

## REVIEW

# Japan and IRRI: Contributions to International Rice Research for Sustainable Development, Lessons Learned and Ways Forward

Yoichiro KATO<sup>1</sup> and Keiichi HAYASHI<sup>2\*</sup>

<sup>1</sup> Department of Global Agricultural Sciences, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan

<sup>2</sup> Crop, Livestock and Environment Division, Japan International Research Center for Agricultural Sciences, Tsukuba, Japan

### Abstract

This paper reviewed the contributions of Japan to rice research through its partnership with the International Rice Research Institute (IRRI), which started in 1960. Japanese scientists were seconded to work at the IRRI headquarters or hired as full-time staff to conduct rice research in the fields of breeding, pathology, physiology, agronomy, and social sciences. Among them is Dr. Akira Tanaka who played a key role in the development of IR8, a rice variety credited for paving the way for the first Green Revolution. To disseminate research outputs from agronomic research on rainfed rice in Asia to farmers, IRRI developed an ICT-based decision support systems (i.e. weather-rice-nutrient integrated decision support system or WeRise) which are ideal platform to enable farmers to access database from various fields of rice research. These web-based technologies are also accessible through mobile devices. Web-based technologies can help accumulate big data that can be used to promote data-driven solutions and enable informed decision-making to help rice farmers adapt to current and future climate. Analysis of big data from various web-based technologies is still a researchable area where IRRI and Japan can work together to exploit valuable information from past researches and further contribute to sustainable development through rice research.

**Discipline:** Crop Science

**Additional key words:** CGIAR, Green revolution, decision support systems

### Introduction

The 2030 agenda for sustainable development that was adopted by member states of the United Nations in 2015 targets 17 sustainable development goals (SDGs). It includes SDG 2 which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. With the world population projected to exceed 8.5 billion by 2030, achieving this goal is a challenge for the agricultural sector. In this context, the role of science remains essential to continue providing solutions for society to move towards the attainment of SDG 2 by 2030. Rice is among the crucial cereals for human consumption globally (GRiSP 2013), but its production faces various challenges due to a changing society and climate. The International Rice Research Institute

(IRRI) with headquarters located in the Philippines was established in 1960 by the Ford and Rockefeller foundations. It is among the non-profit international research organizations that have been supported by the CGIAR (formerly the Consortium of International Agricultural Research Centers). It leads international rice research through collaborating with scientists of various fields from developing and developed countries. Japan is among the countries that support IRRI by seconding rice scientists and allocating funds to advance rice research. In commemoration of CGIAR's 50th anniversary, this paper revisits the history of Japan and IRRI's partnership to review past researches conducted by Japanese scientists in IRRI in the fields of breeding, pathology, physiology, agronomy, and social sciences.

---

\*Co-corresponding authors: [ykato@g.ecc.u-tokyo.ac.jp](mailto:ykato@g.ecc.u-tokyo.ac.jp), [khayash@affrc.go.jp](mailto:khayash@affrc.go.jp)

Received 11 December 2020; accepted 26 July 2021.

## Research findings of Japanese scientists in IRRI

A review of the research findings of Japanese scientists is organized in three sections. The first section aims to recognize the contributions of Japanese researchers to establish modern rice research. It is followed by two consecutive sections on Japanese contributions to rice research through the IRRI-Japan Collaborative Research Project (IJCRP), and research achievements on rainfed rice production. The discussion on the ways forward to contribute to the achievement of SDGs through rice research follows.

### 1. Contributions of Japanese scientists to modern rice research

IRRI is best known for its work with IR8, the first semi-dwarf rice cultivar in the tropics, which sparked the Green Revolution. Several Japanese scientists were deeply involved in its development, characterization, and impact assessment. In close collaboration with Dr. Peter Jennings, IRRI's first breeder, Dr. Akira Tanaka, the first head of IRRI's Physiology Department, significantly contributed to the development of IR8 (Chandler, 1992). His position was taken over by Dr. Shouichi Yoshida, who wrote "Fundamentals of Rice Crop Science (Yoshida 1981)," a widely-read textbook on rice globally. After Dr. Yoshida's death, Dr. Shigemi Akita was seconded to IRRI in the 1980s. IRRI's research program on rice biochemistry was established in 1962 by Dr. Takashi Akazawa. He was succeeded by Dr. Yasuo Natori in 1964. Another essential research at IRRI in its early days was the non-symbiotic nitrogen (N) fixation by Azolla and cyanobacteria in paddy fields discovered by Dr. Tomio Yoshida. Then, Dr. Iwao Watanabe collected the diverse germplasm of Azolla and cyanobacteria around the world. Japanese scientists also dedicated their time to the socio-economic impact assessment of the Green Revolution in Asia (David and Otsuka 1994, Hayami and Kikuchi 2000). The impact assessment of IRRI's modern technology was continued by Drs. Kei Kajisa and Takashi Yamano who worked at IRRI during the last 15 years (for example, Yamano et al. 2016, Kajisa et al. 2018).

### 2. Contributions of Japanese scientists through the IRRI-Japan Collaborative Research Projects (IJCRPs)

The IJCRPs started in 1984. Each project or phase which spanned a period of five years was funded by the Government of Japan through the Ministry of Agriculture, Forestry, and Fisheries (IJCRP 2019). The focus of each phase is described as follows:

(1) Fundamental research on rice pathology for technology development to stabilize production

The first four IJCRPs focused on rice productivity improvement and environment-friendly technology development in the tropics; particularly on bacterial blight, tungro and blast diseases because these diseases cause a significant yield reduction. Ogawa and other scientists promoted the development of a near-isogenic line using a resistance gene of bacterial blight (Ogawa and Yamamoto 1986). Besides, Hibino et al. (1989) and Imbe et al. (1997) revealed that some popular varieties have tungro resistance, and Kobayashi et al. (Kobayashi et al. 1993) identified tungro resistance varieties from wild rice. Furthermore, the study by Tsunematsu et al. (2000) revealed high partial resistance to blast disease in IR64, and the blast resistance in breeding lines was developed in IRRI by Ebron et al. (2004). Hayashi et al. proposed an international system for determining blast disease using LTH monogenic lines (Hayashi and Fukuta 2007).

(2) Research on agronomy to develop appropriate cultivation techniques

Research on agronomy was carried out for efficient fertilizer use (Wada and Sta Cruz 1990), and crop establishment through wet direct sowing (Yamauchi et al. 1995). Kondo et al. carried out their research on stabilizing upland rice production in Asia to show the importance of nitrogen fertilizer application for root water absorption (Kondo et al. 2000). Nozoe et al. conducted research on iron toxicity and demonstrated the importance of root activity at the reproductive stage given the long maturity days helped alleviate iron toxicity (Nozoe et al. 2008).

(3) Research on climate change adaptation and mitigation

Water scarcity and rising temperature are some of the impacts of climate change. In this context, researches on water management and varietal development were carried out during the 5<sup>th</sup> phase of IJCRP. Specifically, researches on water-saving cultivation technology and greenhouse gas reduction through the alternate wetting and drying (AWD) method were carried out. These studies have shown that AWD can reduce water use in irrigated rice cultivation in Southeast Asia by 15-40% (Humphreys et al. 2010) and reduce methane emissions by 48% (Wassmann 2016). A recent study also showed that AWD is effective in reducing water use and improving grain yield (Arai et al. 2021), proving its relevance for rice farmers. On varietal development, Ishimaru et al. (2016) studied the early morning flowering trait as an avoidance mechanism for high-temperature stress. They developed a breeding line that starts flowering earlier than the check variety IR64. On the other hand, WeRise, a seasonal climate predictions-based ICT (Hayashi et al. 2018) was developed through the 6<sup>th</sup> IJCRP to improve the farmers' access to various technologies for better rice production in rainfed rice areas.

### 3. Agronomy research in rainfed lowland rice at IRRI

During the last decade, IRRI's research program on agronomy for unfavorable rainfed (non-irrigated) environments in Southeast Asia, led by the author, Dr. Yoichiro Kato, who worked at IRRI from 2011 to 2017, focused on three aspects: evaluation of improved rice germplasm, exploration of crop management options for stress-prone environments, and the effective technology transfer throughout the region. Breeding programs at IRRI have been tightly linked to the molecular genetics for the DNA marker-assisted selection during the last two decades. The greatest success was the discovery of the submergence-tolerance gene (*SUB1A*) and the development of a series of near-isogenic genotypes known as 'Sub1 cultivars' (Mackill et al. 2012), which can tolerate the inundation for a few weeks. However, low-lying rice areas are subject to different types of flooding stress: transient submergence and stagnant flooding. The collaborative work between IRRI's breeding and agronomy teams established the selection criteria and the desirable cultivars under stagnant flooding stress (Kato et al. 2014), and identified a few promising Sub1 cultivars; they tolerate stagnant flooding to a greater extent than the modern tolerant cultivars which do not carry *SUB1* (Kato et al. 2019).

The IRRI agronomy program was also in line with the national breeding programs in Asia to improve the germplasm selection methods in the target population of environments (Rumanti et al. 2018). Promising genotypes and new stress-tolerant cultivars have been intensively tested not only in on-station experiments (Ohno et al. 2018b, Yamane et al. 2018) but extensively in on-farm trials (Ohno et al. 2018a).

To further increase rice productivity in unfavorable environments of Asia, the introduction of new stress-tolerant rice cultivars has been coupled with the improvement of management practices particularly nutrient management (Haefele et al. 2016). The nutrient management study adopted multi-location on-farm trials covering a wide range of soil types and hydrological conditions (Banayo et al. 2018a,b, Kong et al. 2020a,b, Sansen et al. 2019). These studies showed the importance of phosphorus (P) and potassium (K) management in less productive areas on coarse-textured soils in the Mekong river basins and the importance of N application around the panicle initiation stage to increase the farmer income in rainfed lowlands.

The need for stronger linkages among researchers, extension staff and farmers has long been emphasized in agricultural innovation work. For the rice sector development in Asia, IRRI has facilitated interactions among stakeholders within the National Agricultural

Research and Extension System (NARES). The Consortium for Unfavorable Rice Environments (CURE) program at IRRI has dealt with the actions for climate change adaptation in rainfed rice ecosystems through supporting innovation and technological advances in tropical Asia from 2002 to 2018 (Manzanilla et al. 2017). The role of CURE as a platform to connect IRRI researchers, national agricultural researchers, extension workers, and farmers was crucial to make an impact through researches. CURE aimed to help 100 million rice farmers in Asia through developing, validating, and disseminating rice technologies, and a vast database was created through this platform. The long-term experience of IRRI as a hub of the international rice network clearly indicates the necessity of such a consultative group in the Asian rice value chain in order to fast-track the promotion of innovative rice technologies.

### Enhancing research collaboration between IRRI and Japan

Tremendous researches have been made to harness various constraints in rice production to feed a growing world population. However, it has been argued that the research results were not effectively delivered to farmers. This problem is due to the fragmentation among research, development, and extension agencies. CURE functioned as a catalyst to facilitate the linkage among rice stakeholders. The challenge is how to keep this momentum even after the CURE. ICT-based technologies are advantageous for accelerating technology development. Using ICT can facilitate the access of various technologies by farmers who often confront the difficulty of getting necessary technologies for their production due to their limited capacity to gather information. Technologies consolidated through ICT play a crucial role in making technologies accessible to farmers. ICT-based platforms such as WeRise, Rice Crop Manager (RCM), and site-specific nutrient management-based ICT developed by IRRI (Buresh et al. 2019), are some examples of rice knowledge and technologies from research outputs that have been consolidated and made accessible to farmers through devices such as a mobile phone or tablet. A mobile phone is a standard tool in Asia, where people have more than two devices (Ministry of Internal Affairs and Communications 2020). Information access through individual devices worldwide can promote accumulation of various data in volume, content, and disciplines. Data is essential to help deal with the most pressing challenges such as climate change, food insecurity, etc. Utilizing existing information with innovative approaches is the most effective way to achieve the SDGs (CIAT and IFPRI 2016). Research

outputs that are available and accessible to farmers through ICT promote validation and dissemination of rice technologies. This interaction works as a feedback loop to finetune the developed technologies to make it more relevant for farmers in the target environments. ICT in agriculture, including rice production, plays a crucial role in current and future rice research and production. The ICT is a common platform where researchers of various disciplines can work together through big data analysis and promote data-driven technologies for an efficient and effective agricultural practice at farmers' level. The ICT-based platform is also an area to enhance research collaboration between IRRI and the Japanese government through the involvement of Japanese researchers from different disciplines.

## Conclusion

This paper reviewed past works done by Japanese rice researchers in IRRI, which was demonstrated through the long-lasting and robust collaborations between IRRI and Japan. To utilize past works for future research and harness constraints in unfavorable rice areas, ICT is an example of a platform to facilitate the farmer's access to information and developed technologies for better rice production. ICT is also a relevant tool to attract the youth and promote a market-oriented production through improving resource use efficiency. The application of ICT in agricultural research is one of the areas where research contributions can be enhanced through the smart agriculture developed in Japan. Furthermore, using ICT through a device can promote big data analysis that would be an area where IRRI and Japan can continue working together to feed a growing population.

## References

- Arai, H., Hosen, Y., Chiem, N.H., Inubushi, K. 2021. Alternate wetting and drying enhanced the yield of a triple-cropping rice paddy of the Mekong Delta. JSSPN, <https://doi.org/10.1080/00380768.2021.1929463>
- Banayo, N.P.M.C. et al. (2018a) On-farm assessment of site-specific nutrient management for rainfed lowland rice in the Philippines. *Field Crops Research*, **220**, 88-96.
- Banayo, N.P.M.C. et al. (2018b) Site-specific nutrient management enhances sink size, a major yield constraint in rainfed lowland rice. *Field Crops Research*, **224**, 76-79.
- Buresh, R.J., et al. (2019) Site-specific nutrient management for rice in the Philippines: Calculation of field specific fertilizer requirements by Rice Crop Manager. *Field Crops Research* **239**, 56-70.
- Chandler, R.F. (1992) An adventure in applied science: a history of the International Rice Research Institute.
- CIAT and IFPRI (2016) CGIAR Big data coordination platform. Proposal to the CGIAR Fund Council, 31 March, 2016. International Center for Tropical Agriculture (CIAT), Cali, Colombia and International Food Policy Research Institute, Washington DC, United States of America.
- CURE (2016) <http://cure.irri.org/> (browsed on June 20, 2021)
- David, C.C. & Otsuka, K. (1994) Modern rice technology and income distribution in Asia. Boulder: Lynne Rienner.
- Ebron, L. A. et al. (2004) Estimation of genes in blast resistance in elite Indica-type rice (*Oryza sativa* L.) varieties-bred at International Rice Research Institute. *Breeding Science*, **54**, 381-387.
- GRiSP (Global Rice Science Partnership) (2013) Rice almanac, 4th edition. Los Baños (Philippines): International Rice Research Institute. pp.283.
- Haefele, S.M. et al. (2016) Climate ready rice: augmenting drought tolerance with best management practices. *Field Crops Research*, **190**, 60-69.
- Hayami, Y. & Kikuchi, M. (2000) A rice village Saga: three decades of Green Revolution in the Philippines. London: Macmillan.
- Hayashi, K. et al. (2018) Reducing vulnerability of rainfed agriculture through seasonal climate predictions: A case study on the rainfed rice production in Southeast Asia. *Agric. Syst.*, **162**, 6-76.
- Hayashi, N. & Fukuta, Y. (2007) Proposal of a new international system for differentiating races of *Pyricularia oryzae* Cavara using LTH monogenic lines. *Jpn. J. Phytopathol.*, **73**, 4 (in Japanese).
- Hibino, H. (1989) Insect-borne virus of rice. In "Advances in disease vector research. Vol. 6" Springer Verlag, New York, 209-441.
- Humphreys, E.S. et al. (2010) Halting the Groundwater Decline in North-west India—Which Crop Technologies will be Winners? *Advances in Agronomy*, **109**, 155-217.
- IJCPR (2019) [http://books.irri.org/IRRI\\_Japan\\_brochure.pdf](http://books.irri.org/IRRI_Japan_brochure.pdf) (browsed on June 20, 2021)
- Imbe, T. et al. (1997) A new gene for blast resistance in rice cultivar, IR24. *Rice Genet. Newsl.*, **14**, 60-62.
- Ishimaru, T. et al. (2016) Breeding efforts to mitigate damage by heat stress to spikelet sterility and grain quality. *Plant Production Science*, **19**, 12-21, DOI: 10.1080/1343943X.2015.1128113.
- Kajisa, K. et al. (2018) Lessons from volumetric water pricing trials at the three surface irrigation systems in Northern Luzon, Philippines. *DLSU Business & Economic Review*, **28**, 51-69.
- Kato, Y. et al. (2014) Shoot growth and other traits associated with tolerance of stagnant flooding in rice. *AoB PLANTS* **6**, plu058.
- Kato, Y. et al. (2019) Increasing flooding tolerance in rice: combining tolerance of submergence and of stagnant flooding. *Annals of Botany*, **124**, 1199-1209.
- Kobayashi, N. et al. (1993) Resistance to rice tungro viruses in wild species of rice (*Oryza* spp.). *Japan. J. Breed.*, **43**, 247-255.
- Kondo, M. et al. (2000) Characteristics of root growth and water uptake from soil in upland rice and maize under water stress. *Soil Sci. Plant Nutr.*, **46**, 721-732.
- Kong, K. et al. (2020a) Potential yield and nutrient requirements of direct-seeded, dry-season rice in Cambodia. *Experimental Agriculture*, **56**, 255-264.
- Kong, K. et al. (2020b) Importance of phosphorus and potassium

- in soil-specific nutrient management for wet-season rice in Cambodia. *Experimental Agriculture*, **56**, 204-217.
- Mackill, D.J. et al. (2012) Development and rapid adoption of submergence-tolerant (Sub1) rice varieties. *Advances in Agronomy*, **115**, 303-356.
- Manzanilla, D.O. et al. (2016) Climate-ready technologies: Combating poverty by raising productivity in rainfed rice environments in Asia. Los Baños (Philippines): International Rice Research Institute. pp.204.
- Ministry of Internal Affairs and Communications. (2020) Mobile phone situation <https://www.soumu.go.jp/g-ict/item/mobile/index.html> (browsed on 27 November 2020).
- Nozoe, T. et al. (2008) Characteristics of iron tolerant rice lines developed at IRRI under field conditions. *JARQ*, **42**, 187-192.
- Ogawa, T. & Yamamoto, T. (1986) Inheritance of resistance of bacterial blight in rice. In: Rice genetics. Manila (Philippines): International Rice research Institute, P471-479.
- Ohno, H. et al. (2018b) Longer mesocotyl contributes to quick seedling establishment, improved root anchorage, and early vigor of deep-sown rice. *Field Crops Research*, **228**, 84-92.
- Ohno, H. et al. (2018a) On-farm assessment of a new early-maturing drought-tolerant rice cultivar for dry direct seeding in rainfed lowlands. *Field Crops Research*, **219**, 222-228.
- Rumanti, I.A. et al. (2018) Development of tolerant rice varieties for stress-prone ecosystems in the coastal deltas of Indonesia. *Field Crops Research*, **223**, 75-82.
- Sansen, K. et al. (2019) Farmer-participatory evaluation of mechanized dry direct-seeding technology for rice in northeastern Thailand. *Plant Production Science*, **22**, 46-53.
- Tsunematsu, H. et al. (2000) Development of monogenic lines of rice for blast resistance. *Breed. Sci.*, **50**, 229-234.
- Yamano, T. et al. (2016) Adoption and impacts of international rice research technologies. *Global Food Security*, **8**, 1-8.
- Yamauchi, M. (1995) Anaerobic direct seeding of rice in the tropics. *JIRCAS Journal*, **2**, 65-78
- Wada, G. & Sta Cruz, P.C. (1990) Nitrogen response of rice varieties with reference to nitrogen absorption at early growth stage. *Japan J. Crop Sci.*, **50**, 540-547.
- Wassmann, R. (2016) Overview of AWD. [http://books.irri.org/AWD\\_brochure.pdf](http://books.irri.org/AWD_brochure.pdf), International Rice Research Institute.
- Yoshida, S. (1981) Fundamentals of rice crop science. International Rice Research Institute, pp.269.
- Yamane, K. et al. (2018) Seed vigor contributes to yield improvement in dry direct-seeded rainfed lowland rice. *Annals of Applied Biology*, **172**, 100-110.