasm resources from the IRRI, including repeated introduction of some materials that provide important support for rice variety improvement and breeding technology innovation in China. At the same time, China has also actively shared its own germplasm resources and utilization technology with the international community, promoting the progress of global rice breeding technology. China has also trained a large number of scientific and technological talents in the field of hybrid rice for these countries, promoting the sustainable development of local agriculture. These achievements consolidate the important position of Chinese hybrid rice technology in global food security and the sustainable development of agriculture.

BIOTECHNOLOGY AND BIG DATA MINING: TECHNOLOGY-ENABLED CONSERVATION AND UTILIZATION OF GERmplasm RESOURCES

Data mining and bioinformatics tools and their integration have played a key role in gene mining of wild rice and have also promoted the process of conservation and utilization of cultivated rice and wild rice germplasm resources. Through high-throughput sequencing, genome assembly, transcriptome analysis, and other novel tools, researchers can identify key genes and their regulatory networks more efficiently, providing strong support for precise breeding. Through in-depth exploration in the field of agricultural science and technology, a series of key advances based on scientific data, accompanied by the great contributions of outstanding scientists, have significantly promoted the green, efficient, and sustainable development of agricultural production.

The conservation and utilization of China's germplasm resources have laid a solid foundation for global rice breeding and production. In addition, the application of hybridization technology by Chinese scientists has effectively incorporated valuable genetic resources from wild rice into cultivated rice, driving the improvement of rice varieties. Professor He Guangcun from Wuhan University summarized the systematic studies of his team on the cloning and functional characterization of insect-resistance genes from wild rice, including *Bph 14*, *Bph 15*, and other key genes against brown planthopper (*Nilaparvata lugens* [Stål]). The insect-resistant rice varieties bred by applying molecular marker auxiliary selection technology have significantly improved the level of field insect resistance, not only reducing the insect feed density by more than 85% but also significantly reducing the use of chemical pesticides and increasing rice yield by more than 10 times. Their achievements will provide important support for "green rice" production and also contribute to global food security.

Professor Hu Fengyi from Yunnan University and his team have developed new perennial rice varieties through innovative remote hybridization technology. These perennial varieties showed excellent performance in field trials, including prolific root growth, soil retention enhancement, and soil erosion reduction of more than 20% per year. Meanwhile, these new varieties reduced labor demand by 40% and increased economic benefits by about 15%. This result has significantly improved the ecological and economic benefits of rice production, showing the great potential of distant hybridization technology in the innovation of crop varieties.

Professor Robert Henry from University of Queensland gave a talk about the genomic research of Australian wild rice that are able to survive in different and extreme climate conditions and the discovery of novel disease resistance genes from those materials. The incorporation of such resistance genes into cultivated rice through the genetic engineering approach will provide disease-resistant genetic resources, which is expected to greatly reduce yield losses under adverse conditions.

With the rise of CRISPR-Cas9-mediated genome editing technologies and the integration of multi-omics data and big-data

analysis, rice breeding has stepped into a new era of precision breeding. These technologies have enabled breeders to accurately modify the genes controlling important traits and accelerate the improvement of crop varieties, which allows them to gain a deeper understanding of crop genetic diversity and achieve large-scale and efficient screening of germplasm resources. Professor Yu Hong from the Yazhouwan National Laboratory successfully achieved rapid *de novo* domestication of allotetraploid wild rice using CRISPR–Cas9 technology. By precisely editing key genes controlling important agronomic traits, they have successfully developed new rice varieties with both high yield and strong stress resistance. The data from field experiments showed that the yield of new varieties was about 20% higher than that of check varieties, and the survival rate under drought and incidence of pests and diseases was more than 90%. This technological innovation not only promotes the practical application of gene editing technology in crop breeding but also provides new ideas and methods for crop genetic improvement in the future.

INTERNATIONAL COOPERATION FRAMEWORK AND POLICY: CONSERVATION AND UTILIZATION OF GERMPLASM RESOURCES FROM A GLOBAL PERSPECTIVE

On the premise of abiding by the laws and policies of all countries, the symposium made it clear that all of the countries should establish a framework for contributing to and accessing global wild rice germplasm resources, as well as for the fair and equitable sharing of benefits in accordance with international laws and treaties, such as the International Treaty on Plant Genetic Resources for Food and Agriculture, the Convention on Biological Diversity, and the Nagoya Protocol. In the future, member states of the alliance are requested to ensure that appropriate priority is given to genetic resources in national adaptive planning and the contribution of these resources in global food security toward broader national development programs. Communication among policymakers from different countries will be helpful in promoting the priority settlement of matters related to wild germplasm resources, ensuring the inclusion of genetic resources in specific action plans, guaranteeing the full collection and preservation of the diversity of wild germplasm resources, improving the habitat conditions of wild rice populations to adapt to environmental changes, and increasing the number of wild rice populations with stronger adaptive characteristics.

The establishment of a network for the *ex situ* collection of wild rice germplasm and related international organizations and initiatives has strengthened the global system. This has enhanced the capabilities of developing countries in the conservation and utilization of wild rice resources. The member states of the alliance should carry out protection according to the "Global Action Plan," including assessing risks, protecting the original habitat, etc. Non-native habitat protection and monitoring systems need to be supplemented as needed. Plans need to be formulated to ensure the global implementation of wild rice protection, and threatening factors need to be identified and resolved. Priority should be given to the

plan of collecting wild rice genetic resources, and the collection work should be guided by the conservation gap analysis to increase the probabilities of collecting new and diverse wild rice.

Under the relevant international cooperation framework and policies, this symposium highlighted the aims and goals of the global wild rice alliance. By facilitating the sharing and management of wild rice germplasm resources through international cooperation, the alliance will contribute to the objectives of the global system through enhancing the availability and sustainable use of plant genetic resources. Members of the alliance include scientific research institutions, universities, and international organizations in China, Sri Lanka, Thailand, Malaysia, India, Cambodia, Nepal, Laos, Ghana, Papua New Guinea, Benin, Cameroon, Kenya, Tanzania, Ethiopia, Australia, Myanmar, USA, and other countries. The alliance is committed to the collection, preservation, identification, and utilization of wild rice germplasm resources. The establishment of a globally unified wild rice germplasm resources database and sharing platform will help researchers access the resources and data, thereby promoting global wild rice research.

FUTURE PERSPECTIVES

During the meeting, the alliance not only clarified the direction for the conservation and utilization of wild rice germplasm resources but also engaged in in-depth discussions around this core objective, shaping the priorities for future work.

- (1) Enhance global cooperation. The challenges posed by climate change and ecological pressures highlight the critical importance of conserving and utilizing wild rice resources. Establishing a global germplasm repository, fostering data sharing, advancing international research collaborations, and leveraging knowledge exchange through global platforms can strengthen cooperation, drive innovation, and enhance the efficient use of these vital resources.
- (2) The alliance is committed to enhancing conservation capacity. Effective conservation depends on both technological advancements and human expertise. Building bioinformatics platforms and gene banks, along with adopting cryopreservation techniques and implementing ecological restoration efforts, can safeguard the diversity and security of germplasm resources. Simultaneously, investing in workforce development through training programs and knowledge-sharing initiatives will cultivate the scientific and managerial expertise needed to ensure the sustainable conservation and utilization of these resources.
- (3) The alliance actively promotes accelerating technological integration and application. Emerging technologies such as artificial intelligence (AI), big data, and gene editing provide transformative opportunities for advancing wild rice research. The introduction of AI technology has not only had a significant impact on data processing and resource management but has also brought about a transformation in the research methods related to the conservation and utilization of wild rice germplasm. AI can expedite the identification of high-value germplasm, gene editing can offer

precise tools for the enhancement of desirable traits, and digital monitoring systems integrated with data analytics can optimize resource management, dramatically improving research efficiency and the practical application of findings. Professor Zheng Xiaoming from the Chinese Academy of Agricultural Sciences leverages AI and biotechnology for digital germplasm collection to predict wild rice distribution areas. IRRI scientists use AI technology to enhance the efficiency of rice breeding, shorten planting cycles, reduce emissions, optimize the process of agricultural production, and provide a scientific basis for climate change adaptation.

- (4) The alliance is advancing standardization in various industries. Standardization is crucial for the effective, equitable, and widespread use of wild rice resources. Developing and implementing international standards for germplasm collection, characterization, storage, and application, along with unified breeding methodologies and quality control systems, will ensure the compatibility of research outcomes, improve resource management efficiency, prevent waste, and foster global collaboration and resource sharing.

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AUTHOR CONTRIBUTIONS

D.R., J.F., R.J.H., B.-K.S., P.W., T.P., O.M.A., K.V., X.Z., and Q.Q. conceived and designed the study. D.R. and J.F. contributed to writing the original draft. R.J.H., B.-K.S., P.W., T.P., O.M.A., and K.V. edited the manuscript. X.Z. was responsible for reviewing and editing the manuscript and supervised the research. Q.Q. supervised and acquired funding for the research. All authors read and approved the final manuscript.

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