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Annual Report 2020 (Apr. 2020–Mar. 2021)

JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES

JIRCAS

Japan International Research Center for Agricultural Sciences

Annual Report 2020

(April 2020-March 2021)

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Message from the President

An unprecedented year for international collaboration in agricultural research and for JIRCAS

The year 2020, the final year of the Fourth Medium to Long-Term Plan of JIRCAS for FY 2016-2020, was an unprecedented year for international collaboration in agricultural research and for JIRCAS itself. However, before I discuss the accomplishments and challenges of the past year, allow me first of all, to look back on the global-scale events that happened in the past five years leading up to 2020.

In FY 2015, when we started preparing for our Fourth Medium to Long-Term Plan, international cooperation had been gaining momentum as the Sustainable Development Goals of the United Nations (SDGs) and the Paris Agreement on climate change were adopted. However, as the new administration started in the United States in 2016, the pace of international cooperation was disturbed. In the meantime, extreme weather-related disasters such as forest fires, floods, and droughts were reported in many parts of the world, and scientists warned us that we should review our economic activities, including agriculture and food systems, in the wake of the United Nations Intergovernmental Panel on Climate Change (IPCC) report on the impacts of a global warming of 1.5°C and the Eat-Lancet Commission report on planetary health diet, among others.

In January 2020, an outbreak of a new zoonotic infectious disease was reported in China, leading the World Health Organization (WHO) to declare a pandemic (an infection explosion) of the disease named COVID-19 in March. Mobility control measures to curb the spread of infection were implemented domestically and internationally, resulting in a diastrophic shift in our lives, work, mobility, and social relations. Almost all international travels planned for JIRCAS's collaborative projects were interrupted.

As the year 2020 became one of the hottest years in terms of average temperature worldwide, a new movement against climate change came following the return of the United States to the Paris Agreement. Major countries including emerging countries expressed the goals of their efforts towards carbon neutrality (decarbonization). For its part, Japan declared in October 2020 that it will be "carbon neutral in 2050." This rising momentum in the international community means that it is time that we obligatorily respond to climate change by developing technologies to reduce greenhouse gas emissions from agriculture and fossil fuel use in agriculture or fisheries, as well as stimulate innovation for carbon absorption and sequestration in the agriculture and forestry sectors.

In May 2021, the Ministry of Agriculture, Forestry and Fisheries of Japan determined a new long-term strategy titled "Measures for Decarbonization and Resilience with Innovation" (the so-called "Green Food Systems Strategy"), which describes the desirable outcomes for agriculture, forestry and fisheries of Japan by 2050. JIRCAS will contribute to this strategy by developing green technologies common to our target regions and by harmonizing regional guidelines and standards towards the ones indicated in the strategy. Some of the activities have already been included in our Fifth Medium to Long-Term Plan for FY 2021-2025, which was prepared and documented in FY 2020.

Japan, which depends on the international market for about 60% of its calorie-based food, needs to actively contribute to global food issues through science, technology, and innovation. In 2020, we celebrated the 50th anniversary of JIRCAS, including the period of our predecessor, the Tropical Agriculture Research Center. We are extremely proud of our long-term and successful collaboration with our partners in tropical and subtropical regions and in developing regions for achieving continuous improvements in agriculture, forestry and fisheries technologies.

In particular, what we have achieved in the past five years — for example, greenhouse gas (methane, etc.) reduction technologies in paddy fields and livestock industry in Southeast Asia, the management of an international platform for biological nitrification inhibition (BNI) technology, technologies towards resilient food systems such as the development of new cultivars for abiotic and biotic stresses, measures for preventing cross-border plant pests and diseases, effective use of biomass waste, analysis of international trends in food and nutrition and so on — are quite relevant and timely, and help provide solutions to current global issues facing humanity.

At this point, I would like to recap the main points of our program-based management and strategy:

The four Programs

The Fourth Medium to Long-Term Plan consisted of four research programs, retaining the previous medium-term plan's overall structure of program-based management with some modification of the project level components. The four Programs developed using the mission-based principles were as follows:

1) Program A: Development of agricultural technologies for sustainable management of the environment and natural resources in developing regions
2) Program B: Technology development for stable production of agricultural products in the tropics and other adverse environments
3) Program C: Development of high value-adding technologies and utilization of local resources in developing regions
4) Program D: Collection, analysis and dissemination of information for grasping trends of international agriculture, forestry and fisheries

Program-based management

For FY 2016-2020, we had 14 "Projects" that were placed under the four "Programs" (Fig. 1). The programs enabled us to clarify our overall goals that needed to be achieved and the manner by which we attempted to accomplish our research. Especially assigned Program Directors were in charge of budget, personnel, goal achievement management, and evaluation. Programs A to C had their own so-called flagship projects, representing the most important activity in each program. The projects under each program collectively and coherently contributed to the major goal of their respective programs.

Partnership is the center of our activities

Most of our activities are carried out together with our partner institutions around the world. Effective partnership makes it possible for us to conduct joint research activities that would be of value for social impact for our target beneficiaries in developing regions. The map (Fig. 2) shows locations of our current activities based on formal institutional contracts such as Memorandums of Understanding. We value such partnerships and place it as our organization's core value. We consulted our partners for their feedback on our research activities, and we made the necessary adjustments in our planned research, accommodating our partners' suggestions and our own reflections. This was needed as a mid-course adjustment for better impact delivery. JIRCAS's operational cycle (Fig. 3) illustrates our focus towards impact-oriented research for development. Consequently, we were able to develop a clear impact pathway for the delivery of our research outputs to the respective target beneficiaries of each project.

Strive for impacts

By introducing the program-based system for output development and delivery, JIRCAS was able to depict more succinctly its mission and target beneficiaries, not only to taxpayers and Japanese citizens but also to people in developing countries. Promotion of more efficient and accountable research will further be feasible. Accordingly, it is important for every researcher, manager, and support staff to work together to produce well-considered outputs that will be deemed suitable, acceptable, and adaptable for users. We will keep striving to take advantage of this new structure with the undying passion of our "research for development" tradition encompassing more than five decades, hoping to produce deliverables that will be used by our target beneficiaries, resulting in significant and positive social impacts.

FY 2020 was unprecedented mainly because of the COVID-19 pandemic. Nevertheless, as you can read in this annual report, we were able to successfully complete our mission by implementing our collaborative projects even without cross-border travels. This was mainly due to the hard work of our counterpart researchers and institutions. We are immensely grateful because even under this most difficult and adverse situation, their collective spirit towards science, technology, and innovation remains unchanged. I have become more and more confident about the usefulness and effectiveness of the method of our collaborative research based on long-term mutual trust.

In order for humankind to provide sufficient

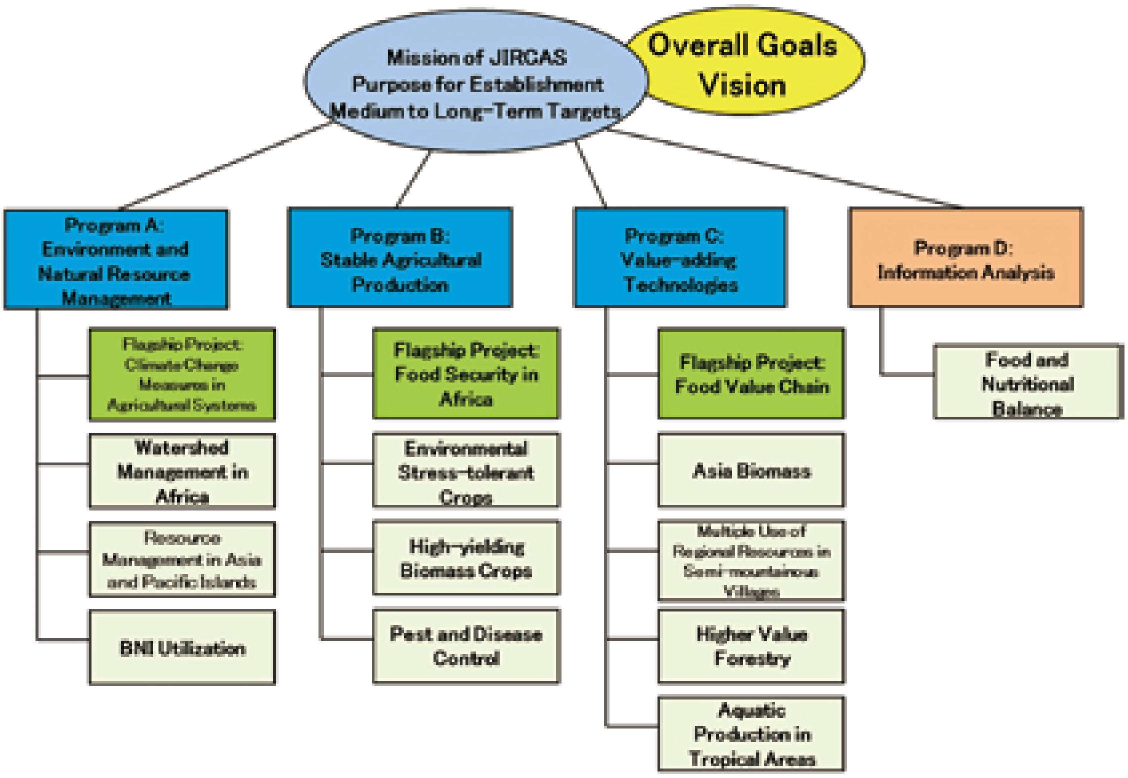

Fig. 1. Program-Project Research Framework (FY 2016-2020)

Collaborative Research Countries and Regions

81 research institutes (30 countries)
149 Memorandums of Understanding (MOUs) and Joint Research Agreements (JRAs)

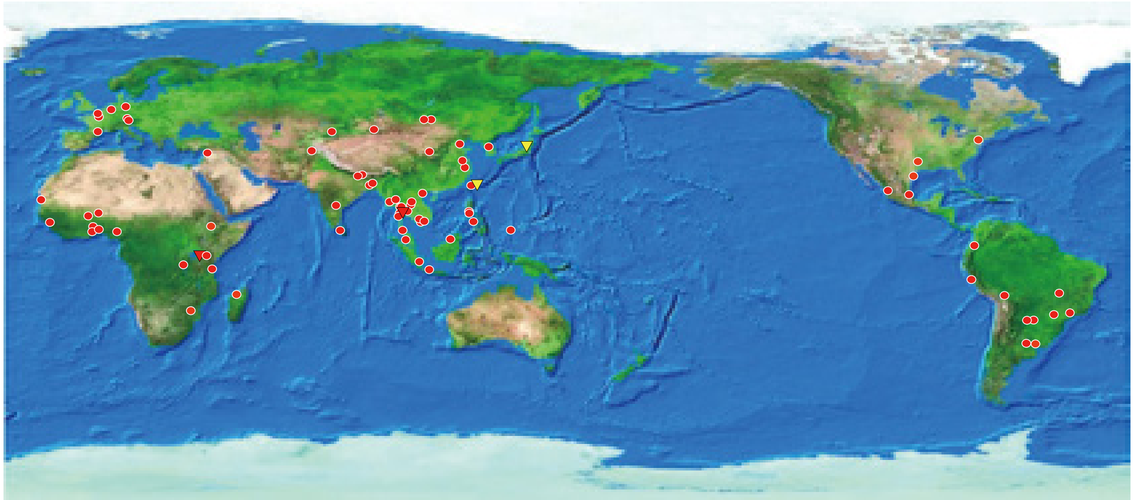

Fig. 2. Locations of our current activities based on 149 MOUs and JRAs with partner institutions

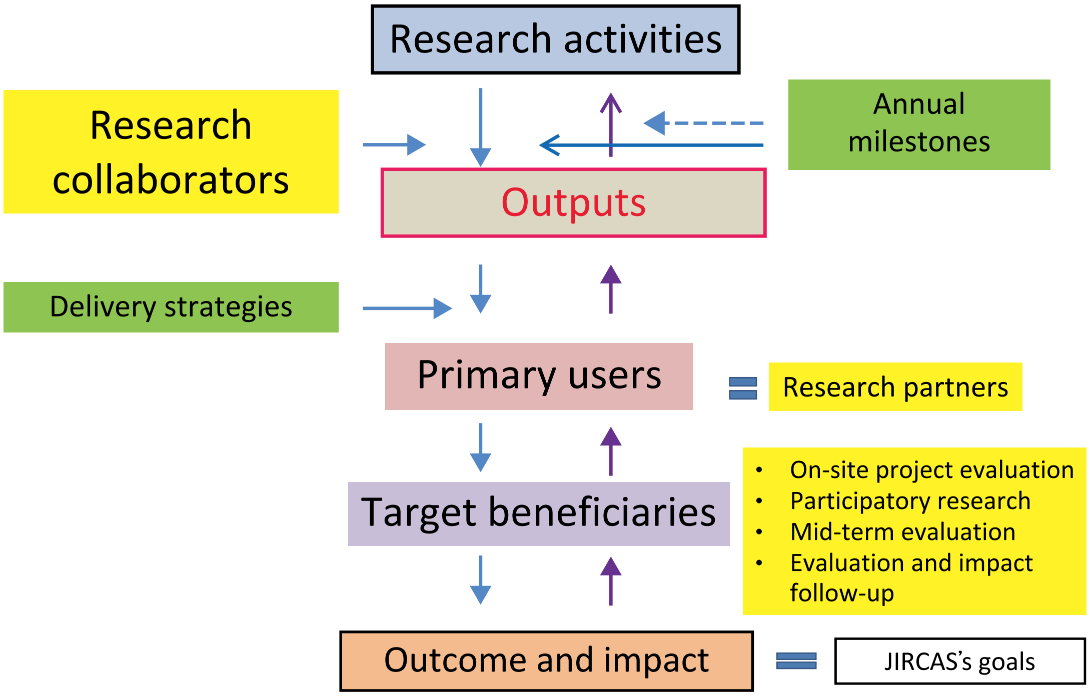

Fig. 3. Impact-oriented research for development (Operational Cycle)

food for ten billion people in 2050 without exceeding the Earth's limits, efforts are required not only to improve productivity and sustainability but also to bring about significant changes in diets and food systems. We need to increase investment in the area of technology development to realize such balanced global food systems. JIRCAS, with a history of 50 years in international collaborative research on a wide range of scientific subjects in the area of agriculture, forestry and fisheries, is in an ideal position to provide interdisciplinary and holistic solutions against those issues containing complex trade-offs and contradictions.

I sincerely hope that the COVID-19 pandemic will soon be controlled and contained and look forward to the time when we can again meet physically and work together on the ground in Africa, Asia, Latin America, and other regions in our collective endeavour to establish sustainable global food systems in the post-COVID-19 era. We also welcome your frank advice and questions relating to this report. Finally, I would like to express my deepest gratitude and appreciation to the former president, Dr. Masa Iwanaga, who had dedicated himself to the mission of JIRCAS for ten years and left at the end of March 2021. It is because of his hard work, leadership, and guidance that we were able to fulfill our goals as contained in this report.

October 2021

Osamu Koyama, President

Highlights from 2020

JIRCAS 50th Anniversary International Symposium 2020

The JIRCAS 50th Anniversary International Symposium 2020 featuring the theme, "The role of international collaboration in agricultural research to address challenges in the post-COVID-19 global food system," was successfully held online on November 10, 2020.

JIRCAS President Masa Iwanaga opened the symposium by referring to the globalization trends over the past 50 years, which he said was responsible for turning the global food system into channels of transmission, exposing the global community to the impacts of climate change and pandemics, which in turn exacerbated poverty and inequality. He also stated that global issues such as the impacts of climate change and nutritional challenges have presented location-specific features, prompting him to pledge that JIRCAS would remain committed to its engagement in joint on-site research activities with partners in the post-COVID-19 era. He concluded his opening remarks with a call for international collaborations to "build back better" for a resilient, equitable, and sustainable future.

Domestic and international partners and counterparts contributed to the symposium through video messages commemorating JIRCAS's 50th Anniversary and expressing their wishes to further strengthen collaboration with JIRCAS to jointly solve the challenges in implementing global agendas. The distinguished well-wishers included Mr. Yoshihisa Hishinuma, Director General, Secretariat of AFFRC, MAFF; Dr. Kundhavi Kadiresan, Managing Director of CGIAR; Dr. Atsuro Matsuda, Vice-President of the National Agriculture and Food Research Organization (NARO); Dr. Sun Tan, Vice President of the Chinese Academy of Agricultural Sciences (CAAS); Mr. Pichet Wiriyapaha, Director General of the Department of Agriculture (DOA), Thailand; Dr. Mamoudou Traoré (on behalf of Director General H. Traoré) of the Institute for the Environment and Agricultural Research (INERA), Burkina Faso; Prof. Dr. Lala Razafinjara, Director General of Madagascar Centre National de la Recherche Appliquée au Développement Rural (FOFIFA); and Mr. Kenyi Nakamura, President of Directive Committee, Fundación Nikkei-CETAPAR, Paraguay.

Three keynote speeches were delivered at the symposium. First, JIRCAS Vice-President Osamu Koyama reflected on JIRCAS's half-century history of endeavors in developing countries to develop agriculture, forestry and fisheries technologies with local partners in response to the shifting priorities of research agendas over the decades. He expressed JIRCAS's continued commitment to international collaboration to contribute to achieving global food and nutrition security and the SDGs. Next, Dr. Josef Schmidhuber of the United Nations Food and Agriculture Organization (FAO) presented his analysis with latest data on the trends and the current status of international trade to illustrate the channels of transmission of COVID-19. His multi-perspective diagnosis highlighted the rather surprising resilience of the food trade in response to COVID-19 shocks in comparison to other crises in recent history on the one hand, and on the other, revealed the exposure and vulnerability of food-importing countries whose economies depend heavily on revenues from energy exports, tourism, and remittances. Lastly, Dr. Miyuki Iiyama, Director of the Research Strategy Office of JIRCAS, elaborated the structural challenges of today's global food system. She emphasized the critical importance of research on sustainable agricultural intensification, especially targeting the smallholder agricultural sector in the developing countries, and called for interdisciplinary science, public-private cooperation, as well as collaboration between research and development institutions.

The Panel Session, titled "The modus-operandi of international collaboration," was chaired by Dr. Masayoshi Saito, JIRCAS Director, Research Planning and Partnership Division, and joined by distinguished panelists including Dr. Iwanaga, JIRCAS President; Mr. Tadashi Sato, Vice President of Japan International Cooperation Agency (JICA); Dr. Marco Wopereis, Director General of World Vegetable Center, and Dr. Nteranya Sanginga, Director General of the International Institute of Tropical Agriculture (IITA). Mr. Sato shared the summary of a survey implemented by JICA in developing countries to assess the impacts of COVID-19 on the agricultural sector, which revealed deteriorating food and nutrition security due to disruptions in distribution channels. He said that JICA responded by providing seeds, fertilizers, and other essentials to ensure food and nutrition security of the target populations. He also stressed JICA's commitment to help the agricultural sector of developing countries improve resilience through capacity development and investment in infrastructure, and to work with research institutions for larger developmental impacts. Dr. Wopereis, meanwhile, acknowledged the dominant presence of private players in the vegetable sector, especially in seed production.

He also emphasized the critical role of public investment and research to address locally specific needs in order to achieve healthy diets through vegetable production and consumption, and appealed for strengthening the alliance among WorldVeg, CGIAR, and international and national agricultural research institutions. Dr. Sanginga, for his part, shared his concern over the dilemma and challenges facing African agriculture – the aging of its farming population, the unemployment among the youth with college degrees, all while the food import bill has been rising; in other words, "the exportation of jobs" to Asian rice-exporting countries. Based on his experiences of interacting with a Japanese yam-processing firm, he stressed the urgency of private sector involvement and business-led agriculture transformation for inclusive growth. Lastly, Dr. Iwanaga, reflecting on the challenges of the current global food system with the triple burden of malnutrition while overstepping the planetary boundaries, proposed a shift of research priorities from internationally traded crops to locally important crops that have been nutritionally and economically valued, yet whose research has been relatively neglected. He then emphasized the importance of communicating the contribution of agricultural research to build a sustainable future to encourage investment and promote collective actions.

JIRCAS Vice-President Koyama in his closing address reiterated JIRCAS's mission to contribute to solving global food and environmental issues since its establishment 50 years ago and pledged to continue international collaborations to achieve the SDGs. He concluded the symposium by expressing his gratitude to all the participants as well as long-term research and development partners and his wishes to physically meet one another in Asia, Africa, Latin America or elsewhere, as soon as the COVID-19 pandemic is contained or controlled.

JIRCAS 50th Anniversary International Symposium 2020

2020 Japan International Award for Young Agricultural Researchers

JIRCAS, in cooperation with the Agriculture, Forestry and Fisheries Research Council (AFFRC) Secretariat, announced the winners of the 2020 (the 14th) Japan International Award for Young Agricultural Researchers (Japan Award) on November 13. The Japan Award is given annually by the Chairman of the AFFRC of the Ministry of Agriculture, Forestry and Fisheries (MAFF) to recognize and honor young foreign researchers (under 40 years old) whose outstanding achievements promote research and development of agricultural, forestry, fishery and other related industries in developing regions. The commendation ceremony — originally planned to be held in November 2020 — has been rescheduled in light of the global COVID-19 situation and will be held in conjunction with the 2021 (the 15th) Japan Award.

The 2020 Japan Award winners and their research achievements:

Dr. Saraswathipura Lakshmaiah KRISHNAMURTHY (India)

ICAR-Central Soil Salinity Research Institute
[Development of salt-tolerant rice varieties through conventional and molecular breeding approaches]

Outline of Research Achievement

In India, around 6.73 million hectares (Mha) of lands are salt-affected, of which 3.77 and 2.96 Mha are sodic and saline, respectively. The productivity of rice under salt stress is very low, and it depends on the level and duration of salt stress. Rice occupies approximately 40.5% of the area in salt-affected soils, and the estimated production loss is about 22% in India. Krishnamurthy and his colleagues developed five salt-tolerant rice varieties (CSR46, CSR49, CSR52, CSR56, and CSR60) in different segments and three genetic stocks (CSR47, CSR51, and CSR53) for salt tolerance. He also produced and sold 754 quintals of breeder seeds and 1,224 quintals of truthfully labelled seeds of salt-tolerant rice varieties to seed-producing agencies and farmers. These rice varieties cover 1.6 Mha of salt-affected land annually in India. Salt-tolerant varieties have been adopted by land reclamation corporations, benefiting about 430,000 farmers. With the introduction of these salt-tolerant varieties, about 0.6 million tons of gypsum were saved, which would have cost about Rs.18M (around USD 250,000). Furthermore, he identified potential and novel donors for seedling and reproductive stage salt tolerance, which are being used in breeding programmes to develop new lines. He also identified novel quantitative trait loci (QTLs) for salinity and sodicity tolerance at reproductive stage using different bi-parental, multiparent advanced generation intercross (MAGIC), and association mapping populations. He successfully introgressed Saltol QTL into mega rice varieties, namely, Pusa44, PR114, and Sarjoo52, and he also focused on the introgression of spikelet fertility QTLs into Pusa44, PR114, and Sarjoo52 through marker-assisted backcross breeding (MABB). These salt-tolerant rice varieties have the potential to spread across salt-affected ecologies and could improve productivity, farm income, and livelihood security of resource-poor farmers in developing countries.

Dr. Kwanrawee SIRIKANCHANA
(Kingdom of Thailand)

Chulabhorn Research Institute
[Novel microbial tools to distinguish fecal pollution sources from livestock for effective agricultural watershed management]

Outline of Research Achievement

Fecal contamination in freshwater has become a problem of increasing concern, particularly in agricultural watersheds where wastewater and surface runoff from livestock farming contribute to water pollution. Accurate wastewater source identification is crucial for effective agricultural watershed management and precise health risk assessment from pathogenic microbial contamination.

This research aimed to pinpoint fecal pollution sources from livestock farming (swine and cattle) and dense residential communities along the 325-km Tha Chin River located in Central Thailand. Microbial markers were developed and validated to specifically track contamination from swine and cattle origins using DNA of the bacterial order *Bacteroidales*, and from human communities using both the DNA of bacteriophage crAssphage and a culturable bacteriophage of *Enterococcus faecalis*. These microbial tools also revealed spatial and temporal patterns of contamination from different sources.

Dr. Edmore GASURA (Zimbabwe)

University of Zimbabwe
[Strengthening quality protein maize resilience and utilization as nutritious food and feed in rural areas of Zimbabwe]

Outline of Research Achievement

Maize is deficient in two essential amino acids, namely lysine and tryptophan, and thus most children in Zimbabwe suffer from protein energy malnutrition since poor families cannot afford alternative protein sources. Poor soil fertility problems coupled with frequent droughts are highly associated with the widespread occurrence of *Striga asiatica*, a parasitic weed that causes up to 100% yield loss. Together with rural farmers, Prof. Edmore Gasura and colleagues developed three high-yielding, drought-tolerant quality protein maize (QPM) varieties resistant to *Striga asiatica*. This maize yields ≥4 t/ha under heavy infestation by *Striga asiatica* and ≥10 t/ha under optimum conditions. This QPM is also rich in lysine and tryptophan, the essential amino acids frequently lacking in cereal diets. The team motivated >500 rural farmers after demonstrating the superiority of QPM by feeding it to their indigenous chickens. Indigenous chickens fed on QPM alone grew at the same rate as those fed on commercial feed and showed improved meat quality. The maize straw was used to grow oyster mushrooms as additional income and protein source for farmers. We established partnerships with the private sector (Mukushi Seeds), development agencies (Welt Hunger Hilfe and RUFORUM), and policy makers. We also trained >500 farmers through field days, trained three master's and six undergraduate students, produced six research articles, participated in three international conferences, and appeared in one newsletter article by the American Society of Agronomy.

NEW RESEARCH COLLABORATION

JIRCAS promotes its research network with international as well as national agricultural research institutions, extension systems, and universities, and the private sector, through information and personnel exchange programs. MOUs have been signed between JIRCAS and its research partners abroad to implement long-term research collaborations. In fiscal year 2020, JIRCAS signed new MOUs with the Malaysian Agricultural Research and Development Institute (MARDI) and the Food and Fertilizer Technology Center for the Asian and Pacific Region (FFTC), bringing the total number of active MOUs to 149 as of March 2021. Based on the work plans elaborated in the respective MOUs, JIRCAS carried out joint research projects with 81 research institutions in 30 developing countries and implemented commissioned research activities with 4 research institutions in 4 countries. JIRCAS also promotes collaboration with international organizations, including CGIAR, in order to contribute to solving global challenges. JIRCAS continued hosting one visiting scientist from AfricaRice.

The fiscal year 2020 indeed revealed the resilience of JIRCAS's mode of operation, which has been honed through 50 years of experience, enabling it to implement international agricultural research during the crises. Since the declaration of COVID-19 as a pandemic, overseas business trips have been difficult for those involved in international cooperation activities. JIRCAS, whose mission is to develop agriculture, forestry, and fisheries technologies through international joint research with Asian, African, and Latin American countries to solve global issues, is no exception. JIRCAS has been exploring an international cooperation system 'with-corona,' based on the trust developed through many years of cooperation, such as by outsourcing experiments and data collection to local partners and by working closely with them through online meetings.

Nonetheless, the greatest strength of JIRCAS based on 50 years of experience lies in its approach to joint research with partners in the field, and we plan to maintain this field-oriented approach even in the post-COVID-19 era. We hope that the COVID-19 pandemic will end as soon as possible, and we look forward to continue working with local partners in Africa, Asia, and Latin America.

TROPICAL AGRICULTURE RESEARCH FRONT

The Tropical Agriculture Research Front (TARF), the sole substation of JIRCAS, is located in Ishigaki, Okinawa, at the southwestern edge of Ryukyu archipelago, Japan. TARF is very far from Tokyo (2,000 km) and is closer to Taiwan (280 km to the west) than to Okinawa main island (410 km to the northeast). The climate is subtropical, with an average temperature of 24.3°C and annual rainfall of 2,107 mm. TARF's facilities include 21 hectares of experimental fields, several types of greenhouses, and lysimeters. With its geographical advantages and facilities, TARF implements basic and fundamental researches and creates improved agricultural technologies that can be adopted by developing countries in the tropics/subtropics and island environments where such researches are difficult to conduct.

Research and development of agricultural production technologies

The following research activities were implemented at TARF through FY 2020: (1) reduction of nitrogen loads to groundwater, (2) creation of a potential map for agricultural development, (3) breeding of biomass crops like sugarcane, (4) improvement of Indica group rice cultivars, and (5) introduction of useful traits into rice by biotechnology.

To develop a fertilizer application technique that reduces nitrogen (N) load to groundwater while maintaining sugarcane yield, we carried out a sugarcane cultivation experiment and monitored N leaching using a drainage lysimeter (Photo 1). We found that if the amount of N applied under the current fertilizer application rate is reduced by 15% (equivalent to 35 kg ha^{-1}), N leaching from fertilizer could be reduced by about 50% (12 kg ha^{-1}) while maintaining the same level of sugarcane yield. The results of this study will provide basic data for the revision of the standard fertilization (amount of fertilizer applied) for sugarcane cultivation in Okinawa Prefecture, as well as information for the analysis of N balance and dynamics in the groundwater basin.

The results of several experiments conducted in the island-nation of Palau in western Pacific Ocean clarified that modified conservation agriculture (combined with spot excavation by gas-powered apparatus and organic mulch) increases taro (*Colocasia esculenta*) yield and mitigates soil erosion. Based on the soil properties, topography, and land use, we created a potential map for agricultural development, classifying areas into six categories. These achievements were summarized and co-published with Palau Community College under the title "Agriculture in Palau -A manual for production through soil assessment-."

To improve sugarcane productivity and adaptability to adverse environments, we focused on the utilization of sugarcane-related wild germplasm such as *Erianthus* because of its high biomass productivity and superior root system. In collaboration with Thai researchers, we tried to develop breeding technologies (crossing, phenotyping, genotyping) that would enable us to introduce desirable characteristics of *Erianthus* into sugarcane. We have developed intergeneric F_1 hybrids between sugarcane and *Erianthus* and their backcrossing populations (BC_1, BC_2, BC_3). We are currently evaluating their agronomic traits such as dry matter and sugar content, root characteristics, and cytogenetic characteristics to develop new breeding materials.

Indica Group rice germplasm and breeding materials and their genetic information were introduced, evaluated, and shared between collaborative countries to achieve genetic improvement and broaden its applications. We conducted genetic improvement experiments on leading rice cultivars of developing countries facing agricultural problems such as blast disease, salinity, phosphorus deficiency, low-fertility soil, and so on. We also focused on the shoot and root architectures (including traits such as culm length, number of tillers, and size of panicle) and the root types. Breeding materials for blast resistance developed at JIRCAS were shared with the Philippines, Bangladesh, Vietnam, Indonesia, Laos, and Africa Rice Center.

The transgenic and genome editing approaches are relatively new plant breeding technologies. We have been using these technologies to introduce useful traits into rice. We have recently demonstrated that transgenic upland rice varieties expressing a gene encoding CCCH-tandem zinc finger protein isolated from rice had higher grain yields than original non-transgenic varieties under drought conditions in field environments. Regarding genome editing, JIRCAS has succeeded in establishing a system for genome editing that is applicable to local rice cultivars in Madagascar and Laos. We are currently working on generating genome-edited rice that can maintain grain yield under nutrient-deficient conditions or can accumulate functional components promoting human health.

Contribution to domestic agriculture

TARF contributes to domestic agriculture through the following activities:

1) Generation advancement

An early generation rice population consisting of 140 accessions from NARO (National Agriculture and Food Research Organization) breeding stations all over Japan were grown two times.

2) Conservation of genetic resources

As a sub-bank for tropical and subtropical crops, the NARO Genebank maintained 534 accessions of sugarcane and its relatives; 62 of *Erianthus*; 150 of tropical fruit trees; and 125 of pineapple, vegetatively in the field or in a greenhouse.

3) Development of varieties for Nansei Islands

Passionfruit breeding at TARF started in 2008, culminating in the variety registration of 'Sunny Shine' on February 12, 2019. Subsequent to variety registration and for effective dissemination of this variety, techniques for obtaining virus-free seedlings for propagation have been developed. In addition, heat-tolerant passionfruit cultivars are being eyed for future development. The application for registration of the *Urochloa* (syn. *Brachiaria*, forage grass) candidate variety 'Isan' has been made and is currently under examination in Japan.

There is an on-going collaboration with a brewer of local distilled spirits (called "Awamori") in Ishigaki Island to test the cultivar's performance and evaluate other possibilities for domestic use in Okinawa of the Indica Group breeding materials developed under international collaborative research with the International Rice Research Institute (IRRI). In relation to this, an application has been submitted for the Indica Group rice "Kachibai" for release as a new variety for brewing "Awamori."

TARF-JIRCAS has contributed to the domestic sugarcane breeding network by taking advantage of the optimum environmental conditions for sugarcane crossing in Ishigaki Island. Approximately 200 crosses (about 300 panicles) were made and provided to the domestic sugarcane breeding programs of NARO and OPARC (Okinawa Prefectural Agricultural Research Center). In addition, promising clones were selected from the BC_3 populations of intergeneric hybrids between sugarcane and *Erianthus* and evaluation has begun in the variety selection trials in Okinawa.

4) Development of a low-cost, high-performance plant factory for tropical and subtropical regions

Integrated research focusing on a plant factory is being conducted at TARF, supported by grants from the NARO Bio-oriented Technology Research Advancement Institution (via R&D matching funds under the Field for Knowledge Integration and Innovation [FKII] platform). The project is a cross-sectoral collaboration among private companies, universities, and NARO to develop cultivation systems that are adapted to tropical/subtropical regions. We have achieved an annual yield of 40 tons of tomatoes and 4 tons of strawberries per 10 ares (1 are=100 sq. m.). We invited all concerned parties and held a briefing session to publicize our final results at Ishigaki Island in March 2021 (Photo 2).

Photo 1. Drainage lysimeters at the Tropical Agricultural Research Front (JIRCAS-TARF)

Photo 2. Asian Monsoon Achievement Report Meeting, JIRCAS-TARF, March 2021

Researcher Hoshikawa receives "Technology Award" from the Japanese Society for Plant Biotechnology

The Japanese Society for Plant Biotechnology (formerly Japanese Society for Plant Cell and Molecular Biology) presented the 2020 Technology Award to JIRCAS Researcher Ken Hoshikawa (Biological Resources and Post-harvest Division), Professor Kenji Miura (University of Tsukuba), and Professor Hiroshi Ezura (Tsukuba-Plant Innovation Research Center, University of Tsukuba).

The Technology Award was given in recognition of their achievement in developing a high-level expression system for recombinant proteins in plant cells using the "Tsukuba System" technology. This system can achieve the world's top class yield (4 mg/g fresh weight) in tobacco (*Nicotiana benthamiana*) comparable to a heterologous protein expression system such as *E. coli*. The system is applicable for expression of transient proteins not only in tobacco but also in various plant groups such as Solanaceae, Cucurbitaceae, Leguminosae, and Brassicaceae.

The award was scheduled to be given at the 38th Annual Meeting of the Japanese Society for Plant Biotechnology in Tsukuba, but was reported instead in the JSPB website due to the postponement of the meeting.

Japanese Society for Plant Biotechnology 2020 Vol.37 No.2 Technology in Tissue Culture
Toward Horizon of Plant Biotechnology
Tsukuba-Plant Innovation Research Center
Kitajima et al. (2020) Plant Biotechnol 37: 89-92
Hoshikawa et al. (2019) Plant Cell Rep 38:75-84
Nishida et al. (2016) Science 353:aaf8729
Shimatani et al. (2017) Nat Biotechnol 35: 441-443
Suzaki et al. (2019) Plant Biotechnol 36:119-123
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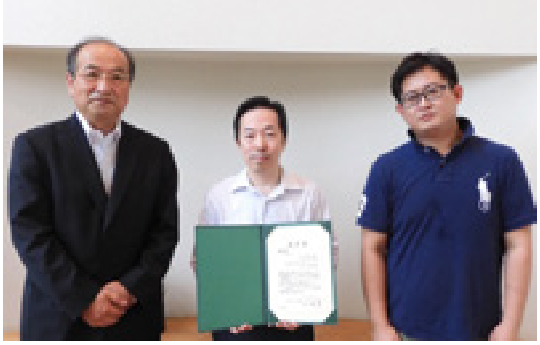
三浦謙治、星川健、江面浩　(2018) バイオサイエンスとインダストリー 76:382-385
三浦謙治、星川健、江面浩 特願2017-107965



From left: Prof. Ezura, Prof. Miura, and Dr. Hoshikawa

Dr. Hoshikawa holding the award certificate

Researcher Maeno receives the "2020 Chinguitt Prize for Science and Technology" from the Islamic Republic of Mauritania

JIRCAS Researcher Kotaro Maeno (Crop, Livestock and Environment Division) received the "2020 Chinguitt Prize for Science and Technology" from the Islamic Republic of Mauritania.

The Chinguitt Prize is awarded annually by the Mauritanian government to recognize Mauritanian and foreign researchers with outstanding contribution to the promotion and advancement of culture, art, and science. It is one of the most prestigious awards in Mauritania, with the president also involved in the selection process. The name "Chinguetti" has prospered as the seventh sanctuary of Islam since the 11th century and represents Mauritania as a designated UNESCO World Heritage Site.

Dr. Maeno has been working on the development of control technologies for desert locust outbreaks in Africa for nine years and has been based in Mauritania where he is pursuing the scientific challenge of solving the desert locust problem. At the recommendation of Mr. Mohamed Abdellahi Ould Babah Ebbe, the former director of the Mauritanian Anti-Locust Center, Dr. Maeno received this award for his research on the spatiotemporal distribution of desert locust in Mauritania to improve preventive

Dr. Maeno's 2020 Chinguitt Prize certificate management. He was also recognized for introducing the culture of Mauritania to Japan through publication of books and by contributing to the friendly relationship between the two countries.

About the Chinguitt Prize: http://www.prixchinguitt.mr

The Chinguitt Prize medal

Senior Researcher Tsujimoto receives the "Young Agriculture, Forestry and Fisheries Researcher Award" from MAFF, Japan

JIRCAS Senior Researcher Yasuhiro Tsujimoto (Crop, Livestock and Environment Division) received the 16th Young Agriculture, Forestry and Fisheries Researcher Award from the Ministry of Agriculture, Forestry and Fisheries (MAFF) for his achievement in the development of an efficient rice production technology in a nutrient-deficient environment in Africa. This award is a commendation given by the Agriculture, Forestry and Fisheries Technology Council Chairman to young researchers with outstanding research achievements in agriculture, forestry, fisheries and related industries, and are highly expected to make further contributions in the future. It is aimed at increasing motivation among young researchers engaged in research and development.

Dr. Tsujimoto has been pursuing research to improve crop productivity in Africa through continuous observations and experiments at production sites. Some of his research achievements include the application of sulfur to unused land of the river floodplains to increase yield in areas without irrigation facilities and the phosphorus-dipping treatment of rice seedlings that has led to increased yield and avoidance of environmental stress. These achievements were highly evaluated as contributing to the realization of sustainable agriculture and the solution of food problems in Africa, where the investment of resources such as fertilizer and irrigation water is limited.

The awardees were announced at the Agribusiness Creation Fair, which was held online on November 11-13, 2020.

Press release (in Japanese) at https://www.affrc.maff.go.jp/docs/press/201112_21.html

Dr. Tsujimoto working on rice cultivation experiments in the flooded lowlands of Ghana

Assessing rice growth in a farm field in Madagascar

Researcher Nishigaki receives the "Best Presentation Award for Cross-Fertilization" at the Science Academy of Tsukuba (SAT) Technology Showcase 2021

Dr. Tomohiro Nishigaki, a researcher in the Crop, Livestock and Environment Division, received the "Best Presentation Award for Cross-Fertilization" at the Science Academy of Tsukuba (SAT) Technology Showcase 2021 held online on February 19, 2021, for his research titled "Development of a rapid soil fertility assessment technique for improving rice production in Madagascar." He was awarded a certificate of recognition on March 15, 2021.

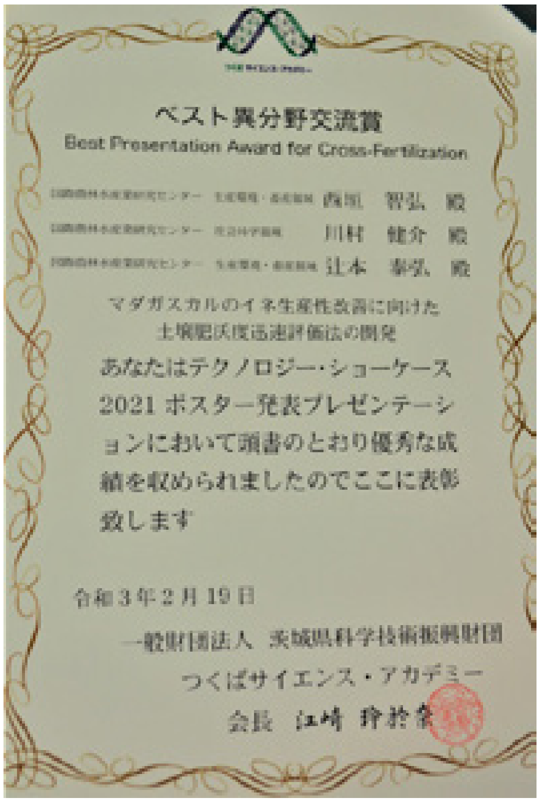
The SAT Technology Showcase is an interdisciplinary exchange meeting where researchers in the Tokyo metropolitan area, including Tsukuba, interact and inspire across disciplines and organizations, and share the latest research results, ideas, and technologies with one another. Eighty-five research results were presented by universities, companies, and public research institutes and among them, the research of Dr. Nishigaki received the award in recognition of his innovative idea of fusing optical spectrum analysis technology and soil fertility evaluation.

In addition to Dr. Nishigaki, the following young researchers from JIRCAS also presented their research at the SAT Technology Showcase 2021.

- Dr. Toru Sakai (Social Sciences Division): Development of forest management technology in the highlands of Ethiopia
- Dr. Shimpei Aikawa (Biological Resources and Post-harvest Division): Suppressing the generation of greenhouse gases caused by tropical agriculture by purifying water with useful algae

This is the 20th time the event has been held and the first time to be held online but with various ideas from the organizer, live streaming of the one-minute presentation (indexing), poster presentation using a virtual conference tool, and exchange of opinions were successfully held. This event is expected to accelerate science and technology innovation, with new knowledge and enhancement of interaction across different disciplines.

Dr. Nishigaki with his award certificate from the SAT Technology Showcase 2021


ベスト異分野交流賞
Best Presentation Award for Cross-Fertilization
西垣 智弘 殿
川村 健介 殿
辻本 泰弘 殿
マダガスカルのイネ生産性改善に向けた
土壌肥沃度迅速評価法の開発
あなたはテクノロジー・ショーケース
2021 ポスター発表プレゼンテーシ
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令和3年2月19日
一般財団法人 茨城県科学技術振興財団
つくばサイエンス・アカデミー
会長 江崎 玲於奈

Senior Researcher Wilder receives the "Japanese Society of Fisheries Science Award for 2021"

Dr. Marcy N. Wilder, a senior researcher in the Fisheries Division, received the Japanese Society of Fisheries Science Award for 2021 in recognition of her outstanding achievements relating to biochemical/physiological research on the mechanisms of reproduction, molting, and osmoregulation in commercially-important shrimp species and the development of new aquaculture technologies.

This award is given to researchers who have made outstanding achievements in academic research and have contributed to the development of Fisheries Science. The award was presented on March 28, 2021.

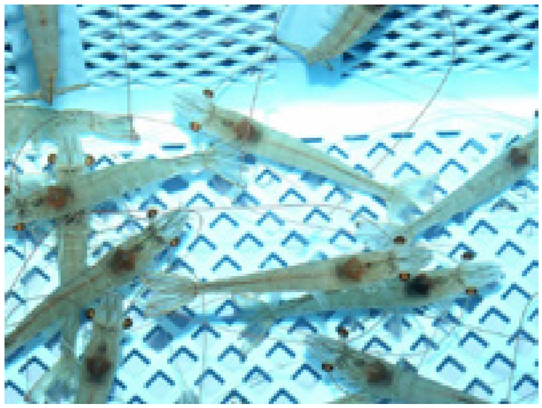
In order to stabilize the shrimp aquaculture industry, Dr. Wilder has conducted physiological and biochemical research on shrimp and applied research on the development of aquaculture technology for more than 30 years, leading to the practical application of knowledge gained from basic studies to the improvement of the aquaculture industry.

In recent years, shrimp farming has become a major industry worldwide, but there are many factors that impede its sustainability. To address these issues, Dr. Wilder has so far succeeded in (1) elucidating the reproductive mechanisms of shrimp and developing technology for controlling the maturation of female parent shrimp, (2) clarifying the osmoregulatory mechanisms of freshwater prawn species and developing shrimp production technology in Vietnam, and (3) developing an innovative closed, land-based aquaculture system known as the Indoor Shrimp Production System (ISPS) for the whiteleg shrimp, *Litopenaeus vannamei*.

In particular, Dr. Wilder was instrumental in establishing an industry-academia-government research consortium with the private sector in order to develop the above ISPS technology. This technology enables the production of whiteleg shrimp under conditions almost similar to freshwater, thus making it possible to both reduce production costs and simplify the work-flow process. Using the results of this collaborative research, this consortium has succeeded in establishing Japan's first commercial land-based shrimp production facility, now currently operating in Myoko City, Niigata Prefecture.

The award was presented in appreciation of Dr. Wilder's achievements in developing and transferring a useful new aquaculture technology, which have received much recognition in terms of international research and social contributions.

Dr. Marcy Wilder, recipient of the Japanese Society of Fisheries Science Award for 2021



Whiteleg shrimp (*Litopenaeus vannamei*)

Research Overview

Overview of JIRCAS's Research Structure

1. History

The Japan International Research Center for Agricultural Sciences (JIRCAS) was first established in 1970 as the Tropical Agriculture Research Center (TARC), one of the research institutes of the Ministry of Agriculture and Forestry of Japan. TARC was reorganized into JIRCAS in 1993.

On April 1, 2001, JIRCAS became an Incorporated Administrative Agency (IAA) under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries (MAFF), in accordance with the administrative reforms of the Government of Japan to facilitate the reorganization of national government-affiliated research organizations.

2. Mission

Through research and development (R&D) and dissemination of information related to agriculture, forestry and fisheries in developing regions, JIRCAS contributes to the improvement of the international presence of Japan and towards a secure and stable supply of food worldwide including Japan.

3. The IAA System

An IAA is an organization responsible for key public services that the government is not required to provide, but which the private sector is likely to neglect for various reasons. The IAA system was introduced in 2001, as part of central government reforms based on the scheme that the planning sectors and the implementing sectors should be separated. Under the IAA system, MAFF defined JIRCAS's Fourth Medium to Long-Term Goals in FY 2016, including the maximization of R&D outcomes, the enhancement of research efficiency, and the improvement of financial performance. Based on the Fourth Medium to Long-Term Goals, JIRCAS drafted and began to implement a detailed five-year plan, the Fourth Medium to Long-Term Plan (FY 2016 - FY 2020).

4. Evaluation

The performance and budgeting management of research activities conducted by JIRCAS undergo regular evaluation by the National Research and Development Agency Council established within MAFF. As for the activities of each fiscal year, the Council investigates and analyzes the progress towards achieving the Medium to Long-Term Plan, and the results of this evaluation shall be applied as deemed necessary to the modifications of the operational and financing systems for subsequent fiscal years. To meet the requirements of the general guideline concerning the evaluation of national research and development (a decision of the Prime Minister in 2016) which requires efficient evaluation, JIRCAS carried out the in-house evaluation in FY 2020 as follows:

1) Research activities were evaluated, and summary reports were prepared in each Research Program.
2) These reports were then collectively evaluated at the meeting for the evaluation of research programs of the Medium to Long-Term Plan by external reviewers (government officials from the Ministry of Agriculture, Forestry and Fisheries and specialists from other research institutes) and internal reviewers (the President, the Vice-President, the Auditor, the Program Directors and the Directors of each research division) in February 2021.
3) Comprehensive evaluation of all JIRCAS activities, which also include administrative operations, was performed by external reviewers of the JIRCAS External Evaluation Committee in March 2021.

The external reviewers are listed in the Appendix. The results of the in-house evaluation and a summary of all activities were submitted to MAFF in June 2021.

5. Medium to Long-Term Plan

JIRCAS implements four programs for research activities under the Medium to Long-Term Plan. Each program consists of several projects. Major accomplishments and research highlights of the programs in FY 2020 are described in the following sections. The contents of the Medium to Long-Term Plan are also described in the Appendix.

Table 1. Number of Projects in the Fourth Medium to Long-Term Plan (FY 2016 - FY 2020)

Program	Projects
A (Environment and Natural Resource Management)	4
B (Stable Agricultural Production)	4
C (Value-adding Technologies)	5
D (Information Analysis)	1

Fourth Medium to Long-Term Plan (FY 2016 - FY 2020)

■ Program A

Development of agricultural technologies for sustainable management of the environment and natural resources in developing regions

Projects:

1. Development of agricultural technologies for reducing greenhouse gas emissions and climate-related risks in developing countries
2. Development of intensive watershed management models for soil erosion-prone areas in Sub-Saharan Africa
3. Development of sustainable resource management systems in the water-vulnerable areas of Asia and the Pacific Islands
4. Development of ecologically sustainable agricultural systems through practical use of the biological nitrification inhibition (BNI) function

■ Program B

Technology development for stable production of agricultural products in the tropics and other adverse environments

Projects:

1. Development of sustainable technologies to increase agricultural productivity and improve food security in Africa
2. Development of breeding materials and basic breeding technologies for highly productive crops adaptable to adverse environments
3. Development of technologies for the breeding and utilization of promising high-yielding biomass crops in unstable environments
4. Development of technologies for the control of migratory plant pests and transboundary diseases

■ Program C

Development of high value-adding technologies and utilization of local resources in developing regions

Projects:

1. Formation of food value chain through value addition of food resources to support sustainable rural development
2. Development of saccharification and utilization technology for lignocellulosic biomass resources in Southeast Asia
3. Multiple use and value addition of regional resources for improvement of sustainable productivity in semi-mountainous villages in Indochina
4. Development of silvicultural and forest management techniques for indigenous tree species in Southeast Asia to achieve higher value production
5. Development of technologies for sustainable aquatic production in harmony with tropical ecosystems

■ Program D

Collection, analysis and dissemination of information for grasping trends of international agriculture, forestry and fisheries

Project:

1. Evaluation of global food supply-demand and nutritional balance

6. Collaborative Research

JIRCAS is required to cover a wide range of research fields. Human resources at JIRCAS, however, are limited. This makes collaborative research with other institutes or universities necessary towards achieving JIRCAS's project objectives. Whenever JIRCAS and its collaborators reach an agreement on the commencement of collaborative research after exchanging ideas and opinions, a Memorandum of Understanding (MOU) or a Joint Research Agreement (JRA) is usually concluded. JIRCAS developed the concept of JRAs in 2006. A JRA is a contract for collaborative research with a particular research subject and with a fixed term. A total of 149 MOUs and JRAs remained in force at the end of FY 2020.

In 2004, JIRCAS was given a Certificate of Recognition by CGIAR as a key partner and as the CGIAR focal point institution in Japan. JIRCAS has been playing an important role in promoting mutual understanding and collaboration between CGIAR and the Japanese government. It has also been intensively implementing collaborative research with several CGIAR research centers.

JIRCAS has been regularly dispatching researchers and research managers to promote research in the developing regions. Likewise, we have been dispatching researchers from other institutes and universities to promote the effective implementation of JIRCAS's projects with the cooperation of such organizations. JIRCAS has also implemented several invitation programs for overseas researchers and administrators at counterpart organizations. These programs facilitate not only the promotion of international collaborative research but also related exchanges of information and opinions.

7. Organization of JIRCAS

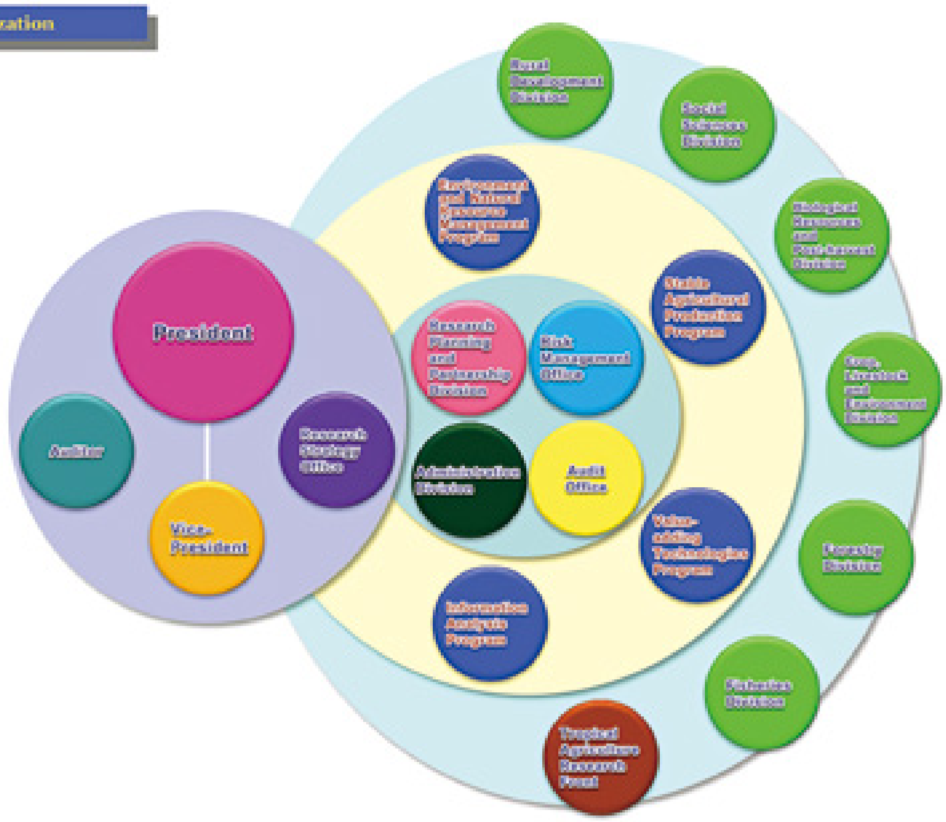
The organizational structure of JIRCAS for the Fourth Medium to Long-Term Plan period is summarized in the figure below.

Four Program Directors are responsible for the implementation of individual programs during the Fourth Medium to Long-Term Plan period.

The directors of divisions, offices, and the Tropical Agriculture Research Front (TARF) are responsible for managing staff and enhancing the capabilities of researchers.

TARF (formerly the Okinawa Subtropical Station), located in Ishigaki Island in the southernmost part of Japan, is JIRCAS's sole substation. It focuses on agricultural, forestry, and fisheries research being carried out in overseas regions with highly similar climatic and geographic conditions as Okinawa, taking full advantage of its subtropical weather and geographic location.

Organization



Main Research Programs

Program A
Environment and Natural Resource Management

"Development of agricultural technologies for sustainable management of the environment and natural resources in developing regions"

The Environment and Natural Resources Management Program aimed at the development of technologies for sustainable management of agricultural resources to cope with global environmental issues, climate change, and land/soil degradation, especially in vulnerable areas of developing regions.

[Climate Change Measures]

We evaluated biogas effluent (anaerobic digestion effluent) potential and found that using livestock biogas effluent as nitrogen fertilizer in a paddy field may increase methane (CH_4) emissions from the flooded soil. In the Mekong Delta, Vietnam, we demonstrated that combining multiple drainage practices reduced CH_4 emissions while obtaining grain yields comparable to conventional practice, which combines synthetic fertilizers and continuous flooding. Using life cycle assessment, the impacts of alternate wetting and drying (AWD) on life cycle greenhouse gas emissions in An Giang Province, Mekong Delta, were evaluated by comparing AWD farmers and non-AWD farmers. The impacts of AWD on profit were also evaluated. Farm-level survey data were collected to determine the effects of combining several agricultural technologies. To promote the dissemination of AWD, information and communication technology (ICT) in paddy fields was introduced in the latter half of fiscal year 2020. Since it was not possible to travel to the project site due to the COVID-19 pandemic, the enormous amount of water level-related field data accumulated during the project implementation period was digitally transformed for analysis. The analysis revealed that field water level at the time of topdressing showed a negative correlation on yield and GHG emissions.

In the field of livestock science, methane emissions from enteric fermentation and manure management in Thailand's typical beef cattle production system were estimated to be 6.87% and 0.69% of the total energy in the feed, respectively.

Concerning carbon sequestration in the soil, our long-term, 10-year (2011-2020) field experiment in Thailand showed that soil organic carbon (SOC) storage was higher with rice straw mulch and cattle manure application but lower with char application compared with no organic matter application. No-tillage cultivation increased SOC storage with cattle manure and char application but decreased SOC storage with rice straw mulch.

We also continued our research activities on adapting agriculture to climate change in countries that are vulnerable to extreme weather events.

A weather index insurance (WII) for rice farmers in the Ayeyarwady Delta region in Myanmar was designed as an adaptation measure. The amount of rainfall, soil salinity, water salinity, and frequency of cyclone landfall were investigated for the weather index. The demand for WII was analyzed using data derived from a choice experiment, which considered farmers' heterogeneity. The results revealed that the demand is higher for insurance against cyclone, drought, and flood disasters than against soil and water salinity. The results of the WII demand analysis and the results of the optimum insurance premium analysis, which was reported in the last fiscal year, were shared with a non-life insurance company.

For the inland area of Myanmar, we proposed a reservoir operation method for the irrigation reservoir to improve both flood mitigation and water supply. The procedure to obtain the flood control capacity applicable to long duration floods in the tropical monsoon region was developed for flood mitigation. We noted that the improved irrigation efficiency due to rotary irrigation could be enhanced by monitoring the flow rate of the water supply.

A field validation on WeRise, a decision support system that applies seasonal predictions to rice growth model and the result of a research collaboration with IRRI, was carried out in the Philippines despite the reduced number of participating farmers due to the COVID-19 pandemic. A technical manual on WeRise was published for agricultural extension workers and researchers.

In the study on water use practices in the Central Dry Zone (CDZ) of Myanmar, we conducted multiple cultivation trials on ratoon rice cropping to develop cultivation techniques that would improve ratoon yield in Myanmar. We evaluated the effect of the stem cutting method and soil moisture management before and after harvesting of main crop on yield and regeneration ability. Lastly, we prepared a technical manual for the ratoon cropping system, including the results of experimental trials in Myanmar.

[Watershed Management in Africa]

Under this project, watershed management technologies for soil and water conservation were developed for the Central Plateau in Burkina Faso, with studies conducted at each section in the upper and middle slopes where land conditions varied.

Regarding techniques for vegetation recovery on the degraded upper slopes, an experiment was conducted by research counterparts at INERA-Saria station to observe the three-year root extension of soil-block seedlings for four species of Fabaceae, including *Piliostigma reticulatum* (a native) and *Leucaena leucocephala* (an exotic; data under analysis).

Aboveground height and weight of Andropogon grown with soil and water conservation facilities such as stone lines or earthen walls were larger than those grown without facilities. In addition, the number of stems per stock that accounts for preventing water erosion increased 10 times in 3 years after planting.

The effects of the "Fallow Band System (FBS)" on sorghum yield under fertilized conditions were revealed. Farmer meetings were held 10 times (with anti-COVID-19 measures) and the developed technologies were transferred to 60 farmers. In the meetings, most farmers (> 60%) showed willingness to adopt the technologies, especially FBS and the use of Andropogon grass strips.

A land cover classification map was created from images taken by a UAV/drone to introduce the technologies to target areas. Agricultural fields of sorghum and cowpea could be delineated, and the distribution pattern of cowpea (ground coverage) was found to be strongly related to soil type.

In order to alleviate the shortage of livestock feed in the local dry season, a high-quality fermented TMR (total mixed ration) containing sorghum stover was prepared. From the results of the *in vitro* digestion test, setting the mixing ratio of sorghum stover to below 20% was appropriate.

On-farm trials (60 fields in 8 villages) showed that the optimal combinations of nitrogen application rate and planting density for Ferric Lixisols and Petric Plinthosols were also effective in the farmers' field from the viewpoint of sorghum yield and income.

A simulation using the Soil and Water Assessment (SWAT) model, in which parameters were adjusted last year, showed that watershed-scale soil loss can be reduced to lower than the soil loss tolerance proposed by the United States Department of Agriculture (USDA) when farmers introduce one of our developed technologies.

In the Ethiopian Highlands in the northern Tigray region, where the slopes are characteristically steep, we proceeded with technological development for forest conservation and agricultural land management in a small watershed where forests and agricultural lands coexist.

A destructive biomass survey was conducted to refine the allometric equations for estimating the mean annual increment (MAI) at the native *Vachellia etbaica* (Schweinf.) community in Kilte Awlaelo district. The data were collected on-site by Mekelle University and jointly analyzed with JIRCAS during the fiscal year.

The three-dimensional structure model of *V. etbaica* was constructed using UAV and SfM (Structure from Motion) to estimate the biomass. The tree height tended to be lower in mountain ridges where environmental conditions are severe, indicating that tree height was an important parameter for biomass estimation.

A survey was conducted to estimate the sediment volume in a typical reservoir located at the exit of a small watershed. Certificates of appreciation were issued by Mekelle University to acknowledge the research outputs, which included papers describing the verification of sustainable vegetable cultivation on reclaimed farmlands by dredging sediments near the reservoir.

Lastly, we investigated communal land management systems and came up with proposals to contribute to soil and water conservation and farmers' livelihood in Kilte Awlaelo. Our proposals focused on the enhanced economic utilization of communal lands, improvement of fuel utilization, livestock management, and increase in feed resources from enclosed areas, as well as improvement of farmers' nutrition intake.

[Resource Management in Asia and the Pacific Islands]

Regarding resource management, we clarified that the combination of modified minimum tillage (by using a portable auger or trencher) and local organic (betel nut leaf) mulch increases taro (*Colocasia esculenta*) yield and mitigates soil erosion in Palau, and that these techniques work independently. Furthermore, the potential for farmland development in Babeldaob Island in Palau was evaluated and classified using topographic, soil, and land use maps. These project achievements were summarized and co-published with Palau Community College. The data set was edited to include chemical properties in major rivers of Babeldaob Island, which was monitored for 4 years, and the distribution of seagrasses and seaweeds including sea grapes (*Caulerpa Lentillifera*), which are expected to absorb nutrients in the water along the coast of Palau. These data sets were handed over to the Palauan authorities.

In Negros Island, Philippines, we concluded and recommended to the Philippine Sugar Regulatory Administration (SRA) that first nitrogen fertilizer should be applied 1 to 2 months after planting, given in half doses of the current application rate, to mitigate NO_3-N leaching to the groundwater and achieve the same sugarcane yield. A training was given to SRA staff on the utilization of a soil-crop simulation model (APSIM), and the developed technology, which promotes both sugarcane production and environmental conservation, will be disseminated throughout the Philippines.

In Haryana, India, the shallow subsurface drainage constructed using the “Cut soiler,” a subsoil breaker introduced by Japan, worked in mitigating soil salinity and increased the yields of pearl millet (*Pennisetum glaucum*) as a rainy season crop and of mustard (*Brassica juncea*) as a post-rainy season crop. We recognized a tendency that the shorter the distance between the drainages (up to 2.5 m), the higher those effects were. For the development of salt-tolerant soybean varieties, BC_1F_2 and BC_3F_3 plants harboring the salt tolerance gene *Ncl* were produced in Indian and Vietnam, respectively. Based on evaluations of their salt tolerance and agronomic traits, promising breeding lines were selected.

[BNI Utilization]

Incorporating biological nitrification inhibition (BNI) function of plants into agricultural systems contribute to sustainable natural resource management through increased N-fertilizer use efficiency and reduced environmental loads such as NO_3-N leaching and N_2O emissions. Wheat lines carrying chromosome translocations containing BNI-traits of wild-wheat (*Leymus racemosus*) into elite-wheat varieties are undergoing field evaluations to determine their yield potential and response to nitrogen fertilizer applications in Japan. The field experiment showed that the BNI-wheat lines needed only 40% of the fertilizer application rate of the original wheat varieties to produce the same yield level as the original wheat varieties, suggesting that introducing the BNI-wheat lines will reduce the nitrogen fertilizer application rate. To identify DNA markers related to BNI in sorghum, development of sorghum recombinant inbred lines (RILs) with different sorgoleone production is ongoing at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. Leaves of the high-sorgoleone sorghum lines were found to have low nitrate concentration and low nitrate reductase activity compared with the low-sorgoleone sorghum lines, suggesting that sorghum absorbed mainly ammonium accumulated by nitrification inhibition in soil. For an ex-ante impact assessment, a model was developed to simulate reductions in nitrogen fertilizer application rates and N_2O emissions by BNI crops. According to the model, the reduction in fertilizer application rate was estimated to be 15% and the improvement of nitrogen use efficiency was estimated to be 9% when BNI sorghum with 40% nitrification inhibition was introduced. Field experiments were conducted at the International Center for Tropical Agriculture (CIAT) in Colombia to clarify the impact of high-BNI *Brachiaria* pastures on subsequent maize productivity and soil nitrification activity. The soil nitrification activity of subsequent maize plots from high-BNI *Brachiaria* pastures was 8% lower compared with subsequent maize plots from low-BNI *Brachiaria* pastures. To construct a high-density genetic map of tetraploid *B. decumbens* ($2n = 4x = 36$), genotyping by random amplicon sequencing-direct (GRAS-Di), simple sequence repeat (SSR), and amplified fragment length polymorphism (AFLP) markers were employed in genotyping an F_1 mapping population (n=146). In contrast to the relatively stable acidic condition, brachialactone was found to undergo structural change due to hydrolysis of its lactone ring in basic conditions. The docking simulation with hydroxylamine oxidase, a part of the nitrification pathway, further supported the notion that BNI by brachialactone is more exerted in acidic conditions. The results and our observations that the BNI effect of *Brachiaria* is usually enhanced in acidic soils were further supported by these findings. MBOA was identified as the hydrophilic BNI compound from root exudates of maize. MBOA also showed a specific BNI-active pattern, in contrast with other BNI compounds, and contributed 70% of the total BNI activity in hydrophilic root exudates of maize. It was also revealed that MBOA was stable in acidic, basic, and organic solvents.

Mitigation of methane emissions from Vietnamese local cattle (Lai Sind) by cashew nut shell liquid (CNSL) feeding

Livestock production, especially ruminant production, is known to be one of the most significant sources of greenhouse gas (GHG) emissions in Southeast Asian countries. Therefore, there is an urgent need to develop technologies to mitigate GHG emissions from this sector in the region. A significant amount of cashew nuts is produced in Vietnam, leaving a significant amount of cashew shells as by-product. Cashew nut shell liquid (CNSL), extracted from the cashew shell, is known to contain antimicrobial compounds like anacardic acid, which can inhibit the activity of methanogens in the rumen of ruminants. Here, we evaluated the effect of CNSL feeding on methane emission from local cattle (named Lai Sind) in Vietnam. We also revealed the effect of CNSL on the activity of the microbiome in the rumen and its function, thus paving the way for

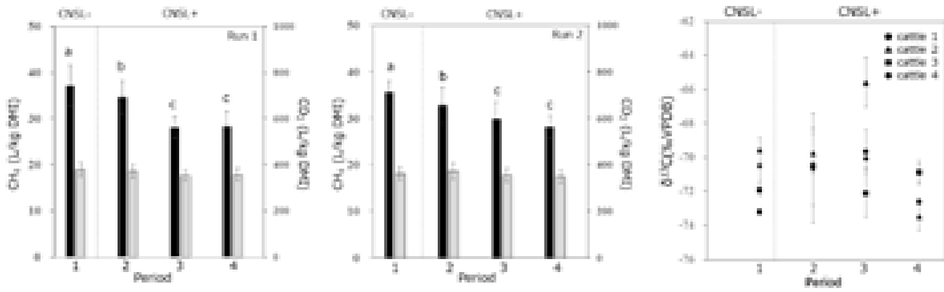


Fig. 1. Enteric CH_4 (black) and CO_2 (grey) emissions per kg dry matter intake (DMI) from Lai Sind cattle, with (periods 2–4) and without (period 1) CNSL feeding (n = 4)

Error bars: standard deviation (SD). Different letters indicate significant differences (p < 0.05). Different doses of CNSL were set in Run 1 (4 g/100 kg BW: A) and Run 2 (6 g/100 kg BW: B). C. Changes in the $\delta^{13}C$ values of enteric CH_4 (Run 1). The $\delta^{13}C$ values are expressed as relative to the VPDB (Vienna Pee Dee Belemnite). Each symbol (circle, triangle, square, and diamond) indicates individual cattle. Error bar: SD (n = 3)

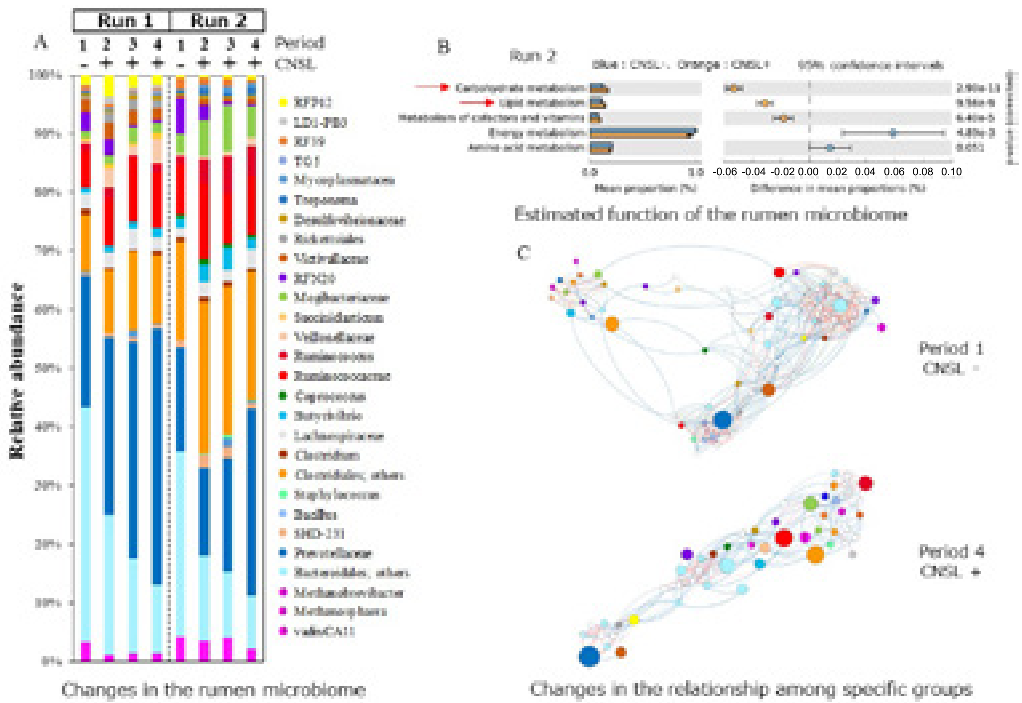


Fig. 2. Effect of CNSL feeding on rumen microbiome

A. The effect of CNSL feeding on relative abundance of each group of the bacteria/archaea. B. Estimated function of the rumen microbiome and significantly changed features by CNSL feeding in Run 2. Orange and light blue at the bottom of the dendrogram indicate the results with (periods 2–4) and without (period 1) CNSL feeding. C. Output of network analysis for period 1 (without CNSL feeding) and period 4 (with CNSL feeding) the development of an effective CNSL feeding technology for GHG mitigation.

Lai Sind cattle, the most widespread cattle breed in Vietnam, were used for the CNSL feeding experiment (n=4), with an average body weight of 246.1±22.6 kg for Run 1 and 375.0±36.0 kg for Run 2. The amounts of CNSL fed were 4 and 6 g/100 kg body weight per day for Runs 1 and 2, respectively.

Average methane emission per kg dry matter intake was reduced from 20.2% to 23.4% by CNSL feeding (Figs. 1A and 1B). Furthermore, CNSL feeding had a significant effect on the $\delta^{13}C$ value of the methane produced, indicating that it significantly affected organic matter degradation in the rumen (Fig. 1C). CNSL feeding also affected the relative proportion of propionate in the short-chain fatty acid concentration in the rumen (Run 1: 8.2%→10.6%, p=0.001; Run 2: 17.7%→21.4%, p=0.015), while it did not affect feed degradation efficiency (data not shown). CNSL feeding significantly reduced the relative abundance of a major methanogen (order *Methanobacteriales*) while it significantly increased the relative abundance of family *Prevotellaceae*, which is known to degrade the polysaccharide or produce propionate (Fig. 2A). The estimated function of the rumen microbiome indicates that CNSL feeding significantly suppressed methane metabolism, which agrees with methane emission measurement, and that it enhanced carbohydrate metabolism or lipid metabolism at the same time (Fig. 2B). The results of 16SrRNA gene amplicon sequencing suggest that CNSL significantly reduced the diversity of the rumen microbiome, and the results of network analysis further indicate that a major methanogen (order *Methanobacteriales*) changed the functional partner in the rumen with the significant metabolic relationship (Fig. 2C).

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C. Hikita [Idemitsu Kosan. Co. Ltd.])

TOPIC 2

Potential mitigation of life cycle greenhouse gas emissions from rice cultivation by alternate wetting and drying (AWD)

Alternate wetting and drying (AWD) has been introduced in Vietnam's Mekong Delta to reduce soil methane (CH_4) emissions from rice (*Oryza sativa* L.) cultivation, to mitigate climate change, and to save water consumption. The benefits of AWD (e.g., reducing irrigation cost and increasing yields) have been reported by many researchers, including researchers in Japan International Research Center for Agricultural Sciences and Can Tho University. However, there is less information about the trade-off among soil CH_4 emissions reduction, nitrous oxide (N_2O) emissions, and agronomic management. The present study carried out a life cycle assessment to evaluate the impacts of AWD on potential mitigation of life-cycle greenhouse gas (LC-GHG) emissions.

A structured interview was carried out in An Giang Province, Vietnam, which is the 5th-largest rice producer in the world. In August and September 2019, 200 farmers were interviewed: 100 farmers with 199 fields and 100 non-AWD farmers with 187 fields. Vietnamese staff members of Can Tho University conducted the interviews. The system boundary and functional unit for the LCA were defined as a cradle-to-farm gate and 1 ha of paddy rice, respectively. The soil and non-soil CH_4 and N_2O emissions for the AWD and non-AWD farmers were estimated with reference to the IPCC tier 1 methodology (2019). The present study showed that AWD farmers lowered the use of seeds, nitrogen, phosphate fertilizers, and operation hours of irrigation pumps without decreasing rice yields. Despite an increase in N_2O emissions by 17% due to wet (anaerobic) - dry (aerobic) cycles by AWD which enhances nitrification-denitrification processes, and application rates of potassium, LC-GHG emissions were reduced by 41%, lowering soil CH_4 emissions by 47% and non-soil GHG emissions (burning straw and other managements) by 9%. LC-GHG emissions from AWD farmers and non-AWD farmers were estimated to be 9.82 and 16.6 t CO_2-eq ha^{-1}, respectively. Unlike water management, straw management had little influence on the CH_4

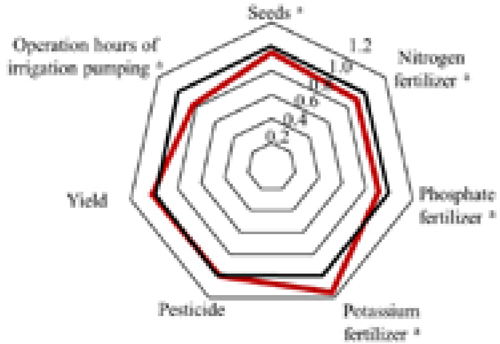

Fig. 1. Ratios of AWD farmers to non-AWD farmers in the use of seeds, nitrogen, phosphate, potassium fertilizers, pesticide, yield, and operation hours of irrigation pumping
The red line in the chart shows the ratio of AWD farmers to non-AWD farmers. If the ratio is greater than 1, the value of the corresponding item for AWD farmers is greater than that of non-AWD farmers (a: Significantly different at $p<0.05$).

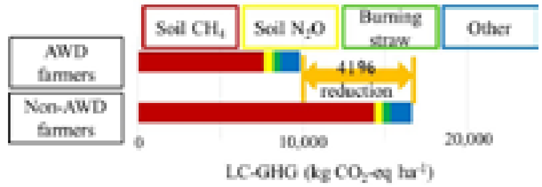

Fig. 2. Comparing GHG emissions between AWD farmers and non-AWD farmers

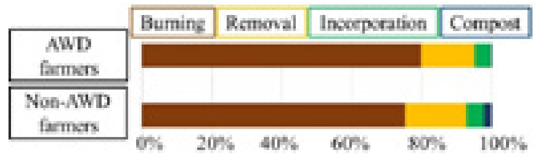

Fig. 3. Rice straw management between AWD farmers and non-AWD farmers

emissions difference between groups, as >75% of farmers irrespective of the water management carried out on-site burning as straw management. To the best of the authors' knowledge, the present study is one of the first studies to survey rice straw management under different water management strategies.

These results can be utilized as scientific evidence for policy making and implementation. In addition, they can be used to estimate potential mitigation of LC-GHG emissions for a country where AWD is introduced. Moreover, the methodology used in the present study can be applied for the other countries.

(A. Leon, K. Minamikawa, T. Izumi, N.H. Chiem [Can Tho University])

TOPIC 3

Monitoring saline intrusion in the Ayeyarwady Delta, Myanmar, using satellite data

Myanmar's agricultural sector, which contributes to most of the country's gross domestic product has great potential. After the government supported the installation of irrigation facilities in 1992, the double cropping system became widespread in Myanmar, and rice production and population both increased in the well-irrigated lowlands of the Ayeyarwady Delta. However, despite the presence of irrigation facilities, rice cropping is impractical near the coast because irrigation water is severely affected by high salinity during the dry season, limiting crop growth and rendering the soil unsuitable for many crops. Therefore, saline intrusion is one of the biggest factors limiting crop production in the Ayeyarwady Delta.

Previous studies based on remote sensing have related the optical variables of water color, such as salinity, turbidity, and suspended sediment concentrations, to single spectral bands. These empirical models are often region- and time-dependent and thus should be calibrated and validated with data that cover a wide range of field conditions. This means that models need to be developed for specific water bodies or sensors. The aims of this study therefore are to (1) develop empirical models by fitting field measurements from three rivers (i.e., the Pathein, Ywe and Pyamalow Rivers) and two sampling occasions (i.e., beginning and end of the dry season) to Sentinel-2 imagery, (2) monitor the spatial and temporal variability of saline intrusion in the Ayeyarwady Delta during the dry season, and (3) assess the impact of saline intrusion on the distribution patterns of paddy fields.

The imagery of Sentinel-2 was suitable for monitoring saline intrusion because of its high spatial (10-m) and temporal (10-day) resolutions. We found that the reflectance of the visible bands correlated with electrical conductivity (EC), which in turn was influenced by the concentration

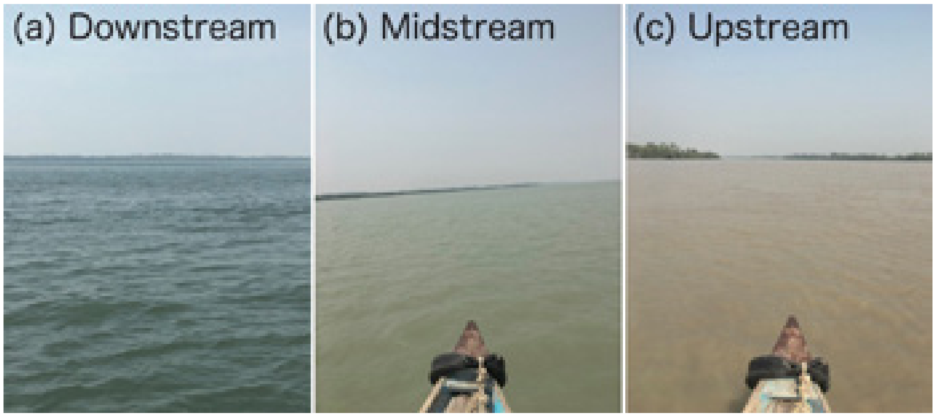

Fig. 1. Photographs of river water conditions in the (a) downstream, (b) midstream, and (c) upstream reaches of Ywe River on 9 March 2018

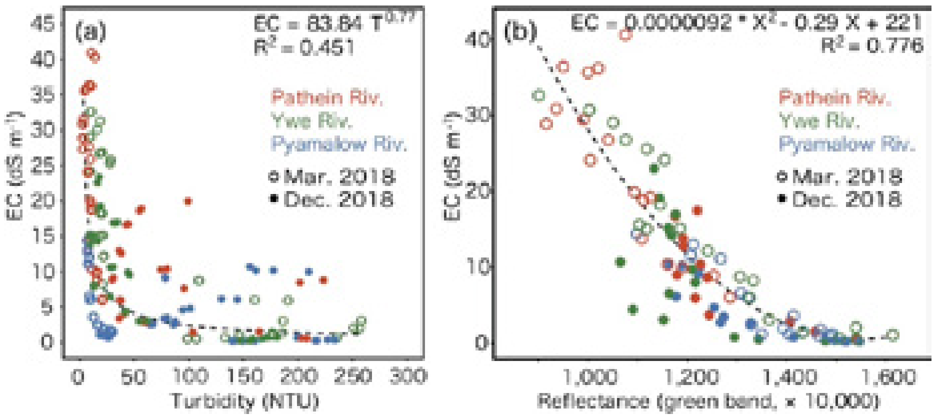

Fig. 2. Relationships between (a) turbidity and electrical conductivity (EC), and (b) EC and green band reflectance retrieved from Sentinel-2

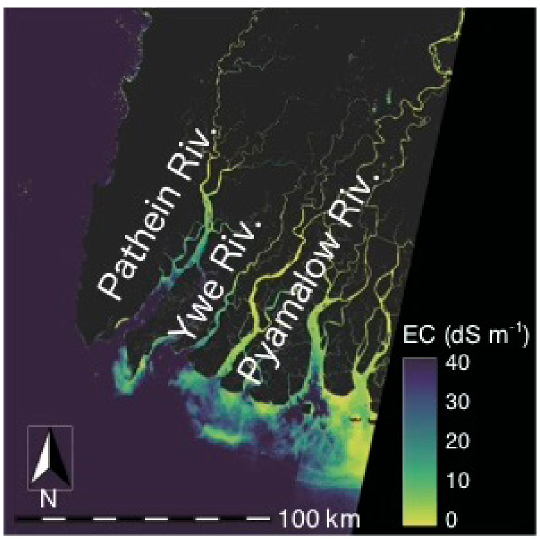

Fig. 3. Spatial distribution of EC on 12 March 2018

Fig. 4. The 1 ppt salt concentration lines during the dry season

The lines connect locations where EC is 1.56 dS m^{-1} (i.e., 1 ppt).

and composition of dissolved salts. When the river water mixed with salt water from the sea, suspended particles tended to flocculate and settle, indicating that less turbid water was more saline. The best-fitting model was obtained with the green band (coefficient of determination R^2 of 0.78, root mean square error of 4.90 dS m^{-1}, and mean absolute error of 3.34 dS m^{-1}). The saline intrusion, which showed considerable spatial and temporal variability during the dry season, extended approximately 80 km inland at the end of the dry season in March at Pathein River. The

1 ppt salt concentration line in March marked the boundary between cultivated and non-cultivated areas of the paddy field, indicating that cultivable areas were strongly affected by saline intrusion. The results show that more frequent monitoring and use of higher resolution Sentinel-2 image data can support effective water resource management.

(T. Sakai, K. Omori, A.N. Oo [Yezin Agricultural University], Y.N. Zaw [Department of Agriculture, Myanmar])

TOPIC 4

Soil oxidation conditions during the initial growth period of ratoons could contribute to improve the yield performance of ratoons

Compared with conventional double-season rice cropping, ratoon rice cropping can reduce production cost because of its advantages in labor, seed, seedbed and water savings. However, the grain yield of ratoon rice is only 40%–60% that of the main crop; thus, most of ratoon cropping is only practiced by farmers as an afterthought. In recent years, in West Sumatra, Indonesia, a perennial rice cropping system called SALIBU has been practiced and found to produce a yield equivalent to that of single rice cropping multiple times annually. Therefore, this study focused on the SALIBU method, whose unique features are double-cutting of stem and humid soil moisture management during the harvesting stage (Fig. 1), in order to find the factors that increase the yield of ratoon. We conducted cultivation trials using a concrete tank (Fig. 2) in Naypyidaw, Myanmar, to evaluate the effect of the cutting times and the soil moisture regimes on grain yield and regeneration rate of ratoon in tropical regions.

Experiments were conducted using a concrete tank filled with paddy to evaluate cutting regimes (single- and double-cutting) and soil moisture regimes (saturated, moist and dry). Double cropping (main crop + 1st ratoon) was carried out from February to August 2019 (first trial), and triple cropping (main crop + 2nd ratoon + 3rd ratoon) was implemented from September 2019 to May 2020 (second trial). Summarizing for the moisture regimes, the soil water potentials of the saturated, saturated-moist, moist, and dry regimes were approximately 0 kPa, -5 kPa, -11 kPa, and -19 kPa, respectively, and the soil redox potentials of the saturated, saturated-moist, moist and dry were 200 mV, 100 mV, 200 mV, and 550 mV, respectively. There were significant differences between moisture regimes with regard to grain yield and regeneration rate of tiller (Fig. 3 and Fig. 4). Double cutting (a cutting height of 30–40 cm for harvesting and a height of 5 cm for ratooning) had no positive effect on grain yield and regeneration rate compared with single cutting. If there is no increase in yield

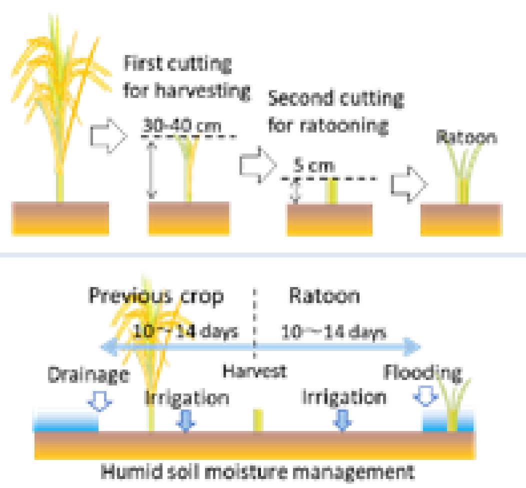

Fig. 1. Double cutting of stem and soil moisture management during the harvesting stages of the previous crop, which are unique features of Indonesia's perennial rice cropping system (SALIBU)

Fig. 2. Cultivation trial using concrete tanks (L 1.8 m × W 0.9 m × D 0.4 m) in a split-plot design, comprising a total of 24 plots (2 cutting, 3 moisture and 4 replications)

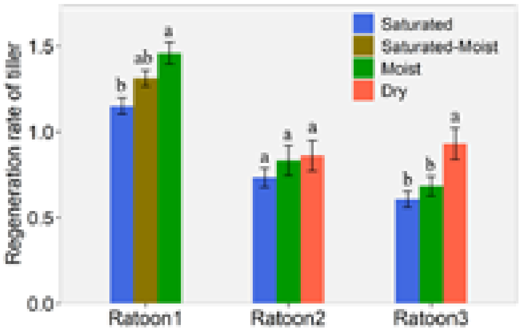

Fig. 3. Effect of soil moisture regime on the regeneration rate of ratoon crops at 3 weeks after harvesting
Ratoon crops were harvested by the single cutting of stem. Regeneration rate of tiller was defined as the ratio calculated by the tiller of ratoon divided by that of residual stubble. Error bars indicate the standard errors (n = 16). Same letters above the bar indicate that there is no significant difference at the 5% level by Tukey's HSD test.

Fig. 4. Effect of cutting times and soil moisture regimes on the grain yield of ratoon, shown by comparing the 3rd ratoon with the main crop
The error bars indicate the standard errors (n = 4). Same letters above the bar indicate that there is no significant difference at the 5% level by Tukey's HSD test.

commensurate with the cost of the additional cutting, stem cutting of ratoon should be cut once with a height of 5 cm at the time of harvesting. The dried soil moisture conditions promote the increase of easily-decomposable nitrogen compounds and the supply of inorganic nitrogen, and activates root respiration. Hence, improving the rhizosphere environment in the initial growth stage of ratoon in soil under oxidation conditions will contribute toward increasing the yield of ratoon.

The above scenario is the result of using a concrete tank that allows for easy drainage management, and various drainage measures such as designing the drainage channel must be considered to improve the yield of ratoon in paddy fields. Water management (amount, frequency, and period of irrigation) during the harvesting stage of the previous crop should be carried out while considering the air temperature, rainfall, water retention of paddy soil, and plant growth of ratoon.

(S. Shiraki, K. Yamaoka,
Thin Mar Cho [Department of Agricultural Research (DAR), Myanmar],
Khin Mar Htay [DAR])

TOPIC 5

Silage preparation improves feed utilization of sorghum and pearl millet stover

Sorghum (*Sorghum bicolor* [L.] Moench) and pearl millet (*Pennisetum glaucum* L.) are the main crops in the semi-arid region of West Africa. After harvest, the stovers of the two crops are usually exposed and stored outdoors. These stovers are used as roughage for ruminants during dry season when there is a severe shortage of feed. However, the drying of feed resources is the only storage method in this area, and a longer storage time reduces the nutritional value of feed due to leaching and decomposition of nutrients. Therefore, silage prepared using crop stover is expected to alleviate feed shortages in the dry season and improve livestock productivity.

After panicle harvest, the sorghum and pearl millet stovers were exposed in the field and garden for 120 days under natural weather conditions. At the same time, fresh stover silages were prepared using a small-scale fermentation system and stored for 120 days. Compared to fresh stover, both types of stover after 120 days of exposure reduced crude protein and fat content and energy, and increased indigestible crude fiber and lignin. On the other hand, stover silage preparation produced good-quality feed, and the nutrients were not lost after 120 days of ensiling (Fig. 1). Lactic acid bacteria were present in both fresh stovers, but after 120 days of exposure, the counts of harmful microorganisms such as aerobic bacteria, coliform bacteria, yeast, and mold increased, and no lactic acid bacteria were detected. After 120 days of ensiling, lactic acid bacteria became the predominant population and

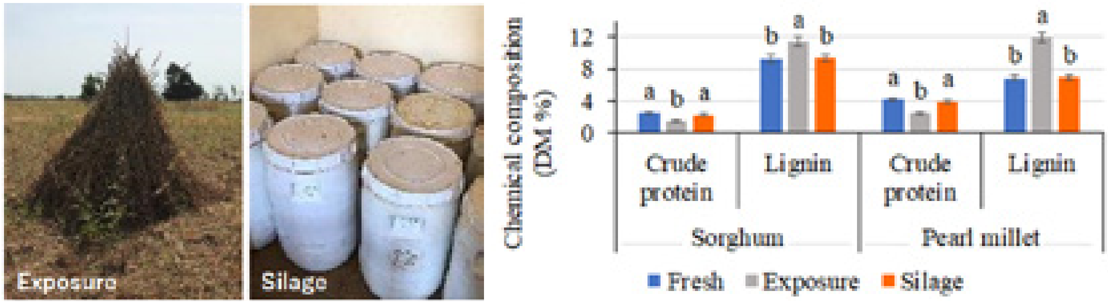

Fig. 1. Storage of crop stovers during exposure and ensiling (left) and changes in their chemical composition (right)
[a, b] Means of three samples differ significantly (*p*<0.05).

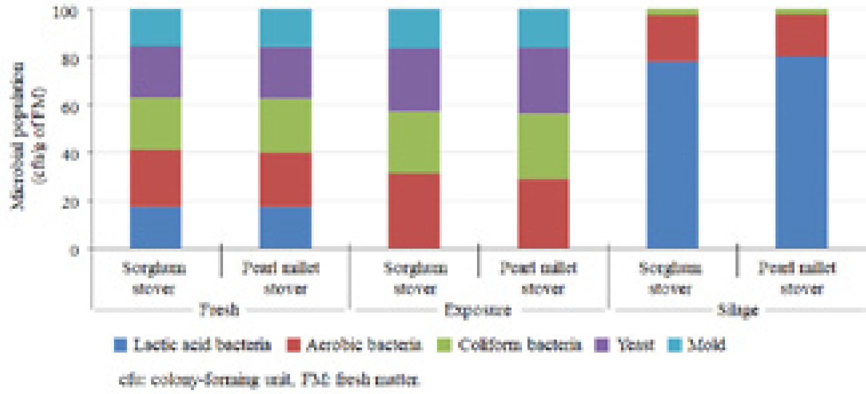

Fig. 2. Microbial population due to differences in the preservation method of crop stover

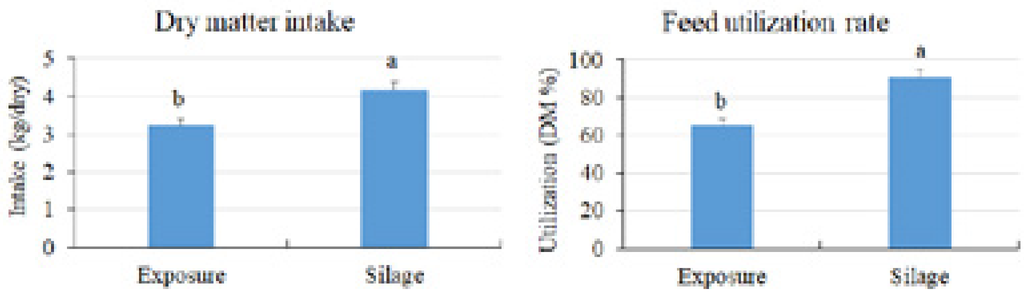

Fig. 3. Dry matter intake and feed utilization rate of beef cattle due to differences in storage method of sorghum stover
Feed utilization rate = cattle intake / total feed × 100%.
[a, b] Means of eight cattle differ significantly (*p*<0.05).

inhibited the growth of harmful microorganisms. As far as the microbial community is concerned, there were no great difference between crop stovers under the same storage treatment (Fig. 2). The prepared silage was of good quality, lactic acid fermentation reduced the pH, and low moisture inhibited butyric acid fermentation. The silage did not deteriorate, and the feed nutrients were well preserved for a long time. Sixteen native beef cattle with an average weight of 257.4 ± 13.5 kg were fed 1 kg of concentrate and free-feeding roughage, including sorghum stover and silage. The intake and feed utilization rate of stover silage significantly (p<0.05) improved compared to exposed stover (Fig. 3).

In terms of utilization of results, farmers in the semi-arid areas of West Africa can easily use local crop stover resources for silage, reducing the shortage of feed for ruminants in the dry season. The silage preparation technology will be released as a technical report by the CNRST (Burkina Faso National Center for Scientific Research and Technology) to improve local livestock raising method. Fresh sorghum and pearl millet stovers after harvest usually have low moisture, so when preparing silage, the moisture should be adjusted to about 60%.

(Y. Cai, S. Yamasaki,
D. Jethro [Institute of Environment and Agricultural Research (INERA)],
M. Nignan [INERA])

Providing information on collaborative behaviors is important for communal forest management in Ethiopia

Many forests in northern Ethiopian highlands are communal forests managed by local farmers. These farmers collectively adopt soil and water conservation practices, such as construction of stone bunds and excavation of deep trenches, to maintain forests and supervise reforestation (Fig. 1). All members of a rural community are supposed to engage in the conservation without cash payment, in exchange for them being able to collect animal fodder and firewood. However, there are concerns over the longevity of the collaboration.

Fig. 1. A soil and water conservation structure for reforestation built through farmers' community work

The sustainability of communal forests depends on whether or not local people are aware of the importance of collaboration in conservation activities. This study investigates whether providing information regarding the importance of collaboration in conservation work using an economic experiment approach enhances farmers' cooperative behavior in Ethiopia.

We conducted an economic experiment called the "public goods game" for participants randomly selected from eleven villages in Tigray Region, Ethiopia. Each session involved ten rounds of the game. The procedure of the experiment followed the standard public goods game. Each participant was asked to contribute any amount worth up to 5 ETB (Ethiopian Birr) for communal forest conservation. During the

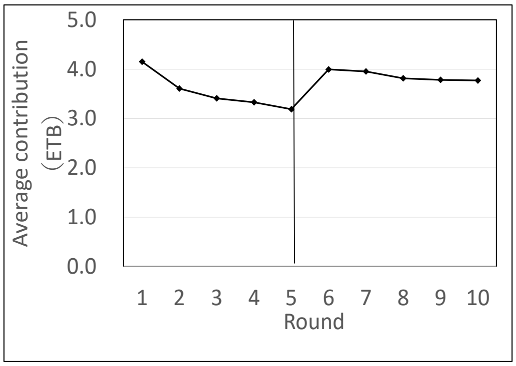

Fig. 2. Average contribution by round
The vertical line indicates the timing of intervention.

Table 1. Changes in average contribution from Rounds 1 to 5, 5 to 6, and 6 to 10 (ETB)

Period	Round 1 to 5	Round 5 to 6	Round 6 to 10
Change in contribution	-0.963***	0.808***	-0.224***
Difference from Round 1–5	-	1.771***	0.739***

Note: Average of all participants. ***p<0.01.

Table 2. Determinants of contribution in the public goods game: Tobit regression model

Variable	Coefficient estimate	Variable	Coefficient estimate
Contribution of other members	1.084***	Distance from town	0.021***
Female	-0.09	Trust among villagers	0.395***
Education	0.014	Farmland area	-0.112**
Age	0.206***	Animal holding	-0.008
Soil fertility	-0.213***		

Note: Contribution of other members: the average value of the contribution in the previous round for all of the other participants (ETB: Ethiopian Birr). Female: female participant. Education: a length of formal education (years). Age: Age of participant. Soil fertility: the dummy variable for soil type (0 if Calcisols is dominant and 1 otherwise). Distance from town: distance from a district center to home (km). Trust among villagers: dummy variable to indicate whether villagers trust each other or not. Farmland area: size of participants' farmland area (ha). Animal holding: the number of livestock in the tropical livestock unit. ***p<0.01, **p<0.05.

initial instruction, we explained the rules of the experiment and consequences of the investment. Also, just after the 5th round of each game, we repeated the instruction, same as that offered before starting the game. The result shows that while the average contribution continues to decline until the 5th round, it jumps up at the 6th round to almost the same level as the 1st round (Fig. 2). The speed of the decline after the 6th round is slower than that before the 5th round (Table 1). These results suggest that repeating the instruction has a positive impact on local people's collaboration. Moreover, we have found heterogeneity in the contribution in terms of social and household characteristics (Table 2). Also, the contribution is higher if other members contribute a larger amount in the previous round (Table 2). This demonstrates endogeneity in voluntary contributions.

The results of this study suggest that conducting periodic seminars to remind local farmers of the benefits of communal land could enable them to maintain a high level of commitment to natural resource conservation and sustainable development. It should be noted, however, that farmers' collaboration for natural resource management may vary among countries, ethnic groups, and geographic characteristics.

(S. Oniki,
H. Etsay [Mekelle University],
M. Berhe [Mekelle University],
T. Negash [Mekelle University])

TOPIC 7

Modified conservation agriculture for taro production in combination with spot excavation by gas-powered apparatus and organic mulch

Taro (*Colocasia esculenta* (L.) Schott) is traditionally produced as a main staple crop in a coastal swamp of the Pacific islands. Sea level rise due to climate change, however, often causes saltwater to intrude into the taro fields and push the taro production area up toward inland slopes. Soils in the volcanic upland of the Pacific islands, however, are heavily weathered and acidic and are extremely infertile with a shallow surface organic layer. Thus, soil fertility should be improved in order to enhance taro production without soil erosion and disturbance to corals which, incidentally, attract many foreign tourists. Conservation agriculture (CA), a farming method composed of three principles, namely, minimum soil disturbance, permanent residue cover, and diverse rotations, is suggested to be the best management practice for improving nutrient cycles and soil organic matter restoration and controlling soil erosion. In this study, the effects of tillage and mulching on soil erosion and upland taro production were investigated, with modifications to the three CA principles depending on applicability to local farmers and availability of local resources.

The experiment was conducted from August to May at a research station in Palau Community College in Babeldaob Island, Republic of Palau. The slopes of the experimental plots were between 8 to 13 degrees, while the total rainfall was 2,800

Fig. 1. Gas-powered portable auger (left) and self-propelled trencher (right)
Left: Gas-powered portable auger (AGZ5010EZ, ZENNOH, Japan) attached with a drill (15 cm in diameter, 80 cm in length); Right: Self-propelled trencher (NF-827-II, KAWABE, Japan)

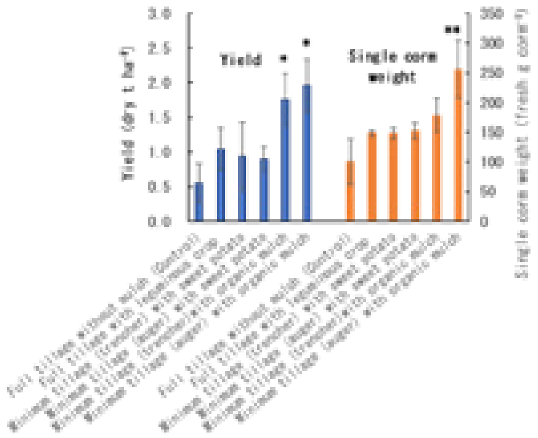

Fig. 2. Combination effects of modified minimum tillage and surface mulch on taro yield and single corm weight
*, **: Significantly different from control
(* : $p < 0.05$, ** : $p < 0.01$) (Dunnett's test)

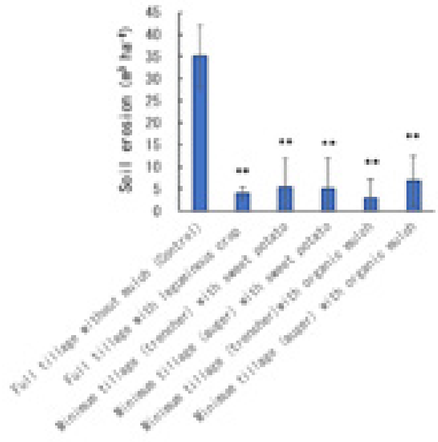

Fig. 3. Combination effects of modified minimum tillage and surface mulch on soil erosion
To measure eroded soil, experimental plot was enclosed with a wooden frame and soil trap was installed at the down end.
: Significantly different from control (: $p < 0.01$) (Dunnett's test)

mm during the cropping season. We introduced a gas-powered portable auger or a self-propelled trencher as a modified technology for minimum tillage and for planting (Fig. 1). After excavating the soil with these apparatuses down to 45 cm depth, the excavated soil and 300 g of compost were mixed and returned into the hole/ditch up to 25 cm depth. Taro seedlings (cultivar: Ngesaus etc.) were then planted in the hole or ditch. As modifications of permanent residue cover and diverse rotations, we tested three types of mulch (yard long beans/sweet potato living mulch, and betel nut leaf mulch) in combination with modified minimum tillage.

When taro was cultivated in combination with modified minimum tillage and local organic mulch (betel nut leaf), taro yield increased by 3.2 to 3.6 times (1.8 to 2.0 t ha^{-1}) compared to control (full tillage without mulch) (Fig. 2). When the portable auger was used, a single corm weighed heavier by 2.6 times (256 g per fresh corm) compared to control. In addition, the combination of modified minimum tillage and organic mulch decreased soil erosion by 80% to 91% (from 35 m^3 ha^{-1} to 3.1–6.9 m^3 ha^{-1}) (Fig. 3).

In conclusion, minimum tillage using a portable auger with betel nut leaf mulch can be recommended as a modified CA method for upland taro production specially in the Republic of Palau where extremely infertile steep inlands are expected to be developed.

(H. Omae, Y.Y. Nwe [Palau Community College])

TOPIC 8

Nitrogen leaching and growth of sugarcane under different nitrogen fertilization levels in a subtropical island

In tropical and subtropical islands where highly permeable limestone rocks are distributed, rainfall causes nitrogen (N) from chemical fertilizers to readily leach underground, with the nitrate leached from fertilization of sugarcane becoming a main source of groundwater pollution. The effect of excessive amounts of fertilizer in early growth stage of sugarcane, before the development of the root system, is limited. Therefore, it is important that fertilizer management should be appropriate for the growth characteristics of sugarcane. This study aimed to develop a fertilizer application technique that reduces N load to groundwater while maintaining sugarcane yield by using a drainage lysimeter.

Our research site was the Japan International Research Center for Agricultural Sciences, Tropical Agricultural Research Front (JIRCAS-TARF), located in Ishigaki Island, Japan. Drainage lysimeters with an area of 10 m^2 and a depth of 2 m were filled with dark red soil derived from limestone, and sugarcane was planted without irrigation (Fig. 1). Drainage water was collected at the bottom of lysimeters and the concentration of nitrate nitrogen (NO_3-N) in drainage water was measured using a spectrophotometer. The experimental design consisted of a randomized block with two replications of a 3 × 2 factorial design and an unfertilized control, totaling 14 plots. The first factor was the N rates of the basal applications (0, 35, or 70 kg N ha^{-1}) and the second factor was the N rates of the supplementary applications (80 or 160 kg N ha^{-1}) (Table 1). Even when the basal N was reduced to 50% of the current fertilizer application standard (T2), the same level of yield was maintained as in T1 where 100% basal N was applied. The timing of fertilizer application is important because T4 with halved N in the supplemental fertilizer has higher yield than T3 with no basal fertilizer, even though the total amount of N applied is lower. Concentrations of NO_3-N in drainage water were high in the early growth stage period from late April to late June, and high concentrations of 8 to 10 mg L^{-1} were detected in the conventional fertilizer rate (T1) (Fig. 2). In the supplemental N-only 50% (T4), basal N 50% (T2 and T5), and basal N 0 application (T3 and T6) plots, the accumulated N leaching was reduced by 10 kg ha^{-1}, 12 kg ha^{-1}, and 19 kg ha^{-1}, respectively, compared to the current fertilizer application of 24 kg ha^{-1} (T1) (Fig. 3). Even if the amount of N applied under the current fertilizer application is reduced by 15% (equivalent to 35 kg ha^{-1}), N leaching from fertilizer could be reduced by about 50% (12 kg ha^{-1}) while maintaining the same level of sugarcane yield.

The results of this study will provide basic data for the revision of the standard fertilization (amount of fertilizer applied) for sugarcane cultivation in Okinawa Prefecture, as well as information for the analysis of N balance and dynamics in the groundwater basin. For appropriate fertilizer management, it is necessary to consider the surrounding environmental conditions in addition to reducing the amount of nitrogen. Therefore, accumulating soil and meteorological data and using them for model analysis is effective.

Fig. 1. Drainage lysimeters at JIRCAS-TARF

Table 1. Sugarcane yield and leaf area in each N treatment

Treatments			Harvest survey			Growth survey	
No.	Basal N	Supplementary N	Cane yield per plot	Cane yield per stalk	Stalk density	Leaf area in April	Leaf area in August
	(kg ha^{-1})		(t ha^{-1})	(kg)	(stalks m^{-2})	(cm^2)	
T1	70	160	91.0	1.13 a	8.4 a	83.3 a	295 a
T2	35	160	88.8	1.11 a	7.9 a	84.5 a	275 a
T3	0	160	76.8	1.03 a	8.4 a	87.4 a	272 a
T4	70	80	83.0	1.01 a	8.4 a	98.3 a	270 a
T5	35	80	74.5	1.07 a	6.8 a	86.3 a	250 ab
T6	0	80	72.3	1.06 a	7.1 a	82.3 a	241 b
T7	0	0	39.8	0.75 b	7.9 a	91.3 a	215 b

Note 1: Treatments (T1–T7) refer to different N application rates.
Note 2: There is a significant difference between different alphabets among N treatments by Tukey method (p<0.05).

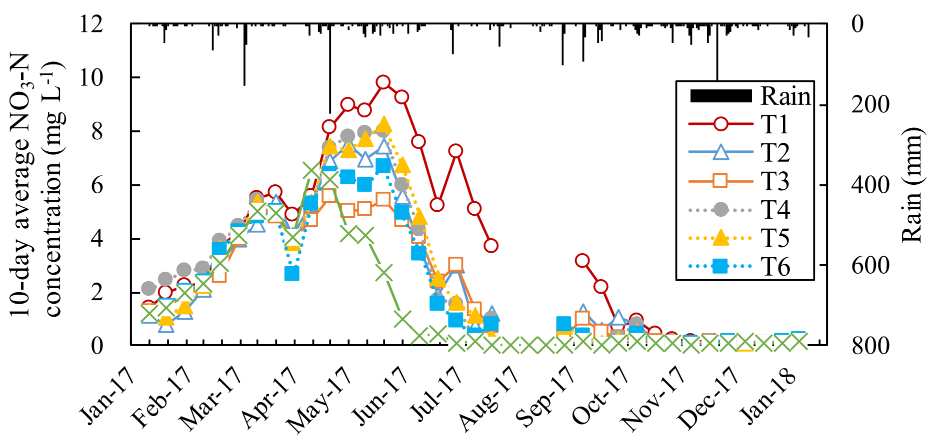

Fig. 2. NO_3-N concentration in drainage water
Note: Treatments (T1–T7) refer to different N application rates.

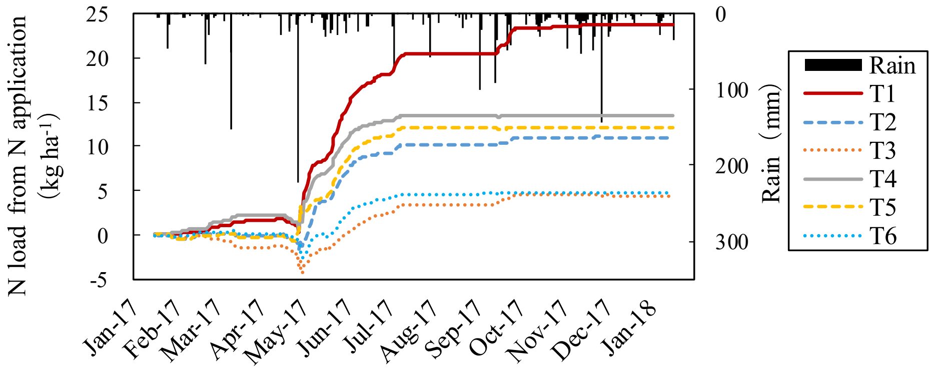

Fig. 3. N load from N application

Note 1: Treatments (T1–T7) refer to different N application rates.

Note 2: N load from N application refers to the accumulated N loads in T1 to T6 minus that in T7 (control treatment).

(K. Okamoto, T. Anzai, S. Ando, S. Goto [National Agriculture and Food Research Organization Kyushu Okinawa Agricultural Research Center])

TOPIC 9

Brachiaria reduces nitrification rate through inhibition of ammonia-oxidizing archaea in inter-plant soil

Modern agriculture requires large amounts of nitrogen (N) to maintain crop yield, but its utilization efficiency is not high. Chemical nitrification inhibitors are used to improve N utilization efficiency, but they are expensive and need to be applied continuously. Biological nitrification inhibition (BNI), a phenomenon in which the plant itself secretes a nitrification inhibitor and exerts its effect, is expected to improve N utilization efficiency in agricultural ecosystems and reduce environmental loads. Many studies have been conducted on BNI plants, especially the tropical pasture grass "Brachiaria," including the identification of brachialactone as a nitrification inhibitor. However, these studies have targeted rhizosphere soils that directly evaluate the effects of plant root secretions, and although there are many studies, there are very few reports on BNI effect in field experiments. Regarding the expression of BNI, it has been shown that sorghum is related to the suppression of ammonia-oxidizing archaea (AOA) (JIRCAS Research Highlights 2019, A05) but not fully elucidated in Brachiaria. On the other hand, at field scale, it is necessary to evaluate the entire field including not only the rhizosphere soil but also the inter-plant soil. This experiment clarifies the change in the nitrification rate of the bulk soil and its mechanism in the cultivation of tropical grass Brachiaria.

Seven varieties of Brachiaria grasses (with different BNI potentials in root exudates) and a bare plot were set as the control plot, and a field cultivation trial was conducted for 18 months at the Tropical Agriculture Research Front (TARF) of JIRCAS (Fig. 1). Among the seven varieties investigated, Tupy has the highest BNI activity in root exudate and Marandu has the lowest (Table 1). The potential nitrification rate in the inter-plant soil (center at 90 cm between stocks, depth 0 to 30 cm) after 18 months of Brachiaria cultivation differs depending on the variety, and among the 7 varieties investigated, 3 varieties (Marandu, Mulato, and Tupy) have particularly inhibited nitrification rates (Fig. 2), and the degree of decrease in the nitrification rate of each variety did not necessarily match the BNI activity of root exudates of each variety (Table 1). Since multiple regression analysis including BNI activity in root tissue enables significant regression, the effect of BNI activity in root tissue reflecting root turnover can be considered. The nitrification rates after 18 months of cultivation were positively correlated with the abundance of AOA in the soil but not with that of ammonia-oxidizing bacteria (AOB) (Fig. 3). The decrease in the number of AOA is the cause of the decrease in the nitrification rate. The study targeted soils collected between Brachiaria plants, so there is a possibility that

Fig. 1. Picture of field experiment

Table 1. Root amount and BNI activities in root exudates and root tissues of seven Brachiaria cultivars

Cultivar	Root amount	BNI activity in root exudate	BNI activity in root tissue
	kg DM ha^{-1}	ATU g^{-1} DM day^{-1}	ATU g^{-1} DM
Marandu	849	2.0	174.9
Basilisk	1,147	18.3	174.5
Kennedy	488	24.4	207.0
Mulato	648	7.0	200.5
Mulato II	855	7.0	202.8
Tupy	699	46.3	208.6
Tully	1,109	17.5	183.2

ATU (allylthiourea unit): The inhibitory effect from 0.22 μM AT in an assay containing 18.9 mM of NH_4^+

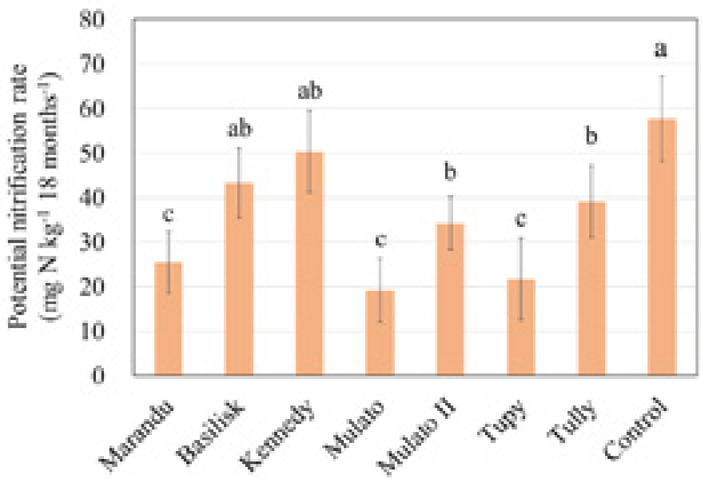

Fig. 2. Cumulative nitrification rate in each treatment
Error bar indicates standard error (n=3), different letters indicate significant differences by Tukey's HSD method.

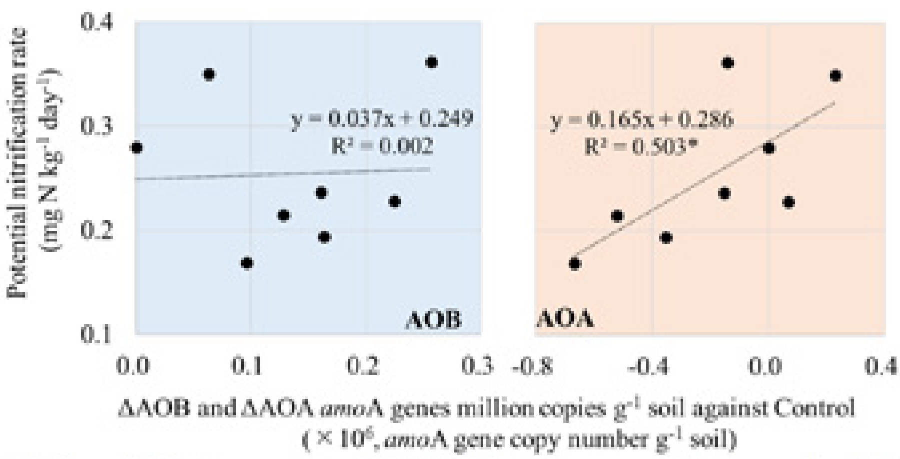

Fig. 3. Relationships between potential nitrification rates and changes in AOB and AOA against Control

stronger nitrification suppression occurs in the rhizosphere soil and in the vicinity of the plants.

From these results, the establishment of a crop rotation system utilizing Brachiaria can be expected because previous studies have reported an increase in subsequent crop yields after Brachiaria cultivation.

(S. Nakamura, P.S. Sarr, Y. Ando, G.V. Subbarao)

TOPIC 10

The optimum application patterns of phosphate rock direct application under several agroecological zones for rainfed lowland rice cultivation in West Africa

Phosphorus (P) is a finite resource that is difficult to reuse once it is released into the environment, in as much as P that is used in agriculture and flows into the ocean cannot be recovered. Studies for efficient P use in agriculture are being carried out internationally, especially in Africa where the use of local phosphate rock (PR) will be expanded as an affordable P resource. However, PRs in Africa are considered to be of low grade due to its low solubility and impurities such as quartz, iron, and aluminum, which are present in large amounts. Because local PRs are not sufficiently utilized, a solubility improvement technology through calcination has been studied (JIRCAS Research Highlights 2019). On the other hand, direct application of low-grade PR is expected to be effective in paddy rice cultivation, but the cultivation environment for rain-fed rice cultivation in Africa is diverse, and the application effect is uneven. Therefore, we investigated the effects of direct PR application in different agricultural ecological zones (AEZs) for rainfed rice cultivation for three years in West Africa and the optimum patterns for PR application with due consideration to the P use efficiency in each cultivation environment.

We have conducted PR application experiments in farmers' fields in three AEZs, namely, the Sudan Savanna Zone (SS), Guinea Savanna Zone (GS), and Equatorial Forest Zone (EF), representing the three cultivation environments of rainfed rice cultivation in West Africa. Table 1 shows the chemical properties of the surface soil of the

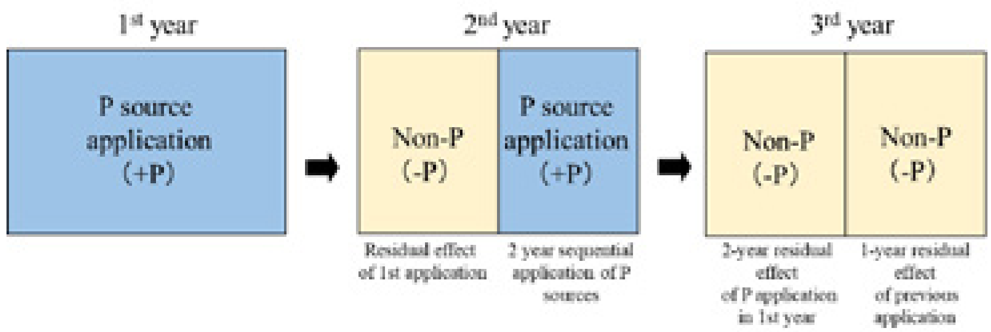

Fig. 1. Outline of phosphate rock direct application experiment

Table 1. Surface soil chemical properties under each agroecological zone

		Agroecological zone (AEZ)		
		SS	GS	EF
Annual precipitation	mm	800	1,100	1,350
pH (H_2O)		5.40	5.72	5.12
Available P	mg P kg^{-1}	1.90	8.51	4.99
Total C	g kg^{-1}	7.73	4.31	10.34
Total N	g kg^{-1}	0.58	0.41	0.82
Exchangeable Ca	cmolc kg^{-1}	2.48	1.88	5.11
Exchangeable Mg	cmolc kg^{-1}	0.93	1.11	2.01
Exchangeable K	cmolc kg^{-1}	0.18	0.15	0.24

SS: Sudan savanna (Burkina Faso, Saria), GS: Guinea savanna (Ghana, Tamale), EF: Equatorial Forest (Ghana, Kumashi)

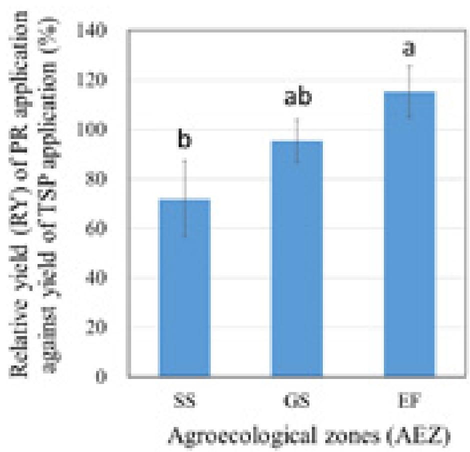

Fig. 2. First year application effect of phosphate rock under each agroecological zone
Error bars are standard error. Different alphabets indicate 5% significant difference by Tukey–Kramer method.

Table 2. Phosphate rock direct application effect with several application patterns under each agroecological zone

PR application patterns /Total phosphate application (kg P_2O_5 ha^{-1} 3 $years^{-1}$)				Averaged rice grain yield (t ha^{-1} $year^{-1}$)			Relative agronomic efficiency† (RAE %)			Phosphate use efficiency†† (kg kg $P_2O_5^{-1}$ $year^{-1}$)		
				SS	GS	EF	SS	GS	EF	SS	GS	EF
-P	-P	-P	0	2.42 c	2.02 c	3.63 b						
+P	-P	-P	135	2.79 b	2.67 b	5.02 a	20.3	62.6	96.5	8.3	14.4	30.9
+P	+P	-P	270	3.65 a	3.13 a	4.99 a	69.6	84.6	84.9	13.7	12.4	15.2
+P	+P	+P	405	3.85 a	3.12 a	5.02 a	63.9	77.2	89.4	10.6	8.2	10.3

"+P/-P" indicates with and without P application in each year. Different alphabets denote 5% significant difference by Tukey–Kramer method.

†Relative agronomic efficiency (RAE): (Yield in PR – Yield in Control)/(Yield in TSP – Yield in Control) × 100

†† Phosphate use efficiency: (Yield in PR – Yield in Control)/Annual phosphate application rate

rainfed paddy field in each AEZ. In each AEZ, a Non-P plot (NK), a PR direct application plot (PR), and a triple superphosphate application plot (TSP) was set up. Powdered PR obtained from the Kodjari deposit in Burkina Faso was used in this study. Each treatment plot was divided into a P continuous application plot and a residual effect plot in the second year. Non-P application was conducted in the third year (Fig. 1). In each year, rice grain yields and biomass were investigated.

Results showed that the yield ratio (RY) between the PR plot and the TSP plot increased in the order of SS < GS < EF with the difference in annual precipitation in the first application (Fig. 2). From the combination of fertilizer application frequencies surveyed, we selected one with high phosphorus use efficiency (PUE) and high relative agricultural efficiency (RAE) as the optimum application frequency for PR application in each AEZ. For SS and GS, "2 years continuous application following 1 year residual effect" and for EF, "1 year application following 2 years residual effect," the amount of PR application can be the minimum, and the same yield as the annual application can be obtained (Table 2).

(S. Nakamura, F. Nagumo, S. Tobita, M. Fukuda [Central Region Agricultural Research Center, NARO (CARC)], T. Kanda [Institute for Agro-Environmental Sciences, NARO (NIAES)], R.N. Issaka [CSIR-Soil Research Institute (SRI)], I.K. Dzomeku [University for Development Studies (UDS)], S. Saidou [Environment and Agricultural Research Institute (INERA)], M.M. Buri [SRI], E.O. Adjei [SRI], V.K. Avornyo [UDS], J.A. Awuni [UDS], A. Barro [INERA], D. Jonas [INERA])

TOPIC 11

Effect of rhizosphere soil addition on available phosphorus content in phosphate rock-enriched compost

The available phosphorus (P) content in sub-Saharan African soils is limited, representing a major constraint on agricultural productivity. Phosphoric fertilizers are used to correct soil phosphorus deficiency, but their high costs have prevented widespread adoption by African smallholder farmers. Phosphate rock, the primary material for manufacturing phosphoric fertilizer, is found in considerable quantities in several African countries, including Burkina Faso. Burkina Faso Phosphate Rock (BPR) is often co-composted with crop residues to enhance P availability through biological processes. Microbial materials are often used to promote P solubilization during the composting process, but it is difficult for many African farmers to obtain commercially available microbial inoculants. Here, we investigated alternative and smallholder farmer-friendly ways of improving P solubilization during composting by supplementing composts with rhizosphere soil as a microorganism source.

In this study, we prepared and monitored three compost types, sole compost, BPR-enriched compost, BPR-enriched compost + rhizosphere soil, for 180 days (Fig. 1). The C/N ratio was adjusted to 25/1 with urea, and the moisture content was maintained at 65% with regular watering. We examined the changes in available P fractions and the dynamics of P-solubilizing microbes, as well as the release of enzymes associated with P solubilization. At compost maturity (180 days), the combined number of P-solubilizing microbes (P-solubilizing bacteria = PSB and P-solubilizing fungi = PSF) in BPR-enriched composts was significantly higher in the treatment supplemented with rhizosphere soil (Fig. 2A). At this stage, the number of microbes producing P-solubilizing enzymes was also significantly higher in the BPR-enriched compost with soil (Fig. 2B). Among these microbes, those producing the alkaline phosphatase enzyme (phoD) were exponentially higher than those that release acid phosphatase and phosphonatase (data not shown). The available phosphorus in composts significantly correlated with P-solubilizing fungi and alkaline phosphatase that dominate the microbes and the enzymes, respectively (Fig. 3). We observed no positive correlation between phosphate-solubilizing bacteria (PSB) and available P. The available phosphorus content (inorganic and organic phosphorus extracted with sodium hydrogen carbonate and water) in the BPR-rock-enriched compost was equivalent until the 60th day after the start of the composting. However, on the 180th day, although the difference was not significant, the available phosphorus content of the compost with the rhizosphere soil tended to be higher than when it was not added (Fig. 4). This result indicates that rhizosphere soil is a promising microbial consortium source to promote phosphorus solubilization during the composting process.

We confirmed through sorghum field trials that BPR-enriched compost with rhizosphere soil leads to yields equivalent to that of chemical fertilizer (NPK).

Fig. 1. Composting trial

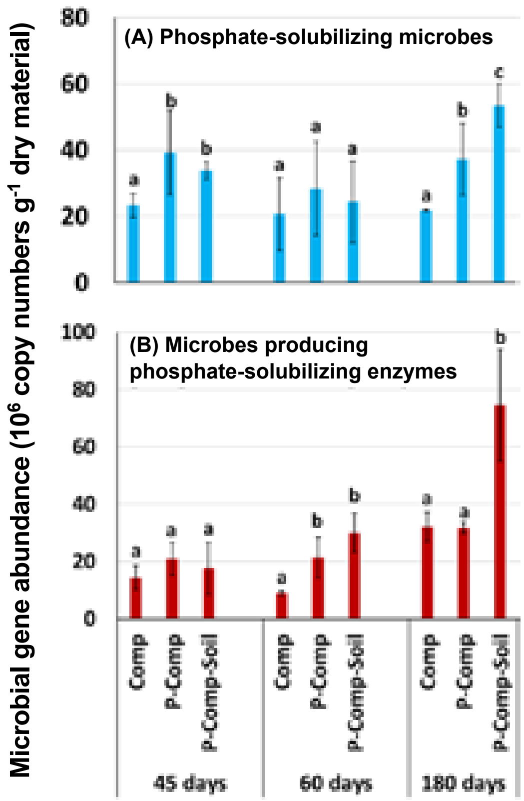

Fig. 2. Changes in the abundance of phosphate-solubilizing microbes and phosphate-solubilizing enzymes during composting
(A) Phosphate-solubilizing microbes = phosphate-solubilizing fungi + phosphate-solubilizing bacteria, (B) Phosphate-solubilizing enzyme-producing microbes = alkaline phosphatase-producing + acid phosphatase-producing + phosphonatase-producing microbes. Alphabets that differ in each sampling period show a significant difference at $p<0.05$ by one-way ANOVA.

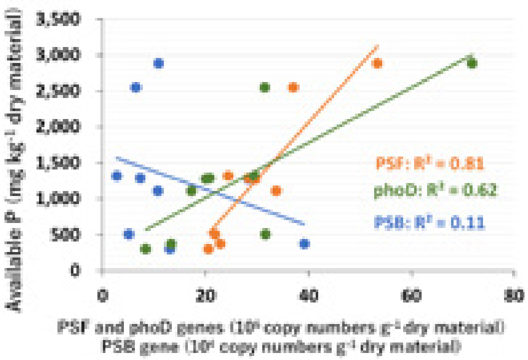

Fig. 3. Relationships between the amount of available phosphorus and microbial gene abundance during composting

●PSF: phosphate-solubilizing fungi,
●phoD: alkaline phosphatase-producing microbes,
●PSB: phosphate-solubilizing bacteria.
Sampling was performed on the 45th, 60th, and 180th day after the start of the composting. The data shown are the means for each type of compost over each period.

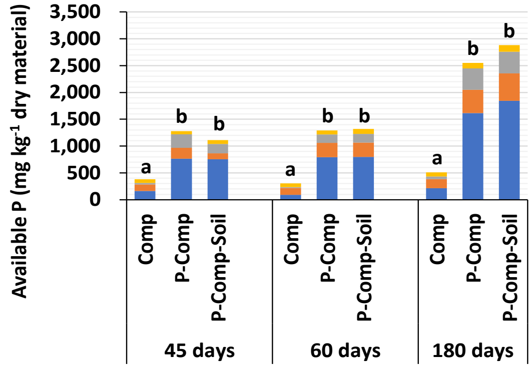

Fig. 4. Transition of available phosphorus fractions during composting

■$NaHCO_3$_Po: sodium bicarbonate-extracted organic phosphorus, ■$NaHCO_3$_Pi: Sodium hydrogen carbonate-extracted inorganic phosphorus, ■H_2O_Po: water-extracted organic phosphorus, ■H_2O_Pi: water-extracted inorganic phosphorus. At each period, different alphabets indicate a significant difference at $p<0.05$ following one-way ANOVA.

(P.S. Sarr, S. Nakamura,
M. Fukuda [NARO],
E.B. Tibiri, A.N. Zongo, E. Compaore [INERA])

Program B
Stable Agricultural Production

“Technology development for stable production of agricultural products in the tropics and other adverse environments”

In developing regions including Africa, agricultural production potential has not been sufficiently realized because of adverse conditions such as low soil fertility and drought. Consequently, food and nutrition security has remained a major challenge. This program, therefore, aimed to enhance agricultural productivity and improve nutrition in developing countries through technology development for stable production of agricultural products in the tropics and other adverse environments. To achieve our goals, we conducted the following four research projects.

[Food Security in Africa]

For the development of sustainable technologies to increase agricultural productivity and improve food security in Africa, we conducted three sub-projects for rice production enhancement, regional crop utilization, and crop-livestock integration. We focused on the following research in FY 2020. Regarding rice production enhancement, we carried out efforts for local evaluation of rice breeding materials and cultivation techniques suitable for sub-Saharan Africa, with the aim of disseminating the research findings on breeding materials that have shown efficient uptake of plant nutrition and on fertilizer application methods that have been developed to increase fertilizer efficiency. A model was also constructed to identify risk-efficient cropping strategies that can help secure food and income for smallholders in northern Ghana by utilizing the supplementary pond irrigation technology. The conditions for promoting the dissemination of the irrigation technology was also verified. Regarding regional crop utilization, we proposed and provided information on excellent genetic resources to partner institutions in order to promote the utilization of various yam and cowpea genetic resources. Furthermore, we proceeded with efforts to disseminate the developed technology and method for evaluating genetic resources. Regarding crop-livestock integration, we made a manual on the developed individual technologies related to silage and fermented total mixed ration (TMR). In addition, we provided an integrated crop-livestock farm management model for small holder farmers to researchers and extension workers in Mozambique.

[Environmental Stress-tolerant Crops]

For the development of breeding materials and basic breeding technologies for highly productive crops adaptable to adverse environments, we focused on the following research in FY 2020. We developed rice breeding lines in which the root length locus *qRL6.1* was introduced into local elite varieties, and conducted field adaptation tests. The agricultural traits of heading date near isogenic lines with the genetic background of IR64 were evaluated under field conditions. Rice lines combining the phosphate (P) uptake locus *Pup1* and a locus associated with P utilization efficiency were evaluated in fields without added P fertilizer. We also created promising soybean breeding lines in which the salt tolerance gene was introduced into local elite varieties in developing countries. Lastly, in order to develop new breeding techniques, we identified some useful molecular materials and mutants in rice and soybean.

[High-yielding Biomass Crops]

For the development of technologies for the breeding and utilization of promising high-yielding biomass crops in unstable environments, we focused on the following research in FY 2020. We selected breeding materials with excellent cane yield in ratoon cultivation from the intergeneric hybrid BC_2 of sugarcane and *Erianthus* in a less fertile sandy soil area in Northeast Thailand. We clarified the hybridism in intergeneric hybrids of sugar cane and *Erianthus* by using SSR markers. Furthermore, the dry matter yield of *Erianthus* at the third ratoon cultivation was measured and nutrient balance in the field was evaluated.

[Pest and Disease Control]

For the development of technologies for the control of migratory plant pests and transboundary diseases, we focused on the following research in FY 2020. We investigated natural enemy species against rice planthoppers in Vietnam and analyzed data on the mating behavior of desert locusts in the solitarious and gregarious phases. We published a manual for the production of healthy seed canes (in Thai and English) to control sugarcane white leaf disease. Promising lines were selected from the hybrid population into which field resistance genes to rice blast were introduced. We selected genetic materials resistant to Cercospora leaf blight from a soybean collection set to develop resistant varieties.

Introducing a quantitative trait locus, *MP3*, improves rice panicle numbers in nutrient-poor soils

The majority of paddy fields in sub-Saharan Africa (SSA) are characterized by nutrient-poor soils. In such fields, tillering in rice plants is severely restricted, which results in a reduced number of panicles and thus a decrease in grain yield. Therefore, genetic improvement to increase rice tillering may ensure sufficient panicles in nutrient-poor soils and thus lead to increase in rice productivity. Because we previously detected a quantitative locus, *MP3* (*MORE PANICLES 3*), to be effective at increasing the number of panicles in nutrient-rich fields, we expected that *MP3* will also be effective in enhancing rice productivity in nutrient-poor soils.

In this study, we used a high-yielding *indica* cultivar, Takanari, and its near-isogenic line bearing the *MP3* allele derived from a *japonica* cultivar, Koshihikari (NIL-*MP3*). They were first grown in pots that contain nutrient-poor soils from Madagascar at various P application rates. The pot experiment demonstrated vigorous tillering in NIL-*MP3* compared to Takanari from the early vegetative stage even under low P levels (Fig. 1). We next conducted multiple field trials in Madagascar with a total of 12 experimental conditions using the two varieties. The experiments produced grain yields ranging from 1.3 to 4.1 t ha^{-1} and panicle numbers ranging from 107 to 270 m^{-2}. The results revealed that NIL-*MP3* produced a greater number of panicles and spikelets m^{-2} (19% and 12%, respectively) than Takanari, with grain yields ranging from 2.0 to 4.1 t ha^{-1}, but not in extremely low yield environments (< 1.3 t ha^{-1}) (Fig. 2).

The results of this study indicate that *MP3* is effective at increasing the number of panicles in nutrient-poor soils in SSA. However, utilization of *MP3* in conjunction with fertilizer management may be necessary in extremely low

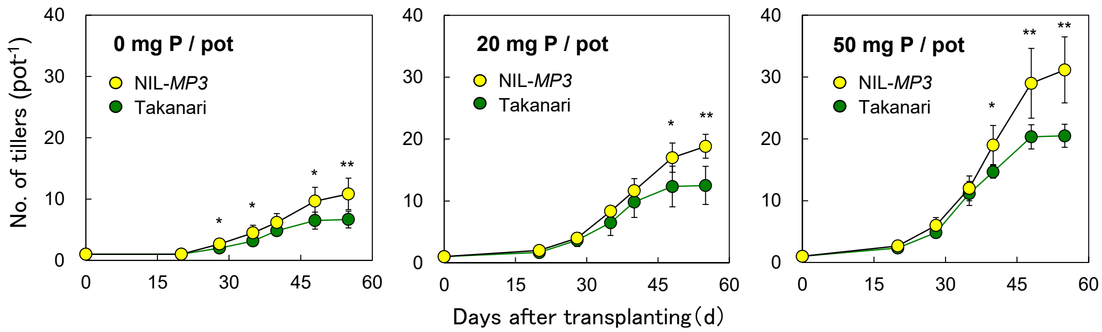

Fig. 1. Changes in the number of tillers between Takanari and NIL-*MP3* grown in pots that contain nutrient-poor soils in Madagascar at various P application rates.
** and * show significance at 1% and 5% levels, respectively.

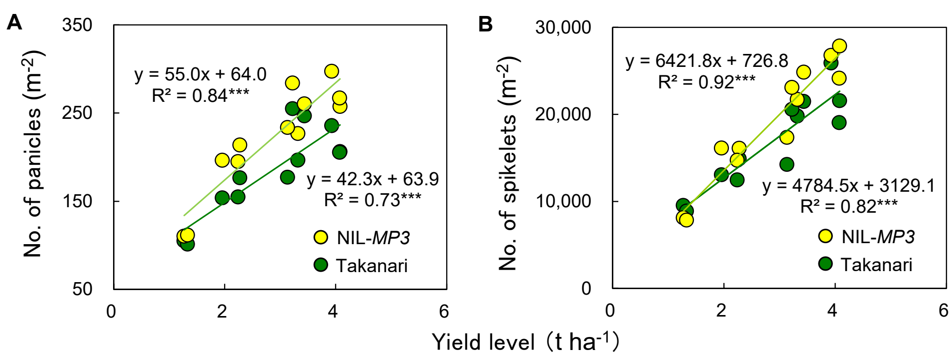

Fig. 2. Comparison of the number of panicles (A) and spikelets (B) between Takanari and NIL-*MP3* across 12 field experiments in Madagascar
Yield level shows mean yield between Takanari and NIL-*SPIKE* in each experiment.
*** shows significance at 0.1% level.

yield environments (< 1.3 t ha^{-1}). We are currently introducing *MP3* into a local Madagascar cultivar, X265, which is adapted to the environments in SSA, to verify the effect of *MP3* on grain yield in such environments.

(T. Takai, Y. Tsujimoto, H. Asai, T. Nishigaki, T. Ishizaki, M. Sakata [Kochi University], N. Rakotoarisoa [National Center of Applied Research on Rural Development, Madagascar])

TOPIC 2

Dipping rice seedlings in phosphorus (P)-enriched slurry at transplanting increases yield and avoids cold stress under P-deficient soils in the tropics

Phosphorus (P) deficiency is a major yield constraint for lowland rice production in Sub-Saharan Africa. Plant P uptakes are restricted not only by low P content in soils but also by high P-fixing capacity with abundant Al- and Fe-oxides in soils in the region. To overcome this constraint, we examined the effect of dipping seedling roots into a P-enriched slurry before transplanting (P-dipping) as shown in Figure 1.

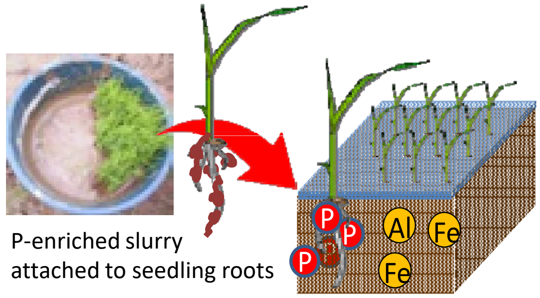

Fig. 1. An illustration of the P-dipping technique

First, we identified that initial rice growth can be substantially improved by the P-dipping (Fig. 2). The optimal duration of dipping and the P concentration in the slurry are less than 2

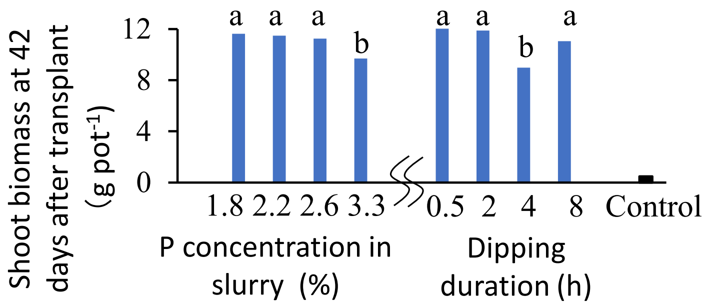

Fig. 2. Effect of P concentration in slurry and duration of P-dipping on initial plant growth

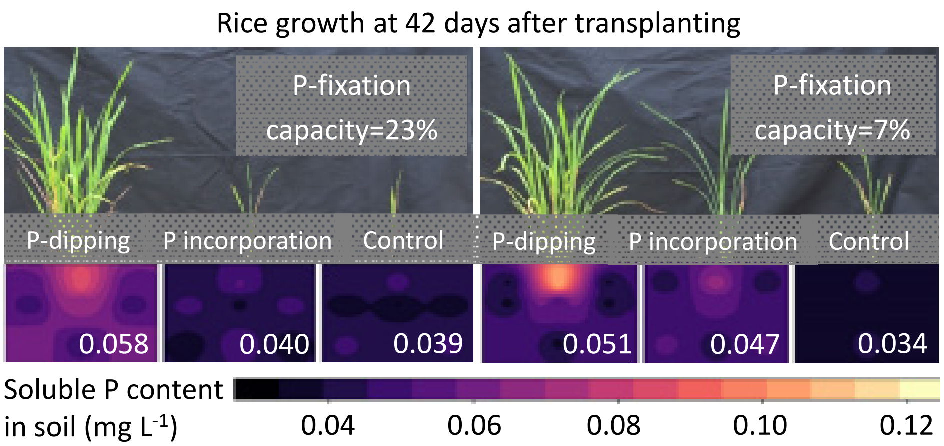

Fig. 3. Effect of P-dipping on plant growth and spatial distribution of soluble P content in the soils differing in P-fixing capacity
Both P-dipping and P incorporation treatments applied P at 40 mg pot^{-1}. The numeric number in the spatial map indicates the average soluble P content (mg L^{-1}) in the pot.

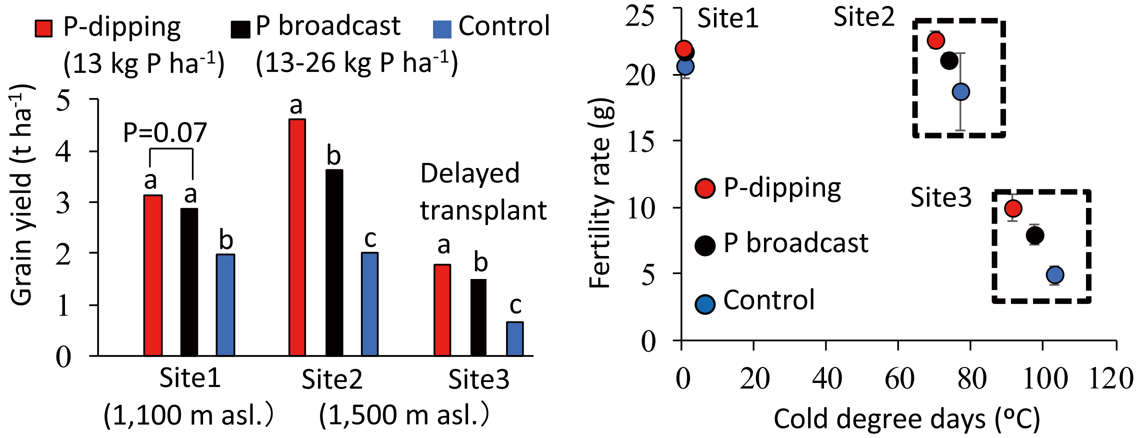

Fig. 4. Effect of P-dipping on grain yield and on cold degree days and fertility rate
Cold degree days is the sum of daily mean temperatures below 22ºC from 15 days before to 7 days after heading. Fertility rate is the product of filled grain weight and filled grain rate.

hours and 1.8%–2.6%, respectively. We further clarified that P-dipping can facilitate plant P uptakes by creating a soluble P hotspot at the plant base or near the root zone even in high P-fixing soils where P incorporation has no effect on rice growth (Fig. 3). Then, subsequent on-farm trials confirmed that P-dipping can significantly increase both grain yield and applied P use efficiency in the typical P-deficient lowlands of Madagascar (Fig. 4). The effect of P-dipping was particularly significant at a high-elevation and cool climate site, where the improved grain fertility is attributable to the avoidance of cold stresses at the reproductive stage because the technique shortens days to heading by 14 days compared to control (no fertilization) and by 6 to 9 days compared to conventional P application via broadcast.

Because lowland rice production in Sub-Saharan Africa is widely subjected to environmental stresses such as low temperature, water shortage at the end of the rice growing seasons, and highly P-deficient soils, P-dipping can be an efficient P fertilization technique for resource-limited farmers in the region.

(Y. Tsujimoto, A.Z. Oo, K. Kawamura, T. Nishigaki, N. Rakotoarisoa [FOFIFA])

TOPIC 3

Selection of a Diversity Research Set to facilitate efficient genetic and breeding studies of Guinea yam (*Dioscorea rotundata*)

Yam, the common name for crop species belonging to the genus *Dioscorea*, is widely cultivated as a staple crop in tropical and sub-tropical regions. West Africa, which accounts for 95% of the world's annual yam production (approximately 54 million tons) recognizes the important role of yam in regional food security and income generation. Guinea yam (*D. rotundata*, Fig. 1) is the most cultivated species in this region, representing majority of the total yam production. While *D. rotundata* is one of most important crops in West Africa due to its long growth cycle, large plant size, dioecy, inconsistent flowering habit, polyploidy, and a high level of heterozygosity, activities related to genetic research and breeding have been limited. To facilitate efficient utilization of plant genetic resources and promote genetic research and breeding of this crop, the *Dioscorea rotundata* Diversity Research Set (DrDRS) was developed. The DrDRS is a subset with a small number of accessions representing the genetic diversity of a core collection of *D. rotundata* accessions, the largest collection of this species worldwide.

In general, the so-called "non-redundant collection" such as Diversity Research Sets representing the genetic diversity of the original collection plays a vital role in facilitating efficient utilization of plant genetic resources. This is particularly relevant for vegetatively propagated large plant size tuber crops with a long growing period such as *D. rotundata*, to enable researchers to conduct detailed research more efficiently. In this study, a total 102 accessions were selected as

Fig. 1. Cultivation of Guinea yam in West Africa (left) and harvested tubers (right)

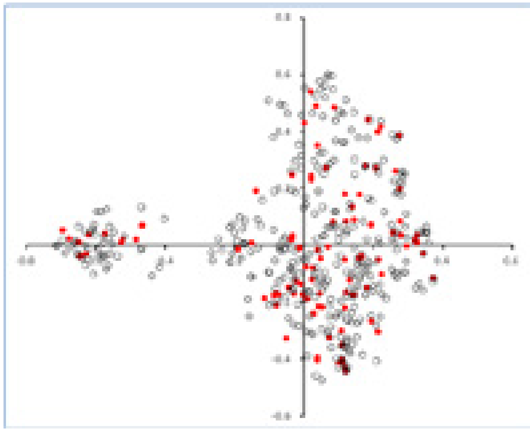

Fig. 2. Distribution of base collection (open) and DrDRS (red) on the principal coordinate analysis plot based on SSR variation

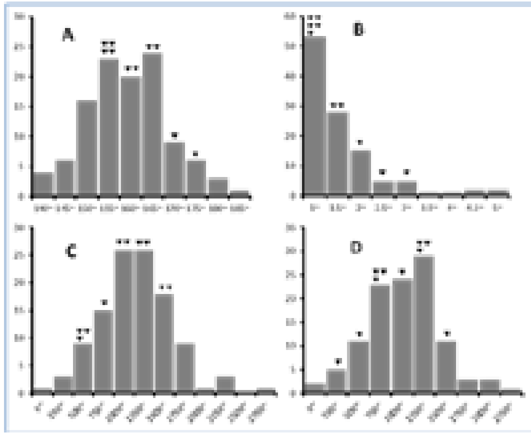

Fig. 3. Variation of basic agronomic traits in DrDRS
A: Growth period (days to harvest), B: Number of tubers per plant, C: Yield per plant (g), D: Average tuber weight (g)
Arrowhead: distribution of ten IITA breeding materials

Table 1. Genetic diversity indices in base collection and DrDRS through analysis of 16 SSR markers

	Na	*Ho*	*He*	PIC
Base (n=447)	96	0.373	0.583	0.549
DrDRS (n=102)	94	0.383	0.563	0.529

Na: number of alleles, *Ho*: observed heterozygosity, *He*: expected heterozygosity, PIC: polymorphic information

DrDRS from the available 447 accessions, which serve as the base collection and are maintained at the International Institute of Tropical Agriculture (IITA), using the simple sequence repeat (SSR) markers we developed (JIRCAS Research Highlights 2015, B05). DrDRS retains the same level of genetic diversity as the base collection (Fig. 2 and Table 1). The average Shannon's diversity index with respect to 21 morphological traits of DrDRS and base collection (1.138 and 1.114, respectively) suggested that a similar level of morphological diversity was also captured within the DrDRS. The accessions of DrDRS showed a wide range of variation in basic agronomic traits such as growth period, number of tubers per plant, yield per plant, and average tuber weight. This variation was considerable when compared with the variation observed among the 10 lines/genotypes conventionally used in the breeding program at IITA (Fig. 3).

The DrDRS accessions could serve as a working collection to broaden the genetic variation for use in practical breeding programs as well as in future genomic analyses using the genome information of *D. rotundata* (JIRCAS Research Highlights 2017, B02) aimed at the genetic improvement of *D. rotundata* in West Africa. The DrDRS is expected to facilitate the development of excellent varieties that make effective use of the wide range of genetic diversity of this crop.

(S. Yamanaka, S. Muranaka, H. Takagi, B. Pachakkil [Tokyo University of Agriculture], G. Girma, R. Matsumoto, R. Bhattacharjee, M. Abberton, R. Asiedu [International Institute of Tropical Agriculture], M. Tamiru-Oli, R. Terauchi, [Iwate Biotechnology Research Center])

Variety selection for improving cowpea production under multi-environmental conditions in the Sudan Savanna

Cowpea (*Vigna unguiculata* (L.) Walp) is a legume crop widely grown in West Africa. Farmers traditionally cultivate cowpea as a low-cost and high-quality protein source and as a major cash crop. The primary production area is located between 600 and 900 mm yr^{-1} isohyet, which roughly corresponds to the semi-arid region in the Sudan Savanna. However, the average yield is substantially below the biological potential, and yield vulnerability has been a cause of food insecurity in this region. One of the yield constraints is unstable meteorological conditions, especially low precipitation, causing drought stress. However, the occurrence of agricultural drought is not only determined by precipitation but also by soil type. Therefore, both climate and soil type should be considered in genotype selection and distribution.

To identify environmental and plant factors underlying this yield variation and select cowpeas with a stable yield, the grain yield variation of 16 cowpea genotypes in three dominant soils in the Sudan Savanna (Fig. 1) were analyzed in two consecutive years with different precipitation levels. In this study, the three soils were located near each other at the experimental site and thus the meteorological conditions were assumed to be identical for the soil types. The result showed that grain yield was largely different between years even for the same soil type, indicating no single genotype achieved both stable and high yields across these soil types (Fig. 2). In 2016, which had higher precipitation than the average year, variety J showed the highest grain yield across all soil types, while in 2017 with normal precipitation, different varieties showed the highest grain yield depending on the soil type. Based on this result, environment was defined as each combination of year and soil type, and this was subsequently analyzed through an additive main effect and multiplicative interaction (AMMI) model to detect the effects of the environment, genotype, and genotype-environmental interaction (GEI) on grain yield variation. The AMMI model uncovered two cowpea genotypes with stable and higher basal yields across all environments (variety G and variety P in Fig. 3); however, the grain yields of these genotypes were not the highest in each environment. Selection of a genotype with a medium but stable yield would be favorable to improve long-term average yield in the Sudan Savanna, where multiple soils with a large GEI are distributed in mosaic patterns.

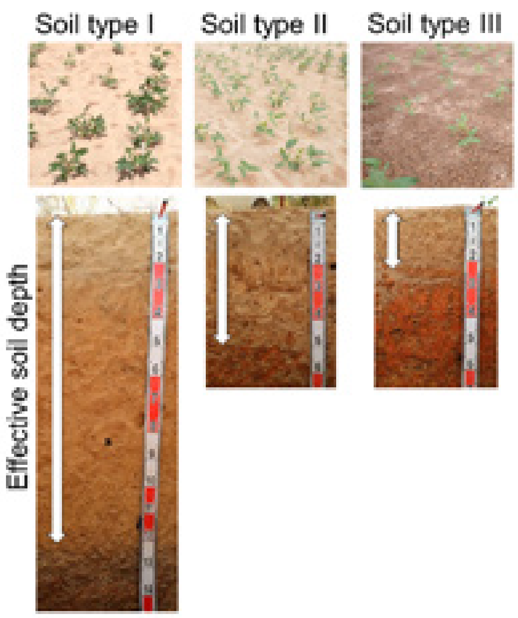

Fig. 1. The three predominant soil types in the Sudan Savanna
Each soil type has a different effective soil depth (rooting depth represented by the arrows). Soil type I > type II > type III in terms of soil depth, soil fertility, and water retaining capacity.

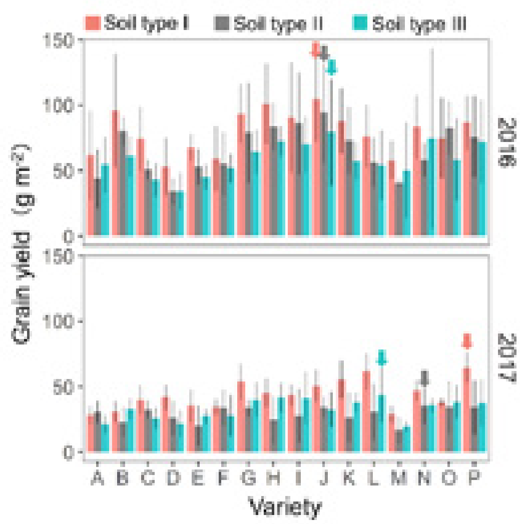

Fig. 2. Grain yield of the 16 cowpea varieties (A-P) used in this study
Bars are means ± standard deviations for five replications. The arrows indicated the variety of highest grain yield at each of the soil type. Annual precipitation was 999 mm and 795 mm in 2016 and 2017, respectively.

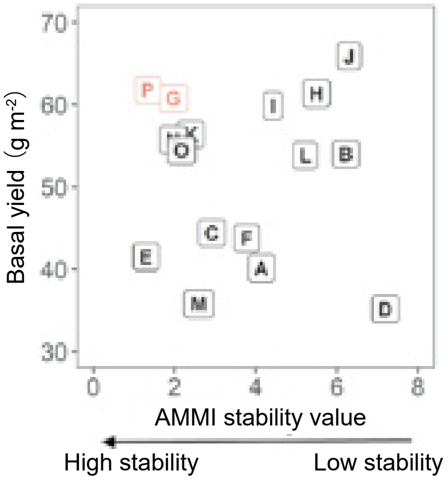

Fig. 3. Yield stability of the 16 varieties under the environments defined by the soil types and annual precipitations
The x-axis represents the AMMI stability value. The varieties with lower values have higher yield stability among the environments. The y-axis represents the genetically determined basal yield of each variety. The varieties G and P indicated by the red color have higher stability and higher basal yield at the same time.

The variety selection process employed in this study could be applied also for other regions with different annual precipitation in the Sudan Savanna where the three soil types investigated in this study are widely distributed, although historical cultivation data including sufficient annual rainfall variation is needed for analysis. This method reveals cowpea varieties or genotypes with stable yields for each of the environment and enables increase of cowpea production on a long-term-basis. To further improve cowpea production, appropriate cultivation practices such as fertilizer application and ridge planting may be determined depending on the soil type.

(K. Iseki, K. Ikazaki, J.B. Batieno [National Institute of Environment and Agricultural Research])

TOPIC 5

Feeding of fermented TMR prepared with local feed resources improves milk production and profitability in Mozambique

In Sub-Saharan Africa, feed shortages during the dry season are a major factor restricting livestock production. In Mozambique, which is located in Southern Africa, ruminants graze mainly on native grasslands and are customarily raised in combination with supplementary feeding of crop residues. However, this feeding method could not meet the nutritional requirements of dairy cows, and feeding them low-quality roughage adversely affects milk production. Therefore, locally available feed resources are expected to be used for preparing fermented total mixed ration (TMR) and improving livestock raising methods to promote the revitalization of local animal husbandry and improve the livelihoods of local people.

Fermented TMR was prepared in Mozambique with locally available feed resources including grass, crop by-products, and formulated feed using the simple plastic bag storage method (Fig. 1). Ten Jersey dairy cattle aged 3 to 4 years old with an average weight of 336.6±19.8 kg were used for a livestock feeding experiment. Fermented TMR prepared with Napier grass (*Pennisetum purpureum* Schmach), corn bran, wheat bran, and formula feed, was found to be rich in nutrients such as crude protein and crude fat, and can meet the nutritional needs of Jersey

Fig. 1. Preparation (left), storage (middle), and dairy cattle feeding (right) on fermented TMR

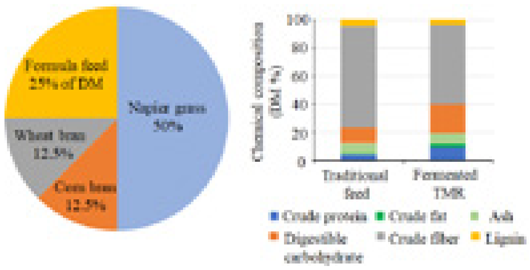

Fig. 2. Ingredients (left) and chemical composition (right) of fermented TMR
Digestible carbohydrate = carbohydrate – crude fiber – lignin

Table 1. Fermentation quality of TMR after 14 days of ensiling

	Evaluation criteria	TMR material	Fermented TMR
pH	<4.2	6.2	3.9
Lactic acid, FM %	≧1.0	ND	1
Acetic acid, FM %	-	ND	0.3
Propionic acid, FM %	ND	ND	ND
Butyric acid, FM %	ND	ND	ND
Ammonia-N, FM %	<0.05	ND	<0.01

ND: not detected, FM: fresh matter

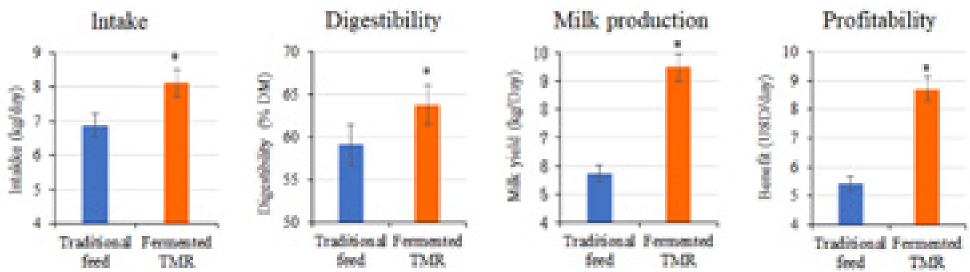

Fig. 3. Performance of dairy cattle fed traditional feed and fermented TMR
*Means of five cattle differ significantly (p<0.05).

dairy cattle (Fig. 2). After 14 days of fermentation, the pH value of the fermented TMR was as low as 3.9, the ammonia nitrogen content was less than 0.01% of fresh material (FM), butyric acid and propionic acid were not detected, while lactic acid was produced in FM 1.0%. According to the criteria for evaluation of silage, the fermented TMR showed good fermentation quality (Table 1). Compared with the traditional diet, dairy cattle fed with TMR had better palatability, and the intake, dry matter digestibility, milk production, and profitability were significantly (p<0.05) improved (Fig. 3).

As an application of this result, the available sealing materials and feed resources can be used to prepare fermented TMR in other tropical and subtropical regions during the rainy and dry seasons. By using TMR to improve the feeding method of dairy cows, milk production can be stably increased. One thing to keep in mind is that when the TMR prepared by this simple preparation method is stored for more than one month, it is necessary to pay attention to the occurrence of aerobic deterioration caused by damage to the plastic bag. In this study, only fermented TMR with high-moisture Napier grass as the main component was prepared, so it is necessary to compare and analyze the feeding effects of fermented and non-fermented TMR on dairy cows. In addition, these results are limited to the improvement of raising methods, and other factors that hinder the promotion of dairy farming, such as hygiene management, disease control, and breeding management require other improvement efforts.

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TOPIC 6

An integrated crop-livestock farm management model that can meet the reproductive conditions of dairy cattle in Mozambique

In southern Mozambique, development programs have promoted the provision of exotic dairy cattle coupled with technical and marketing assistance to smallholder farmers to complement their cropping activities, improve income, and meet the increasing demand for milk products in the country. However, sustainable dairy production and integration with crop production is still limited. This study unravels the major constraints to sustainable dairy cattle farming in the Manhiça district of Maputo Province, where Jersey cattle was imported from South Africa and offered to farmers through development programs. To support farmers in making decisions, the study also develops an integrated crop-livestock farm management model to efficiently secure food and feed and improve income through crop-dairy interactions.

In addition to the three conditions regarding farmers' demands for food, risk management, and non-farm activities integrated into "A farm management model for assisting smallholder farmers in Africa" (https://www.jircas.go.jp/en/publication/research_results/2018_b02), the model developed in this study integrates the following conditions regarding dairy production: adequate feed supply that can satisfy the nutrient requirements of dairy cattle, proper herd structure that enables animal reproduction, and sufficient shed space (Fig. 1). Using a mixed integer programming method, the model is designed to simultaneously identify the optimal cropping system and dairy herd size to maximize total farm income while meeting food and feed requirements. From a structured questionnaire survey of all dairy cattle farmers in the Manhiça district (70 households), we found that the farmers face considerable difficulty in establishing a reproductive cycle due to high mortality and long calving interval of dairy cattle caused by infectious diseases and lack of artificial insemination (Fig. 2: red). The results of the model analysis applied

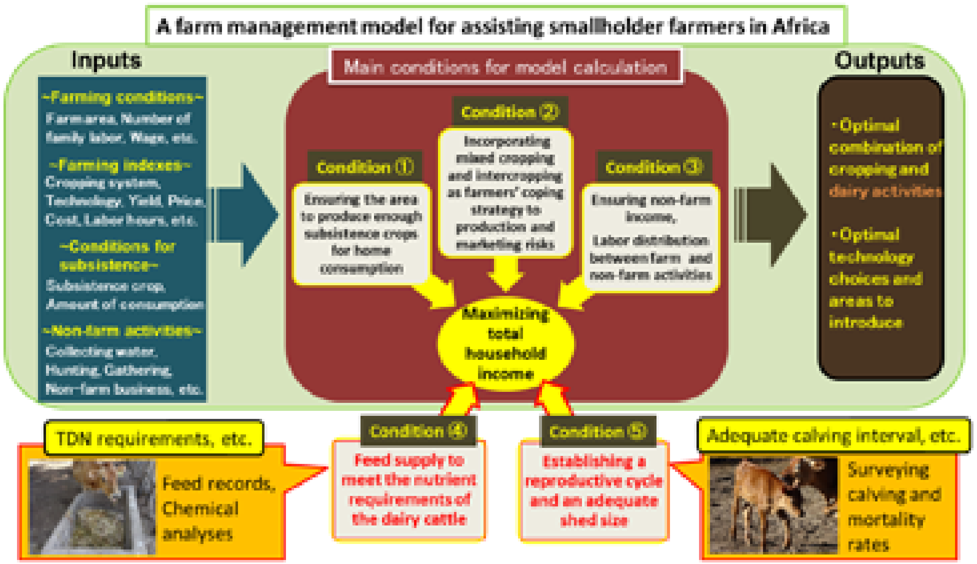

Fig. 1. An integrated crop-livestock farm management model developed in this study

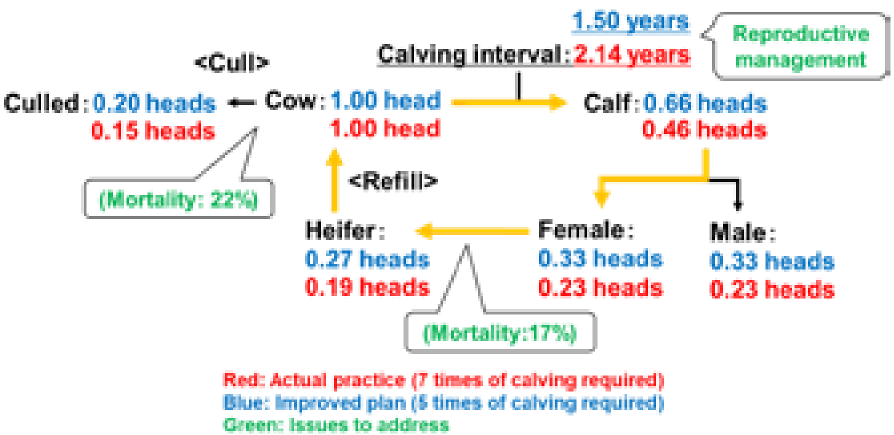

Fig. 2. Reproductive conditions of dairy cattle in the Manhiça district

Under the current conditions (red), for every heifer, 0.19 cows are refilled for succession per year, while 0.15 cows are culled given the mortality rate during the service (22%). This situation calls for seven offspring to maintain the herd, which takes about 15 years of service life with a calving interval of 2.14 years. If the calving interval is reduced to 1.5 years by reproductive improvement (blue), the required calving number becomes 5, and the service life is reduced to 7.5 years.

Table 1. Optimal cropping system and dairy herd size of a representative farm in the Manhiça district

		Actual	Optimal
Cropping (ha)	Cassava+Maize+Cowpea+Peanut+ Pumpkin mixed cropping	0.22	0.24
	Maize+Cowpea+Peanut mixed cropping	0.33	0.32
	Maize+Sweet potato+Sugar cane+ Pumpkin mixed cropping	0.48	0.70
	Maize+Sugar cane+Banana+Pumpkin mixed cropping	0.28	0.89
	Others	0.84	0
Dairying (head)	Jersey cow	1	3
	Jersey heifer calf	3	1

Actual: Actual crop and dairy farming by the farm
Optimal: Optimal crop and dairy farming identified by the model

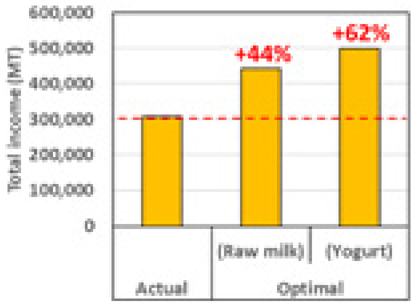

Fig. 3. Expected income increase by introducing optimal cropping system and dairy herd size
Actual, Optimal: Same as Table 1
MT: Metical (currency of Mozambique)
Rate of income increase is indicated above the bars.

to a representative dairy farm in the district show that once the calving interval is significantly shortened by reproductive improvement (Fig. 2: blue), the farm can keep three cows and one heifer calf and feed them enough to maintain actual productivity through effective use of crop residues, while producing enough food to meet household demands. Compared to actual farming, optimal crop-dairy farming (Table 1) will increase total income by 44%, or by 62% if the farm additionally processes the harvested raw milk into yogurt (Fig. 3).

The developed model can be used to i) support farmers' decisions to improve dairy cattle keeping and integration with crop enterprises, ii) support policy decisions to finance health and reproductive improvements of dairy cattle by informing the expected economic benefits to farmers, iii) identify the optimal dairy-crop interactions using newly developed cropping and/or feeding technologies along with their likely impacts on farmers' food security and income status.

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TOPIC 7

Key metabolites for estimating phosphorus use efficiency in rice

Phosphorus (P) is an indispensable macronutrient for plants, and it is widely applied as fertilizer to crop fields. However, the overuse of P fertilizers causes problems such as eutrophication of water bodies and depletion of P reserves on earth. In contrast, insufficient amounts of P fertilizers are often applied in developing countries due to their high cost. The development of more P-efficient crop varieties offers one avenue to increase yield in such environments. In our previous study, P use efficiency was investigated in a wide range of rice accessions collected from different regions of the world. This screening identified characteristic *Indica* rice accessions contrasting in P use efficiency, e.g., Taichung and IR64 (one of the major rice varieties in the world) have low P use efficiency, while Mudgo

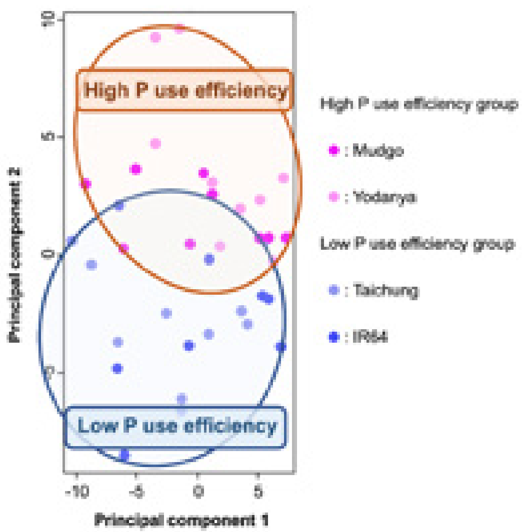

Fig. 1. Metabolite profile of rice varieties contrasting in P use efficiency
Result of principal component analysis based on the foliar metabolite content of the plants grown under P-deficient condition is shown.

and Yodanya have high P use efficiency. In the current study, we hypothesized that P-efficient varieties have characteristic metabolic profiles that enable efficient use of P. To identify potential metabolites associated with high P use efficiency, plants were grown in a hydroponic culture containing different concentrations of P, and metabolic profiles were analyzed.

Based on the metabolomics data, a principal component analysis was conducted (Fig. 1). Under the P-deficient condition, metabolite profiles between the two groups (i.e., P-efficient and P-inefficient) were clearly separated, indicating that P-efficient and P-inefficient varieties have characteristic metabolite signatures. We next aimed at identifying key metabolites that distinguishes the P-efficient and P-inefficient variety groups. Our statistical analyses using LIMMA and ANOVA indicated key metabolites whose abundance is significantly different between the two groups. Notably, these metabolites were previously unassociated with P metabolism, implying that identification of these metabolites may shed light on basic molecular mechanisms of P use efficiency in rice. We further adopted a logistic Ridge regression model, which is a multi-variate analysis to predict a binary classification, and demonstrated that these key metabolites are indeed effective in predicting P use efficiency. Based solely on the contents of 14 key metabolites (such as benzoate and threonine; Fig. 2), P use efficiency (high or low) of 7 other rice varieties could be predicted successfully.

This study identified characteristic metabolite signatures for P-efficient varieties, whose usefulness was further validated through logistic regression analysis. Because analyses of P use efficiency from a large number of plants are cumbersome, identification of these key metabolites shall accelerate the selection of P-efficient accessions without the need for actual assessment of P use efficiency, and thus, boost rice breeding targeting efficient use of P. Based on the result of this study, we suggest that 1) metabolites serve as important molecular markers for complex trait that is difficult to assess, and 2) phenotypes can be predicted through combination of metabolite analysis and statistical modeling. In addition, the key metabolites may serve as the basis for further elucidation of the molecular mechanisms for P metabolism and P use efficiency.

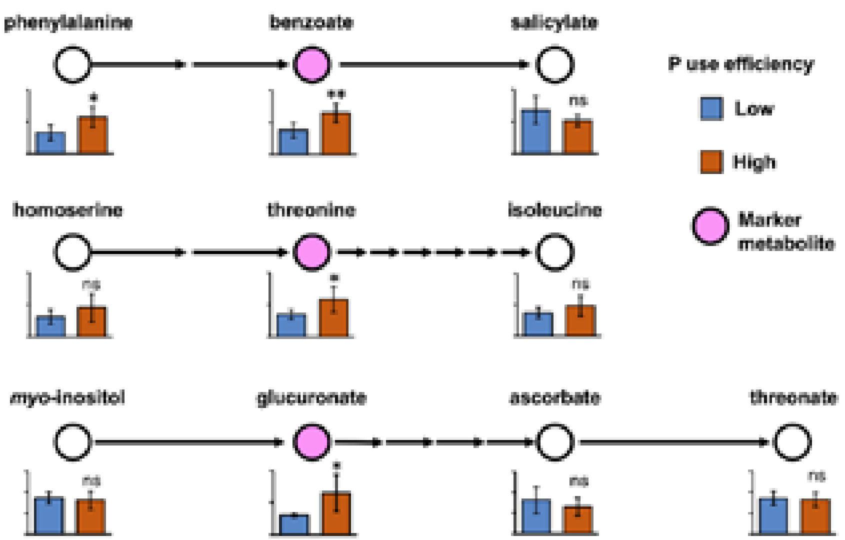

Fig. 2. Marker metabolites for P use efficiency and related metabolic pathways
Examples of metabolic pathways involving marker metabolites and their relative contents are shown. ** and * indicate statistical significance at 1% and 5% levels (by *t* test).

(M. Wissuwa, Y. Ueda, K. Kondo [Research Institute of Rice Production & Technology Co., Ltd.], M. Watanabe, T. Tohge [Nara Institute of Science and Technology], S. Ishikawa [Institute for Agro-Environmental Sciences, NARO], A. Burgos, Y. Brotman, A.R. Fernie, R. Hoefgen [Max Planck Institute of Molecular Plant Physiology])

Genetic and phenotypic variation of agronomic traits and salt tolerance among quinoa inbred lines

Chenopodium quinoa (quinoa) has been recognized as a key crop with great potential for improving global food security due to its outstanding nutritional properties and ability to tolerate abiotic stresses such as drought and high salinity. However, a genome complexity derived from allotetraploidy and a genetic heterogeneity resulting from partial outcrossing have hampered genetic analysis of quinoa over the years. We established a standard inbred quinoa accession Kd and were first in the world to provide the draft genome sequence (2016 Research Highlights: Draft genome sequence of an inbred line of *Chenopodium quinoa*, an allotetraploid pseudocereal crop with high nutritional properties and tolerance to abiotic stresses). Moreover, an understanding of the genotype-phenotype correlation between comprehensive inbred lines will bring about advances in molecular breeding and research due to the molecular elucidation and genetic improvement of quinoa.

To evaluate genetic diversity in quinoa, we genotyped 5,753 single nucleotide polymorphisms (SNPs) in 136 inbred lines using Genotyping-by-Sequencing (GBS) based on next-generation sequencing. Our quinoa inbred lines were classified into three genetic sub-populations, corresponding to northern highland, southern highland, and lowland sub-populations using STRUCTURE, a neighbor-joining phylogenetic and principal component analysis. We also assessed salt tolerance and important growth traits (1,000-grain weight, plant height, stem diameter, leaf dry weight, seed yield per plant, and days to flowering) and generated a heatmap that provides a succinct overview of the genotype-phenotype relationship between inbred quinoa lines. Most lowland and southern highland lines were able to germinate even under high salinity conditions. In addition, most lowland lines displayed larger plant sizes and late flowering phenotypes, indicating that lowland lines are more suitable for growth in a temperate climate than the other lines.

The heatmap of the phenotypic traits, combined

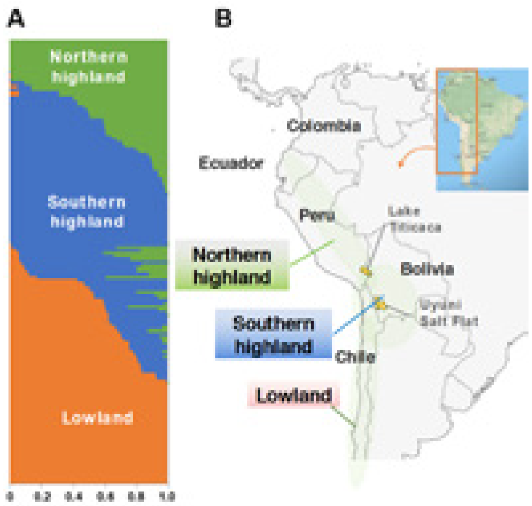

Fig. 1. Population structure of quinoa inbred lines based on SNP genotype data
(A) Each quinoa line's genome is represented by each bar on the y-axis, and the colors of the bar indicate the proportion of estimated membership in the three sub-populations. Lines having <80% of inferred ancestry from any one group are identified as an admixture. (B) Distribution of quinoa grouped into northern and southern highland and lowland sub-population in South America

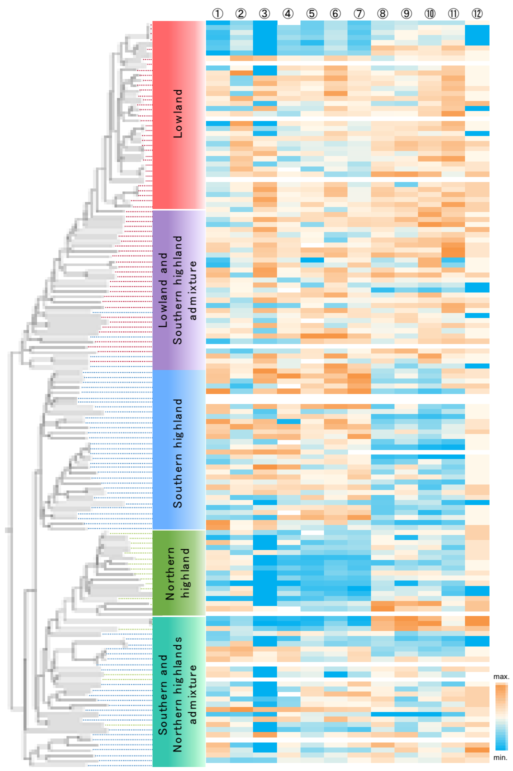

Fig. 2. Heatmap of the phenotypic traits combined with the phylogenetic tree of quinoa inbred lines
①-③: the average total hypocotyl and root length (mm) of seeds treated with 0, 300, and 600 mM of NaCl for 24 hours, 4 days, and 16 days, respectively; ④-⑦: thousand grain weight (g) during 2014-15 (Tsukuba), 2015-16 (Tsukuba), 2016 (Tsukuba), 2016-17 (Tottori); ⑧: plant height (cm); ⑨: stem diameter (mm); ⑩: leaf dry weight (g); ⑪: seed yield per plant (g); ⑫: days to flowering

with the phylogenetic tree, provides quick access to the genotype-phenotype state of each quinoa line. We will therefore be able to accelerate the development of climate-resilient quinoa through efficient molecular breeding and research.

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TOPIC 9

A behavior-predictive model based on thermoregulatory behavior of the desert locust in Africa

There is an urgent need to develop better forecasting capacities so we can anticipate how species of economic importance will respond to environmental change. Pest insects are one of the most economically important groups of species requiring forecasting capacity. Any efforts to predict environmental constraints on the behavior, distribution, and abundance of terrestrial ectotherms such as insects must adequately capture how environment and behavior interact to determine body temperature, because virtually all biological processes are temperature-dependent. This is a significant challenge due to the complex, nonlinear responses of heat exchange between organisms and their microclimates, but it is possible to compute such responses from first principles using techniques in biophysical ecology.

The desert locust, *Schistocerca gregaria*, is one of the world's most destructive pest insects. Sometimes, desert locust populations grow explosively, forming swarms and causing locust plagues. A plague can affect up to 20% of the earth's surface across Africa, the Middle East, and Southwest Asia. Desert locusts can potentially damage the livelihoods of a tenth of the world's population. The preventive approach seeks to monitor and spray locust breeding areas. However, this is difficult in practice as many of the principal breeding zones are located in remote areas and are difficult to reach. We have been studying the locust and are developing efficient and sustainable control measures with due consideration to environmental well-being. For example, we have found that gregarious nymphs actively migrate during the day (Fig. 1), while they remain on relatively large plants during night under fluctuating thermal conditions. If we can understand these behavioral patterns and thermoregulatory behaviors, we can develop a predictive model. To obtain these ecological information and to develop a predictive model, we have taken temperature data on desert locusts doing different activities and their circumstances in the Mauritanian fields.

Using a thermal infrared camera in the field, we showed that gregarious nymphs altered their microhabitats as well as their postural thermoregulatory behaviors to maintain a relatively high body temperature (nearly 40°C) (Figs. 1 & 2). We used our data (Table 1) to successfully parameterize a general biophysical model of thermoregulatory behavior that could capture hourly body temperature and activity at our remote site using globally available environmental forcing data (Fig. 3).

This modelling approach provides a stronger

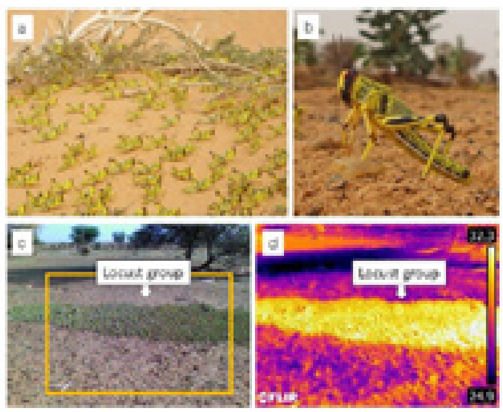

Fig. 1. Behaviors of gregarious nymphs of the desert locust
a: marching as a group, b: stilting behavior, and c: basking in the cool morning. Photo d shows thermal image of the basking locusts.

Table 1. Parameters used in the model for the desert locust hoppers

Description	Value
lethal maximum body temperature	50℃
lethal minimum body temperature	1℃
thermoregulation target body temperature	40℃
maximum foraging body temperature	43℃
minimum foraging body temperature	25℃
minimum basking temperature	15℃
minimum temperature for movement to basking site	15℃

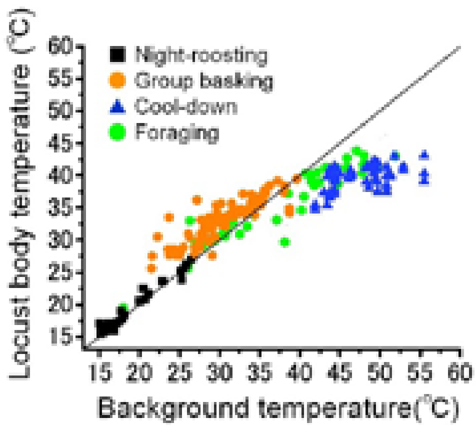

Fig. 2. Relationships between background temperature and locust body temperature when locusts displayed various behaviors such as roosting on plants at night, group basking, cooling-down, and foraging

		Predicted behaviors			
		Night-roosting	Group basking	Cool-down, foraging	Total
Observed behaviors	Night-roosting	37	0	2	39
	Group basking	0	5	90	95
	Cool-down, foraging	8	0	163	171
	Total	45	5	255	305
	Accuracy (%)	82.2	100.0	63.9	

Fig. 3. Confusion matrix of the observed vs. predicted behaviors of hoppers with the ectotherm-microclimate model

basis for forecasting thermal constraints on locust outbreaks under current and future climates. Our technique may prove especially useful if it contributes toward developing forecasting capacity and preventive control, both short-term in response to weather events and long-term in response to climate change.

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M.R. Kearney [The University of Melbourne]
S. Ould Mohamed [The Mauritanian National Anti-Locust Centre (CNLA)])

TOPIC *10*

Healthy seedcane propagation and distribution manual against sugarcane white leaf disease

Sugarcane white leaf disease (SCWLD) is one of the most devastating diseases affecting sugarcane production in Asia. In Thailand, which is the world's second-largest exporter of sugar, SCWLD is considered to have the most serious effect on sugarcane production. The pathogen of SCWLD is phytoplasma, and effective treatments against SCWLD have not yet been developed. Two leaf hoppers, *Matsumuratettix hiroglyphicus* and *Yamatotettix flavovittatus*, are known as vector insects. From the results of our study in a severely infected commercial sugarcane field, the probability that the seedcane was already infected with SCWLD was high. Therefore, it was highly possible that healthy seedcane distribution was effective for reducing SCWLD occurrence. Sugarcane is a plant species grown through vegetative propagation. Its intergenerational propagation rate is low, multiplied only by a factor of approximately seven to ten per generation. Thus, to propagate a sufficient amount of healthy seedcane, a propagation system extending across multiple generations is required. On the other hand, healthy seedcane propagation in the spread area is difficult because vector transmission occurs frequently. In order to solve this problem, we developed the "Healthy seedcane propagation and distribution manual against SCWLD" for sugar mills and public institutions interested in healthy seedcane production.

The manual is composed of a preface and three chapters (Table 1). Chapter 1 describes a healthy seedcane propagation method and an effective seedcane distribution method. It also recommends that management techniques should be combined

Table 1. Contents of the manual

Chapter title		Contents
Preface		Basics of SCWLD and purpose of this manual
Chapter 1	Propagation Field Management and Healthy Seedcane Product Distribution	Damage caused by the SCWLD, ecology of the pathogen and the vector; Management of the healthy seedcane propagation field and efficient distribution methods of the products
Chapter 2	Experimental Protocol: Detection of SCWL Disease by LAMP Assay	Detection protocol of SCWLD pathogens from latent plants
Chapter 3	Protocol for Producing Disease-Free Sugarcane Seedlings Through a Tissue Culture Process	Disease-free sugarcane seedling production protocol by tissue culture techniques

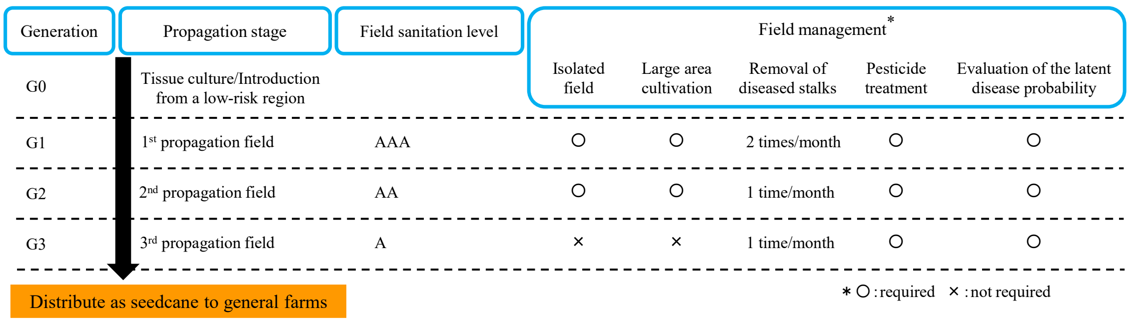

Fig. 1. Complete overview of the healthy seedcane propagation system

Fig. 2. Sugarcane in the verification test field for 1st propagation

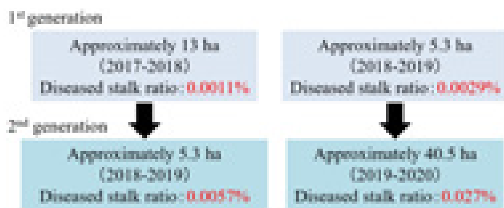

Fig. 3. Results of the healthy seedcane propagation verification test

These fields were managed following the propagation system described in Figure 1. Compared to newly planted fields in the same region, disease prevalence was extremely low. The infection ratios of commercial sugarcane fields around the verification test area were 0% to 20% (from 32 fields, mean 5.8%: median 5%). Several farmers and sugar mills commended these products as acceptable and healthy seedcane.

depending on the field sanitation level (Fig. 1). According to the results of the verification test, low-risk seedcane could be propagated by this technique (Figs. 2 & 3). Chapter 2 presents a simple protocol for SCWL disease detection using the loop-mediated isothermal amplification (LAMP) method. This method should be used "to obtain healthy seedcane as a source for propagation" and "to evaluate the latent disease probability." Chapter 3 describes a protocol for producing healthy seedcane using the tissue culture method. The products could be used as seedcane for the 1st propagation field.

This manual is available in both Thai and English. As a measure against SCWLD in each region in Thailand, domestic sugar factories in particular are expected to make use of the Thai language version in the production and distribution of healthy seedcane. The English version is similarly expected to be used not just in Thailand but also in other countries that are affected by SCWLD. In any case, users are advised to check and confirm current pesticide treatment regulations in their respective countries.

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TOPIC 11

International differential system to protect against rice blast disease

Blast disease has been found to have caused serious damage to rice production in all areas of the world where rice is cultivated, from tropical to temperate regions. The use of resistance varieties is the most economically and efficient way to protect against rice blast disease in developing countries. The differential system, which can clarify the pathogenicity of blast isolates and resistance in rice cultivars, is a basic and important tool for breeding and pathological works. However, few countries or research institutes have used the differential system and applied the developed technology for crop protection.

To establish this protection system against blast disease in developing countries and regions, JIRCAS has conducted international collaborative research for developing and distributing the differential system in Asian and African regions.

Under the international research network, blast isolates and rice germplasm were collected. The pathogenicity of blast isolates using international differential varieties (DVs) and genetic variation of resistance in resistant rice cultivars were clarified. Based on these information, international standard differential blast isolates (ISDBIs) collected from different origins under the research network were selected (Table 1).

The ISDBIs and DVs comprise the international differential system, and the system is being used as the international standard for characterizing the pathogenicity of blast isolates and resistance of rice cultivars. It can also be applied to breeding works in rice cultivars and pathological studies for the development of a protection system.

Participants of the research network including Indonesia, Philippines, Vietnam, Laos, and Bangladesh also selected their respective local standard differential blast isolates, and these domestic differential systems were applied to breeding and pathological studies in each country.

One of the network's research achievements was the clarification of the wide variations in blast races (Fig. 1). The frequency of blast isolates virulent to DVs was clarified in each country and region and at the global level. The frequency of virulent blast isolates varied among DVs and regions. Particularly, high frequencies of wide-spectrum blast isolate virulence to DVs were found in Bangladesh and West Africa.

Furthermore, the highest diversities of blast races were found from Yunnan province, China, to Bangladesh. The diversities of blast races were corresponded with the those of resistance in rice cultivars. The relationships between blast races and rice varieties are explained by the gene-for-gene theory. The differential system will make it possible to characterize previous resistance genes and to find new genes, such as partial resistance genes, and provide access to the development of application methods for them in rice breeding. The information, i.e., the differential system and these new approaches, will contribute to the development of a durable protection system and for harmonizing agriculture with environment.

Table 1. International differential system for rice blast disease

Blast race	Differential variety and resistance gene in the genetic background																									Origin
	LTH	IRBLsh-B	IRBLb-B	IRBLt-K59	IRBLa-A	IRBLi-F5	IRBL3-CP4	IRBL5-M	IRBLks-F5	IRBLkm-Ts	IRBL1-CL	IRBLkh-K3	IRBLk-Ka[LT]	IRBLkp-K60	IRBL7-M	IRBL9-W	IRBLz-Fu	IRBLz5-CA	IRBLzt-T	IRBLta2-Pi	IRBLta2-Re	IRBL12-M	IRBLta-K1	IRBLta-CP1	IRBL19-A	IRBL20-IR24	
	-	*Pish*	*Pib*	*Pit*	*Pia*	*Pii*	*Pi3*	*Pi5* (t)	*Pik-s*	*Pik-m*	*Pi1*	*Pik-h*	*Pik*	*Pik-p*	*Pi7* (t)	*Pi9*	*Piz*	*Piz-5*	*Piz-t*	*Pita-2*	*Pita-2*	*Pi12* (t)	*Pita*	*Pita*	*Pi19* (t)	*Pi20* (t)	
U62-i6-k000-z03-ta001	R	M	S	S	S	R	S	S	R	R	R	R	R	R	R	R	M	M	R	R	R	R	R	R	S	R	Philippines
U63-i7-k157-z04-ta431	S	R	S	S	S	S	S	S	S	S	R	S	S	S	S	R	R	R	S	R	R	S	S	S	S	R	Bangladesh
U63-i0-k100-z05-ta731	S	R	S	M	S	R	R	R	S	R	R	R	R	R	R	R	M	R	S	S	S	S	S	S	S	R	Philippines
U03-i7-k177-z01-ta733	S	R	R	S	S	S	S	S	S	S	S	S	S	S	S	R	M	R	R	S	M	M	S	S	S	S	Benin
U23-i7-k177-z02-ta733	S	R	S	R	S	M	S	S	S	S	S	S	M	S	S	R	R	M	R	S	S	S	S	S	S	S	Benin
U61-i7-k100-z04-ta003	S	R	S	S	R	S	S	S	S	R	R	R	R	R	R	R	R	R	S	R	R	R	R	R	S	S	Philippines
U73-i6-k111-z02-ta500	S	S	S	S	S	R	S	S	S	S	R	R	M	R	R	R	R	M	R	S	R	S	R	R	R	R	Laos
U53-i5-k157-z04-ta001	S	S	R	S	S	S	R	S	S	S	R	M	S	S	S	R	R	R	S	R	R	R	R	R	M	R	Japan
U41-i2-k100-z05-ta401	S	R	R	S	R	R	S	R	S	R	R	R	R	R	R	R	M	R	S	R	R	S	R	R	S	R	Philippines
U01-i0-k073-z01-ta010	S	M	R	R	R	R	R	R	R	S	S	M	S	S	R	R	S	R	R	R	R	R	S	R	R	R	Japan
U01-i4-k143-z00-ta021	S	M	R	R	R	R	R	S	S	R	R	S	S	S	R	R	R	R	R	R	R	R	R	S	S	R	Philippines
U23-i6-k157-z05-ta403	S	R	S	R	S	S	S	M	S	S	R	S	S	S	S	R	R	R	M	R	R	S	R	R	S	S	Bangladesh
U03-i7-k137-z04-ta503	S	R	R	R	S	S	S	S	S	S	S	R	S	S	S	R	R	R	S	S	R	S	R	R	S	S	Indonesia
U73-i4-k102-z01-ta333	S	S	M	S	S	R	R	R	S	R	R	R	R	M	R	R	M	R	R	S	M	R	S	S	S	S	Japan
U23-i7-k155-z04-ta403	S	R	S	R	S	S	S	S	S	S	R	S	S	R	S	R	R	R	S	R	R	S	R	R	S	S	Bangladesh
U43-i7-k173-z04-ta003	S	R	R	S	S	S	S	S	S	S	S	S	S	S	R	R	R	R	S	R	R	R	R	R	S	S	Bangladesh
U01-i7-k177-z06-ta021	S	R	R	R	R	S	S	S	S	S	S	S	S	S	S	R	R	S	S	R	R	R	R	S	S	R	Bangladesh
U73-i0-k000-z16-ta403	S	S	S	S	S	R	R	R	R	R	R	R	R	R	R	S	R	S	S	R	R	S	R	R	S	S	Philippines
U73-i0-k100-z05-ta403	S	S	S	S	M	R	R	R	S	R	R	R	R	R	R	R	S	R	S	R	R	S	R	R	S	S	Philippines
U53-i7-k100-z01-ta031	S	S	R	M	S	S	R	S	S	R	R	R	R	R	R	R	S	R	R	R	R	R	M	S	S	R	Japan
U63-i7-k100-z04-ta403	S	M	S	S	S	S	R	S	S	R	R	R	R	R	R	R	R	R	S	R	R	S	R	R	S	S	Philippines
U71-i0-k101-z01-ta333	S	S	S	S	R	R	R	R	S	R	R	R	M	R	R	R	S	R	R	S	S	R	S	S	S	M	Japan
U63-i0-k153-z05-ta403	S	M	S	S	S	R	R	R	S	S	R	S	S	S	R	R	M	R	S	R	R	S	R	R	S	S	Philippines
U23-i0-k104-z06-ta412	S	R	S	R	S	R	R	R	S	R	R	R	R	R	S	R	R	S	S	R	R	S	S	R	R	S	Laos
U23-i0-k177-z06-ta031	S	M	M	R	S	R	R	R	S	S	S	M	S	S	S	R	R	M	S	R	R	R	S	S	S	R	Laos
U63-i3-k102-z02-ta021	S	M	S	S	S	M	R	R	S	R	R	R	R	S	R	R	R	S	R	R	R	R	R	S	S	R	China

The international differential system consists of 25 differential varieties and the susceptible variety LTH, and 53 international standard blast isolates (Several blast isolates were omitted in the table). Blast race names were designated to each blast isolate selected according to the method of Hayashi and Fukuta (2009). Reactions: S: virulent (susceptible), M: moderate, R: Avirulent (resistant)

Fig. 1. Frequency of virulent blast isolates to differential variety in each country and region
Wide variations in virulent blast isolates to each differential variety were found, and they varied among regions. Wide-spectrum blast isolates virulent to differential varieties were found in Bangladesh and West Africa at high frequencies.

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TOPIC 12

Effect of non-flooded water management on inside-canopy temperature dynamics, spikelet sterility, and grain yield of lowland rice in the tropics

Increasing temperatures and water scarcity are concomitant threats to sustainable rice production in future climates. Although both aspects have been widely studied, little is understood about how water-saving management might affect heat-induced stress and grain yield of rice under open-field conditions. We implemented field experiments in four consecutive wet and dry seasons in the sub-humid tropics of northern Ghana to clarify how water management practices affect daily inside-canopy temperature (Tc) dynamics, flowering time, heat-induced spikelet sterility, and grain yield of rice. Two rice varieties, IR64 and Jasmine85, were grown under two water regimes: 1) continuous flooding (Flooded), and 2) continuous flooding except for an approximately 20-day drainage treatment at the flowering period (Non-flooded). The Non-flooded treatment maintained high moisture contents above 60% of saturated volumetric water to avoid any significant drought stress. Inside-canopy temperature (Tc) during the flowering periods were monitored at 2-minute intervals by placing MINCER (Micrometeorological Instrument for the Near-Canopy Environment of Rice) inside the canopy.

The effect of water regimes on grain yield and Tc differed significantly between the dry season (DS) and wet season (WS). Non-flooded management significantly reduced yields by 13–26% in the DS but not in the WS (Table 1). However, the effect of Non-flooded management on Tc at flowering time (0.2–0.3°C increase across varieties and years) (Fig. 1) and spikelet sterility (3–5% increase) (Table 1) was relatively

Table 1. Effect of water management on spikelet sterility and grain yield

Variety	Water management	Spikelet sterility (%)				Grain yield (t ha^{-1})			
		Wet season		Dry season		Wet season		Dry season	
		2016	2017	2017	2018	2016	2017	2017	2018
IR64	Flooded	2.4^{b}	8.9^{a}	4.1^{b}	4.0^{a}	6.1^{ab}	5.2^{a}	6.1^{b}	6.3^{b}
	Non-flooded	2.3^{b}	5.9^{a}	7.5^{ab}	8.9^{a}	5.4^{b}	5.0^{a}	5.2^{c}	4.7^{c}
Jasmine85	Flooded	5.7^{a}	10.8^{a}	6.7^{b}	4.2^{a}	6.6^{ab}	5.6^{a}	7.4^{a}	7.7^{a}
	Non-flooded	2.6^{b}	8.2^{a}	11.8^{a}	7.2^{a}	7.0^{a}	5.5^{a}	6.4^{b}	6.4^{b}

Two varieties were allocated in 5.7 m × 4.5 m plots with 4 replicates, in different water management practices. Different alphabets indicate significant differences at 5% by Tukey's HSD test.

*Flooded: Continuously flooded from transplanting to maturity.

*Non-flooded: Continuousy flooded except for an approximately 20-day continuous non-flooded period, at around the heading dates of the two varieties. Volumetric moisture contents of soils were retained above 30% during the non-flooded period in all seasons except the dry season cultivation in 2018 in which volumetric moisture content went down to 26% due to the lack of irrigation water.

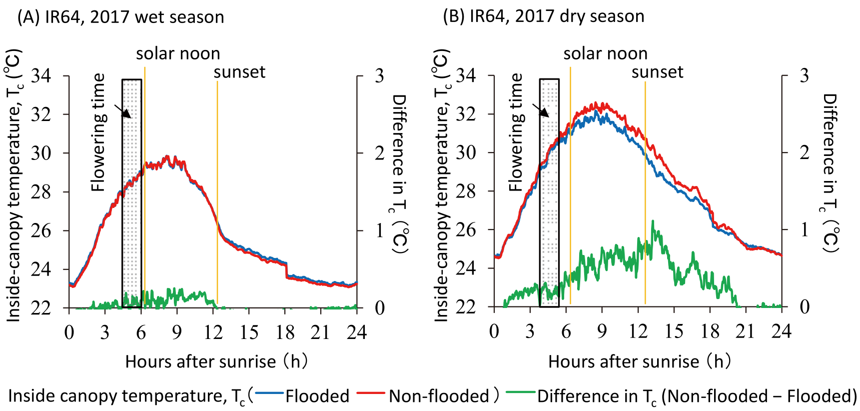

Fig. 1. Diurnal changes in inside-canopy temperature (Tc) in the Flooded and Non-flooded water management and the Tc differences between these two management schemes for IR64 in the 2017 wet seasons and 2017 dry seasons

The trend was equivalent for both varieties and in the other years.

The average of two replicates over peak flowering days (7 observation days around the day of 50% heading excluding any rainy days) is depicted. Grey bars within each figure indicate the period from initial to peak spikelet opening time which were determined by digital images taken at 10-minute intervals. Orange lines indicate the solar noon and apparent sunset time.

small even in the DS. In contrast, Non-flooded management greatly increased Tc from solar noon to midnight in the DS (Fig. 1). Tc did not differ between Non-flooded and Flooded treatments either at flowering time or nighttime in the WS (Fig. 1).

Tc changes over the course of the day imply that Non-flooded management may have a higher risk of yield reduction in the DS of the sub-humid tropics by increasing late-afternoon-to-nighttime temperatures, which can cause physiological stress and respiration loss. The results can help improve water-saving management practices under contrasting climatic conditions in the sub-humid tropics and predict the combined effect of increasing temperatures and water scarcity on rice production.

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Program C
Value-adding Technologies

"Development of high value-adding technologies and utilization of local resources in developing regions"

The Value-adding Technologies Program addressed the utilization of indigenous regional resources in Asia and the development of high value-adding technologies. To ensure high quality products and stable food value chains, we implemented research on the identification of regional food resource characteristics, the development of effective food processing technologies, and the elucidation of consumer needs. The program also supported rural development by utilizing regional resources in agriculture, forestry and fisheries. To achieve our goals, we conducted the following five research projects.

[Food Value Chain]

This project aimed to solve problems related to the coordination of effective and sustainable food value chain cycles. The first major research subject relates to food scientific research and was composed of two themes, namely 1) Evaluation of local food resources and 2) Development of utilization and processing technology for local food resources. The second major subject relates to socioeconomic research and was also composed of two themes, namely 1) Improvement of food production and distribution systems to meet consumer needs and 2) Development of methods to evaluate the food value chain. Under these subjects, joint research activities were conducted with institutes in Thailand, Lao PDR, and PR China. We determined cereals, as well as processed and traditional fermented foods, of which similar products appear widely in the Asian region, to be the main target foods.

A project team composed of scientists from JIRCAS and Kasetsart University in Thailand found that some amylolytic bacteria are causative agents of liquefaction in the fermented rice noodle, *khanom chin*, and they proposed a low-cost and effective measure to prevent liquefaction by controlling the pH of the final product. The team demonstrated the importance of *khanom chin* liquefaction risk control at the manufacturing stage, based on business management evaluation studies. Meanwhile, they constructed a QR-code based framework for disseminating the results of research on *khanom chin*. In addition, a joint research team composed of scientists from JIRCAS and a private company developed a polyurethane elastomer-based husker roll (suitable for long-grain rice) that has both a high husking ratio and a long life by running a simulation based on the construction model.

[Asia Biomass]

To encourage the use of biofuels and biomaterials produced from agricultural residues, we successfully developed a new saccharification technology called Biological Simultaneous Enzyme-production and Saccharification (BSES), which is efficient and low-cost because it does not require enzymes. For efficient biofuel production, we discovered and characterized a new β-glucosidase-producing bacterium that is useful in constructing BSES and can be co-cultured with thermophilic anaerobic cellulose-degrading bacteria used in BSES. Furthermore, we discovered a new genus and a new species of thermophilic anaerobic bacterium, *Capillibacterium thermochitinicola*, which can decompose crystalline chitin from compost in Ishigaki Island. Since the bacterium can grow under the same growth conditions as the β-glucosidase-producing bacteria, it can be incorporated into the BSES.

[Multiple Use of Regional Resources in Semi-mountainous Villages]

As part of JIRCAS's social implementation activities, workshops for improving the nutritional status of residents were held in two mountainous villages based on information on protein deficiency among villagers and the nutritional potentials of indigenous fishes/rice. In addition, a technical manual on indigenous fish culture in paddies/ponds was prepared, and an explanatory meeting on using the manual was held for villagers. Regarding upland rice, three highly productive varieties out of around 800 varieties were selected, and their autonomous seed production/distribution systems were established by local institutes. Furthermore, analyses of detailed genomic information on Laotian colored rice varieties, as important future breeding materials, have progressed. Meanwhile, a considerable number of scientific papers on various research topics such as UAV (drone) image interpretation for rapid phenotyping of rice varieties, technical improvement for producing safe Pa daek (fermented fish), rice productivity improvement in rainfed areas, and basic nutritional evaluation of fishes and indigenous fish aquaculture etc., were published in scientific journals, in addition to the social implementation activities.

[Higher Value Forestry]

Under this project, we developed technologies to improve the value of planted forests through advanced use of genetic resources and proper management of native tree species in Southeast Asia. Thinning experiments at a teak plantation in Thailand indicated that tree diameter growth is affected by the initial tree size before thinning and the basal area of competing trees around the target tree. Teak plus trees at the clonal test site in Kanchanaburi were classified into three genetic clusters, and it was estimated that the heritability of tree height was high. In Laos, a soil erosion risk assessment model was constructed for the northern mountainous region, and a method for determining suitable sites was developed for teak plantations in consideration of soil conservation.

Moreover, we analyzed the effect of temperature and drought on leaf production and height growth in dipterocarp seedlings. Methods for selecting superior individual dipterocarp trees were developed by using a genome-wide association study (GWAS) between genotype and phenotype and a genomic prediction model using neural network. A mangrove biomass estimation model based on forest canopy height was developed, and it is expected to become widely applicable for large scale estimation of Asian mangroves.

[Aquatic Production in Tropical Areas]

Development of technologies for sustainable aquatic production was conducted in Southeast Asian countries. In Malaysia, the project on the management of blood cockle fishing grounds and its growth condition evaluation was wrapped up and the research achievements were published as a special issue of the Malaysian Fisheries Journal. In Myanmar, monthly environmental surveys of potential oyster aquaculture sites were conducted, and the produced environmental map was shared with fishers through social media. A manual on oyster culture in Myanmar was published and disseminated to local fishers. In Thailand, the developed technique for the giant tiger prawn co-culture system with seaweeds and small snails, which enabled prawn production to rise above the amount (0.4 kg/m^2) expected by the farmers, was disseminated through published manuals and promotional videos in English and Thai versions. In the Philippines, the research studies on Integrated Multi-Trophic Aquaculture (IMTA) for milkfish, seaweeds, and sea cucumber were concluded, and the achievements and challenges were assessed and disseminated through pamphlets.

TOPIC 1

Designing a polyurethane-based husker roll for long-grain rice using a finite element model

Rice husking is an operation where the husks are peeled from rough rice, and a rubber roll husker conventionally consists of two rubber rolls with different peripheral velocities that rotate to provide the shear stress needed to husk rough rice (Fig. 1). Both short- and long-grain rice, which have different shapes, affect rice husker performance, especially the husking ratio and wear of the husker roll. The performance with long-grain rice, which accounts for 80% of world rice production, is poorer than with short-grain rice.

We analyzed the fundamental mechanisms of the roll husker, and then compared the performance for long- and short-grain rice using a finite element model constructed based on high-speed camera observation.

A husking simulation based on the constructed model revealed that long-grain rice exhibited more accumulated friction loss (121.6 mJ) than short-grain rice (40.1 mJ) (Figs. 2 & 3). The difference in accumulated friction loss at the roll surface may lead to increased friction heat, which in turn induces wear. Since sufficient shear force is needed with rough rice to achieve a higher husking ratio, the optimum coefficient of friction and Young's modulus of the husker roll, which is related to viscoelasticity, for long-grain rice were

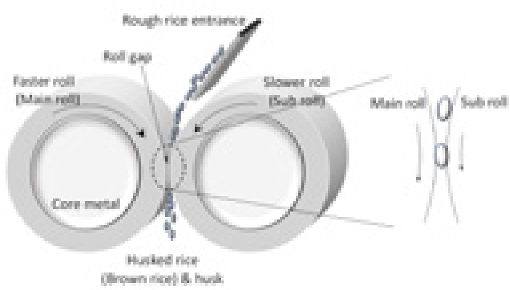

Fig. 1. Schematic diagram of rice roll husker

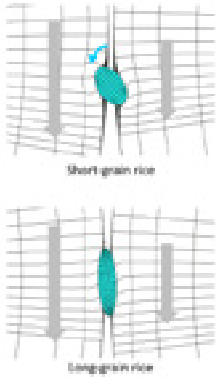

Fig. 2. Differences between short- and long-grain rice in the roll gap

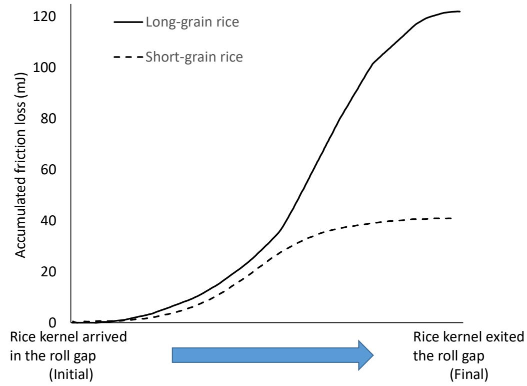

Fig. 3. Accumulated friction losses for husking of single kernel

Table 1. Results from field husking tests at a rice mill in Thailand

Husker roll	Viscoelasticity (tanδ, 90°C)	Coefficient of friction	Husking ratio	Broken rice ratio	Actual wearing	Estimated durability
Rubber roll (conventional)	0.089	0.514	77-85%	7-8%	10-10.5 mm at 10 hr	24-30 hr
Polyurethane-based roll designed for short-grain rice (commercial product)	0.021	0.544	55-61%	5-7%	5-7 mm at 1 hr	3.6-5 hr
Polyurethane-based roll designed for long-grain rice based on simulation results (improved)	0.035	0.699	82-88%	5-7%	7.3-7.4 mm at 72 hr	242-243 hr

calculated based on the model as being 0.8 and 8.1 MPa, respectively.

Newly designed polyurethane-elastomer-based husker rolls based on these results showed a better husking ratio and nearly 10 times greater durability than conventional rubber rolls in experiments undertaken in Thailand using long-grain rice (Table 1).

Roll huskers are the mainstream in commercial rice mills around the world, in terms of continuous operation and brown rice quality after husking. Their replacement rolls are commercially available as consumables, and the developed polyurethane-based husker roll is applicable to all roll huskers. Therefore, the results provide new opportunities to prepare new materials for the rice roll husker.

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TOPIC 2

Cost accounting for evaluating liquefaction of Thai fermented rice noodles and its prevention focusing on pH management

Traditional Thai fermented rice noodles, *khanom jeen*, are produced and consumed widely in the nation as well as the Greater Mekong Subregion. A well-known problem with noodle production is sudden noodle liquefaction soon after production, severely affecting business and undermining buyer confidence. JIRCAS found that the increased pH level of *khanom jeen* noodles induced liquefaction; noodles with weak acidic (pH 6) or alkaline (pH 8) buffers result in liquefaction, while acidic (pH 4) buffers do not (Research Highlight 2017, C01 “Liquefaction of Thai fermented rice noodles can be prevented by maintaining the product in acidic condition of pH around 4”). Thus, managing the pH level can be a promising method for preventing noodle liquefaction.

We conducted simulation analyses, including cost-volume-profit analysis, to evaluate the effect of liquefaction on small-scale rice and noodle producers’ profitability and the cost of preventing the problem by focusing on pH management (Fig. 1). The results show that the instability of product quality, particularly noodle liquefaction, severely affects the profitability of flour and noodle producers (Fig. 2). Frequent pH level measurements at critical points of the production process can capture and prevent the risk of liquefaction. The cost for this is small (Table 1A), and simple to use digital meters are beneficial for measuring the pH of products at many different points. Incorporating practices to reduce high pH levels at appropriate points can reduce the risk of liquefaction. One approach is to

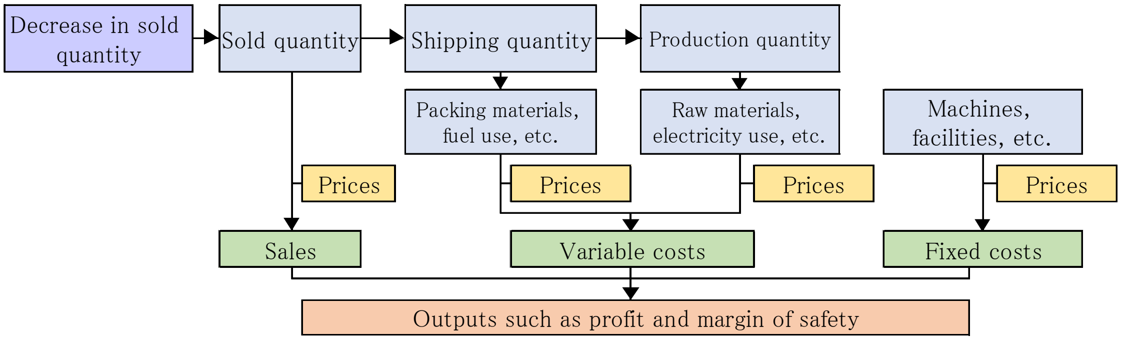

Fig. 1. Conceptual chart of the simulation model
Models for production of both the fermented rice flour and noodles are built based on the survey. The figure shows the common diagram for both processes.

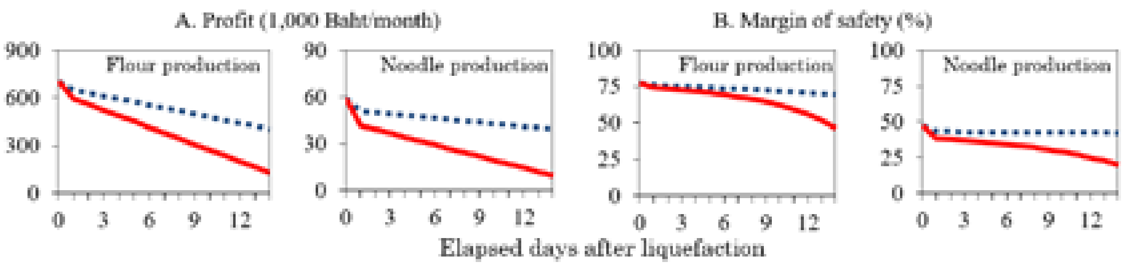

Fig. 2. Estimated profit and margin of safety according to the decrease in sold quantity
Solid line = 100% reduction in daily sales volume. Dotted line = 50% reduction in daily sales volume. “Noodle production” assumes that the process only uses purchased flour. It also assumes small businesses, an average size of fermented rice flour, and noodles producers registered with the Department of Industrial Works, Ministry of Industry (flour production: laborers = 13, raw material rice = 5.5 tons/day; and noodle production: laborers = 6, raw material flour = 0.6 tons/day). Only the sales volume is reduced on the first day, and the shipment and production volumes are also reduced to control variable costs on the second and subsequent days. The margin of safety measures the percentage decrease in monthly sales resulting in zero profit after the liquefaction.

Table 1. Monthly average costs for preventing liquefaction focusing on pH management

		For the surveyed company	For further pH management
A. Costs for measuring pH in the flour and noodle production processes by indicator papers	Measuring points (point/day)	10	20
	Costs (Baht/month)	373	746
	Percentage of total cost (%)	0.01	0.03
B. Costs for washing noodles by the water containing acetic acid	Volume of acetic acid (L/day)	0.2	1
	Costs (Baht/month)	216	1,083
	Percentage of total cost (%)	0.01	0.04

The surveyed company is the representative small-scale noodles producer, which uses a noodle-making machine that operates for 8 hours and produces 830 kg/day. The total cost for the surveyed company is 2.82 million Baht/month, with flour and noodle production accounting for 2.68 million Baht/month and 0.14 million Baht/month, respectively. The cost of measuring by pH meter is 431 Baht/month, assuming 6 years of durability. The cost of adding the maximum level of a common food preservative to noodles is 2,647 Baht/month.

wash the noodles with acid water (low pH) after the boiling process. The cost for this procedure is minimal and lower than using common food preservatives (Table 1B).

As mentioned above, the rudimentary management of the production process focusing on the pH level can secure product shelf life in the market and profitability. Note that the flour producer should adequately monitor and manage the fermentation, rather than merely reduce the products' pH at the final stage. A high pH level of the products just after solid- or liquid-state fermentation indicates something abnormal in the process that needs corrective action through reviewing operations. The noodle producer needs to consider that the amount of acetic acid for washing noodles depends on each site's water quality and the products' flavor. The results of this study should not be generalized without carefully considering the businesses' differences in technologies and capabilities, since the analysis is based on a small-scale noodles producer's data.

(E. Kusano, J. Marui, T. Yoshihashi)

TOPIC 3

Discovery of *Capillibacterium thermochitinicola*, a thermophilic anaerobic bacterium that decomposes chitin

Chitin, a type of polysaccharide contained in many organisms such as shrimp, crab, insects, shellfish, and mushrooms, is the second-most abundant natural biological resource on earth next to cellulose. It is expected to be used as a biomaterial such as fiber material and soil conditioner, but its poor solubility makes it limited to industrial use. Biomass containing chitin such as shrimp shells and crab shells from fish processing factories is discarded in large quantities. There are many microorganisms that have chitin-degrading enzymes, but no bacteria that can decompose and assimilate chitin in a thermophilic anaerobic environment have been found. Therefore, in order to make effective use of chitin-based biomass by microbial saccharification, we researched for thermophilic anaerobic bacteria that can efficiently decompose chitin in a high-temperature environment and clarified their novelty and usefulness.

To identify a microorganism that decomposes chitin, we screened from composts on Ishigaki Island at 60°C in an anaerobic environment using a medium containing crystalline chitin as a carbon source. A new genus and new species of chitin-degrading, thermophilicanaerobic bacterium was successfully isolated and identified as *Capillibacterium thermochitinicola* UUS1-1 (Fig. 1)[1-3]. This bacterium is taxonomically positioned in the OPB54 cluster of uncultured bacteria of the phylum *Firmicutes*, a gram-positive bacterium. Its discovery as a bacterium that can be cultivated in the OPB54 cluster[1-3] followed that of the previously known *Hydrogenispora ethanolica*. Strain UUS1-1 is the first thermophilic anaerobic bacterium that has been confirmed to be able to decompose and assimilate crystalline chitin by producing two types of chitin-degrading enzymes (Fig. 2)[2]. From genome analysis, strain UUS1-1 has at least 6 chitin-degrading enzymes and metabolic pathways required for chitin utilization[1, 2], and it can produce hydrogen directly from chitin. Strain UUS1-1 has been deposited as a reference strain

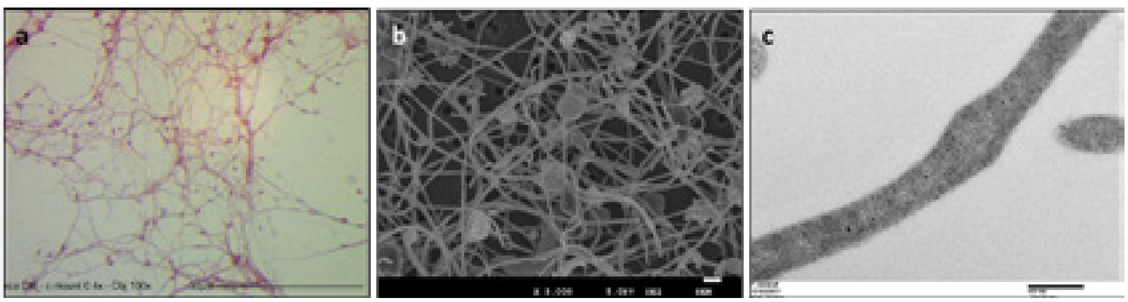

Fig. 1. Morphological observation of *C. thermochitinicola* UUS1-1
a: UUS1-1 optical micrograph (black horizontal bar scale at the bottom of the photo is 50 μm), b: UUS1-1 scanning electron micrograph (white horizontal bar scale at the bottom of the photo is 1.0 μm), c: transmission electron micrograph (black horizontal bar scale at the bottom of the photo is 0.4 μm).

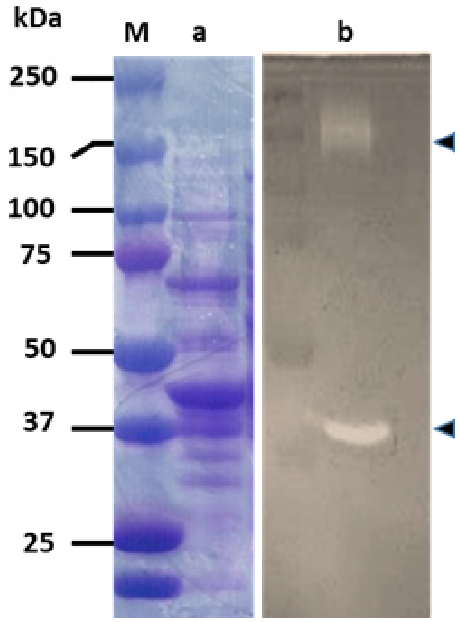

Fig. 2. Chitin degradation ability by extracellular enzyme of *C. thermochitinicola* UUS1-1
a: SDS-PAGE of the extracellular enzyme of the isolate UUS1-1, b: Zymogram analysis on chitin degradation activity of the extracellular enzyme prepared from the isolate UUS1-1. ▲: Chitin degradation activity is observed in the molecular weight. M: Molecular weight marker

at RIKEN BioResource Center (JCM 33882T) and German Microbial Cell Culture Collection Center (DSM 111537T)[3].

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(A. Kosugi, A. Uke, S. Baramee, U. Ungkulpasvich [University of Tsukuba])

TOPIC 4

Initial salinity adjustment effectively prevents histamine accumulation in *padaek*, a Laotian salt-fermented freshwater fish paste

Padaek is a shelf-stable salt-fermented freshwater fish paste popularly used for seasoning various Laotian dishes. Pieces of fish remaining in the fermented product can also be cooked for consumption. Although commercial products are currently available, *padaek* is still made and eaten at home in rural areas to make use of indigenous freshwater fish as an important source of nutrition. In traditional *padaek* production, the fish are washed with water and then mixed with salt and rice bran at a ratio by weight of 3:1:1 to adjust the salinity to around 20%, which is common in *padaek* products in Laos. Halophilic lactic acid bacteria, such as *Tetragenococcus halophilus* and *muriaticus*, are found in the fermented product. According to the producers, *padaek* is considered edible after 2 to 3 months of fermentation, with further fermentation for at least 6 months or more to make it more palatable.

Histamine is an endogenous substance in the human body, playing an important role in modulating diverse physiological functions. It can also accumulate in amino-acid-containing foodstuffs including fermented fish due to bacteria that possess amino acid decarboxylation activity. The intake of an excess of dietary histamine can cause poisoning symptoms such as stomach upset and hives. Histamine levels of 500 to 1,000 ppm in foodstuffs are considered to be potentially hazardous to human health, although the sensitivity to histamine is largely varied between individuals. Research on the histamine level in *padaek* and its accumulation mechanism is needed to develop a strategy for preventing excessive histamine accumulation that could adversely affect nutrition security and human health.

Histamine levels in *padaek* made in rural households negatively correlated with the salinity (Fig. 1). Experimental *padaek* fermentation with initial salinity of 10% and 6.5% exhibited significant histamine accumulation after 2 weeks of fermentation, while no histamine was detected with initial salinity of 18% for 6 months (Fig. 2), indicating that salinity was a critical factor for

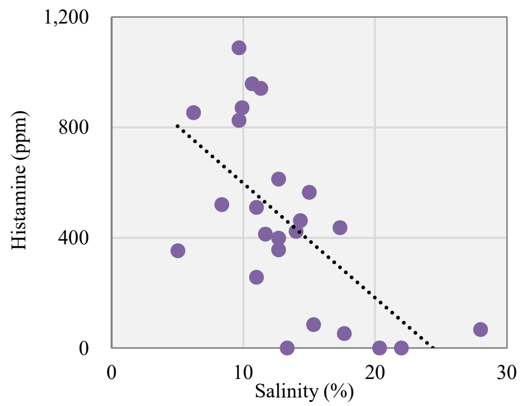

Fig. 1. Negative correlation between salinity and histamine contents (r = 0.633, *p* < 0.01, n=24) observed in homemade *padaek* samples collected from rural households

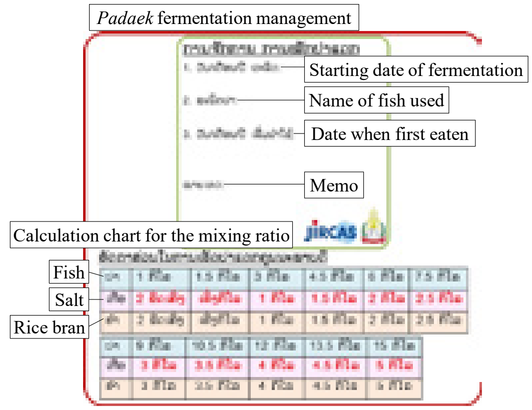

Fig. 3. Table showing the simplified calculation chart recommended for *padaek* fermentation
Figure shows English translation of the Lao language used in the table.

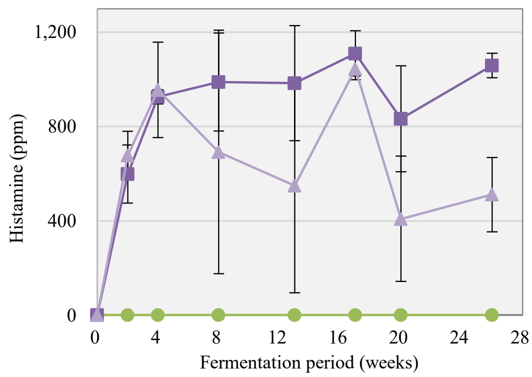

Fig. 2. Fermentation period-dependent change of histamine contents in experimental *padaek* fermentation under salinities of 18% (●), 10% (■), and 6.5% (▲)

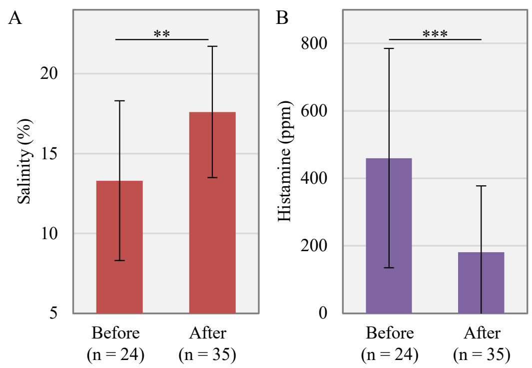

Fig. 4. Comparisons of average salinity (A) and histamine content (B) of homemade padaek samples collected from the village before implementing the salinity management practice (Before) and the samples from the households after being instructed on how to adjust the initial salinity using the simplified calculation chart (After)

controlling the risk of histamine accumulation during *padaek* fermentation. Households in the rural village were invited to further test the practicability of salinity adjustment to reduce histamine accumulation in their *padaek*. For that purpose, we prepared a simplified calculation chart (Fig. 3) by referencing a traditional recipe to ensure that the weight ratio of fish, salt, and rice bran was 3:1:1. The participants were instructed on how to use the chart to properly adjust the initial salinity in their *padaek* fermentation. The average salinity and histamine contents of *padaek* produced by the participants after the instruction were significantly higher and lower, respectively, than those in the samples collected in the same village before implementing the salinity management practice (Fig. 4), thus demonstrating the usefulness of salinity adjustment for reducing histamine accumulation in their *padaek*. This producer-friendly approach is recommended for the effective implementation of good manufacturing practice for *padaek* in Laos.

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S. Boulom [Faculty of Agriculture, National University of Laos])

Rice and weeds in upland rice fields can be discriminated with good accuracy from a commercial-grade small drone

Weed control is an important task to improve the productivity of upland rice, which is a major crop in Laos. Aerial images of fields taken with drones are effective tools for early detection of weeds and rapid herbicide treatment, but there is no practical method that can be used in farm fields. Therefore, based on object-based image analysis (OBIA), this study developed a method for discriminating rice and weeds using RGB (Red-Green-Blue) color images of upland rice fields in Laos taken with a commercial-grade small drone.

The experimental results are summarized as follows.

- In an experimental field (furrow 25 cm × 25 cm), a small drone (DJI Phantom 4) was used to capture RGB images at a flight altitude of 20 m (ground resolution 1 cm) 29 days after sowing. HSV (Hue-Saturation-Brightness) and Texture (spatial variance) were calculated from the RGB color image. As training data, the positions of rice, weeds, and soil on the image were collected from the RGB color image by visual interpretation. In OBIA, (1) the images were segmented by similar pixel values using the SLIC (Simple Linear Iterative Clustering) method, (2) statistics were extracted from the segments of classification class (rice, weeds, and soil) in the training data, and (3) the extracted statistical values were used as explanatory variables for random forest classifier.
- OBIA classified rice and weeds, mainly *Asteraceae* and *Legumes*, which dominated the upland rice fields in Laos, with overall accuracy (OA) of 90% or more (Table 1), and provided the spatial distributions (Fig. 2).
- Soil was classified with a recall value of 99.0% even if only the HSV color information was used, but the accuracies of rice and weeds classification could be improved by adding Texture information (Table 1).
- Since the coverage of rice, weeds, and soil classified from the drone changed between 1, 17, and 34 days after weeding (Fig. 3), it is possible to quantitatively grasp the situation in which weeds grow over time after weeding treatment.

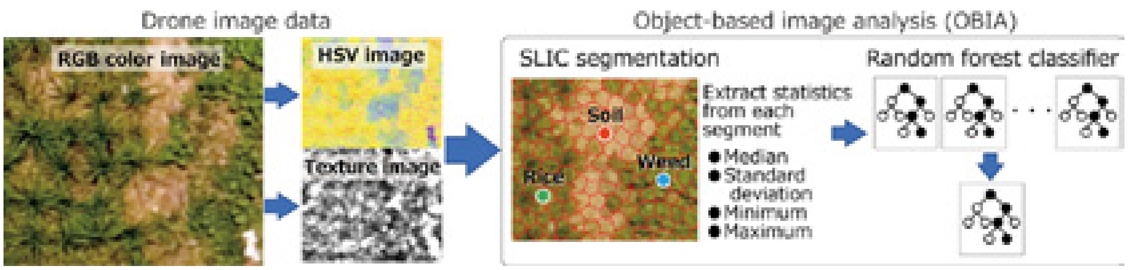

Fig. 1. Processing flow of object-based image analysis using HSV image and Texture image (spatial variance) calculated from RGB color image of drone
Extracted statistics from the segments created by the SLIC (Simple Linear Iterative Clustering) method are used as input values for random forest classifier.

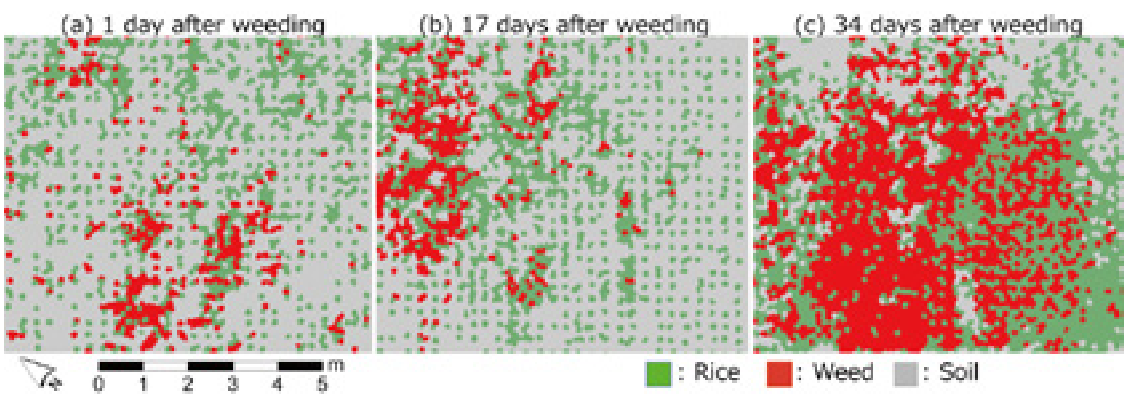

Fig. 2. Spatial distribution map of rice, weed, and soil classified by object-based image analysis of drone images
Comparison of treatment plots with different days after weeding (1, 17, and 34 days after weeding)

Table 1. Confusion matrix in random forest classification

		Classified as			
		Rice	Weed	Soil	Recall
(a) HSV (OA = 0.901, *F*-score = 0.900)					
True class	Rice	**82**	18	0	0.820
	Weed	11	**89**	0	0.890
	Soil	1	0	**99**	0.990
Precision		0.872	0.832	1.000	
(b) HSV + Texture (OA = 0.910, *F*-score = 0.906)					
True class	Rice	**83**	17	0	0.830
	Weed	9	**91**	0	0.910
	Soil	1	0	**99**	0.990
Precision		0.892	0.843	1.000	

OA: overall accuracy

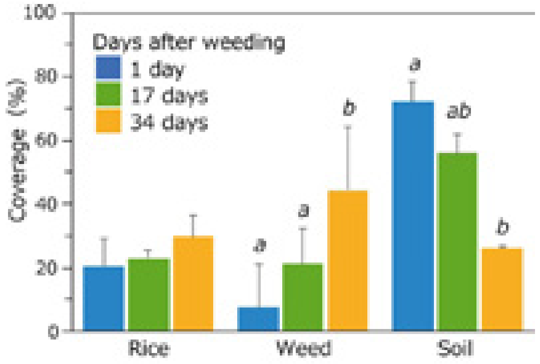

Fig. 3. Comparison of rice, weed, and soil coverages
Different letters on the bar indicate significant differences at 5% level (Tukey HSD).

Rice and weeds could be rapidly discriminated with practical accuracy by OBIA with a small drone. Farmers can grasp the weed growth in the field at an early stage and use it as basic information for appropriate weed management (herbicide treatment). If this method is applied to field phenotyping, the influence of weeds can be removed from the image without weed removal in the field, and improvement of the accuracy and efficiency for rice growth monitoring can be expected. It should be noted that it is possible to fly at a higher altitude to shoot a wider area in a short time, but the classification accuracy will decrease accordingly, so it is necessary to formulate a flight plan that suits the purpose of use. In addition, the classification accuracy may decrease for weed species with similar morphology, such as grass weeds.

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TOPIC 6

Possibility to introduce genomic selection into tree breeding for important timber species distributed in the tropical rainforests of Southeast Asia

In Southeast Asian rainforests, commonly adopted logging systems allow only trees larger than the regulated cutting limit to be selectively felled, with the next harvest expected after the forests have naturally recovered (35-year rotation in Indonesia). However, poor recovery and a decline in production levels have caused problems in second and further harvesting. Indonesia, which has the largest tropical rainforest in Southeast Asia, is implementing a system that restores productivity by artificial planting after logging, but the seedlings have not been genetically improved. Thus, this research aimed to clarify how genetically improved seedlings greatly contribute to the recovery of tropical rainforests and the improvement of productivity.

In recent years, advances in next-generation sequencing have made it possible to detect genome-wide DNA polymorphisms from a large number of individuals. This technology allows the development of a genomic prediction model that can estimate phenotypes from DNA polymorphisms, which can be used for the selection of superior progenies in the next generation (genomic selection). Conventional forest tree breeding requires a long period of time to evaluate phenotypes due to their longevity, but predicting future phenotypes from DNA polymorphisms at seedling stage can significantly shorten the breeding cycle. Therefore, to restore the rainforest and improve productivity with superior seedlings, we clarified the possibility of genomic selection for dipterocarp species, which are the dominant tree species in the rainforest and provide various ecosystem services including timber production.

Genome-wide DNA polymorphisms (5,900 loci) were obtained from 356 progenies derived from open-pollinated mating of 77 mother

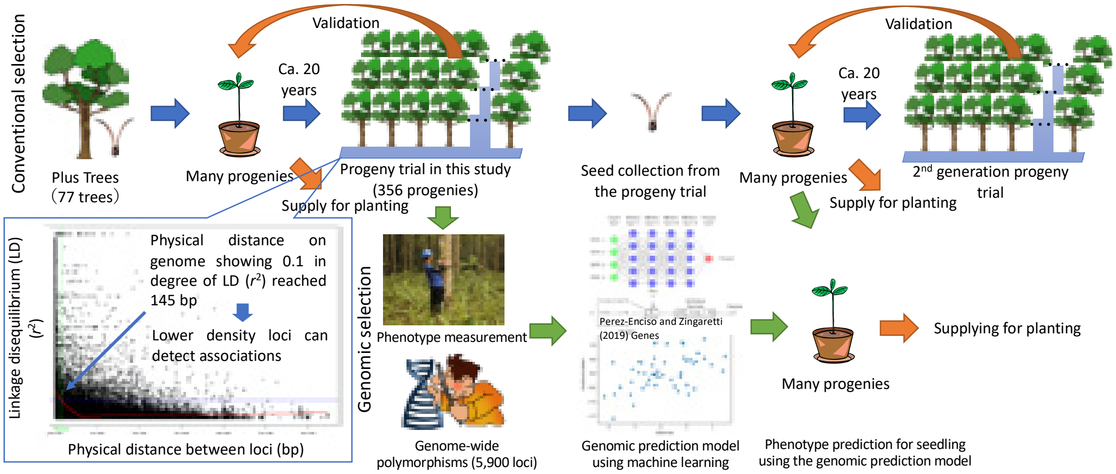

Fig. 1. Genetic characteristics of the progeny trial in this study and genomic selection
Conventional selection requires about 20 years for validation. The genomic prediction model can shorten this process, which in turn can shorten the breeding cycle.

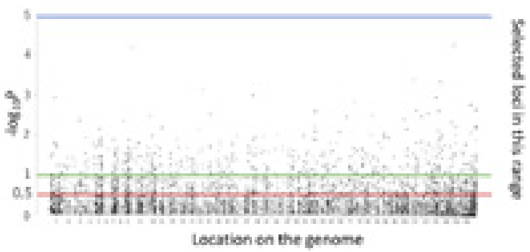

Fig 2. Manhattan plot showing association between tree height after thinning and genotype of each loci
GWAS on all measured traits showed no significant association except for a significant locus on tree height before thinning.

Table 1. Genomic heritability estimated from genotypes

	Genomic heritability All loci	Genomic heritability Selected loci
Tree height after thinning (11 years)	0.313	0.573
Trunk diameter after thinning	0.292	0.615
Branch angle	0.190	0.342
Wood density	0.263	0.516
Wood swiftness	0.252	0.473

Genomic heritabilities on growth (tree height and trunk diameter) were improved when the loci were selected using a $-\log_{10}P$ value threshold of 0.5 (red line in Fig. 2), which indicated that there are many associated genes with weak effect.

trees of *Shorea platyclados*, one of the main dipterocarp timber species, which were planted in a progeny trial at a forest concession area in central Kalimantan. Linkage disequilibrium over long physical distances showed that the progenies were suitable for genome-wide association studies (GWAS) and genomic predictions. GWAS revealed that a locus showed significant association with tree height before thinning (8th year), but did not exhibit significant association with tree height after thinning (11th year), trunk diameter, tree shape, and wood density, which suggest that these traits are regulated by many weakly effective genes. Selection of informative loci based on GWAS improved genome heritability, which represented that phenotypic variance was well explained by the genotype of the selective loci (Table 1). Furthermore, the genomic heritability of growth-related traits is higher than that of tree shapes and wood density. Therefore, genomic selection is particularly effective for breeding fast-growing individuals.

We identified that deep learning and increasing the numbers of analyzed individuals and loci contribute to improving the accuracy of the genomic prediction model. Using the developed genome prediction model, selection of seedlings for growth-related traits will lead to a significant shortening of the breeding cycle. However, our results suggest that these traits are regulated by many weakly regulated genes, hence are not suitable for marker-assisted selection.

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Temperature-regulated leaf production in the family Dipterocarpaceae

Dipterocarpaceae is a dominant tree family in Southeast Asia. This family consists of more than 500 species, many of which are important timber trees. To achieve sustainable timber production of dipterocarp species, a stable supply of planting materials is required. However, dipterocarp species flower at irregular intervals from three to ten years, which leads to difficulties in collecting seeds and providing good planting materials. To overcome the shortage of planting materials, we studied the regulation of growth in dipterocarps. Understanding their growth regulation helps to supply dipterocarp saplings by controlling their growth.

For this purpose, we focused on leaf production as an indicator of plant growth. We developed an observation system using time-lapse digital cameras and monitored daily leaf production by two dipterocarp species, *Shorea leprosula* and *Neobalanocarpus heimii* (Fig. 1). To exclude the effect of rainfall variations on leaf production, we covered the observation system with transparent plastic sheets and installed it in the nursery of Forest Research Institute Malaysia (FRIM). The observation showed that leaf production by dipterocarp saplings fluctuated without variation in rainfall (Fig. 2). This suggests that the timing of leaf production cannot be explained by the rainfall pattern. Instead, we found similarities in leaf production and temperature patterns (Fig. 2).

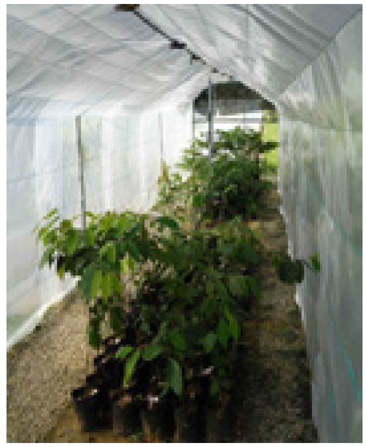


Fig. 1. Leaf production observation system using time-lapse digital cameras
To exclude the effect of rainfall variations on leaf production, the observation system was covered with transparent plastic sheets.

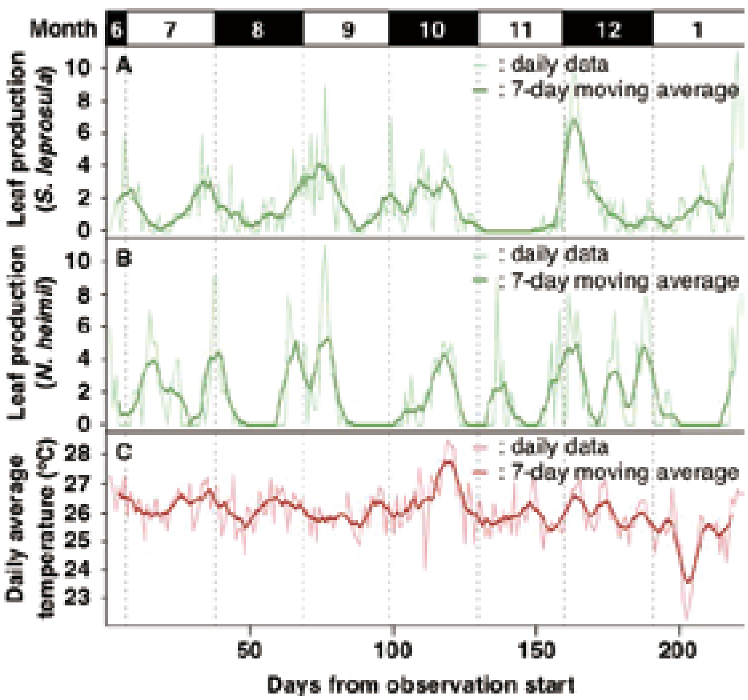


Fig. 2. Daily leaf production and temperature data obtained by the observation system
(A) No. of produced leaves by *Shorea leprosula*, (B) No. of produced leaves by *Neobalanocarpus heimii*, and (C) Daily average temperature. The data were obtained from June 2017 to January 2018.

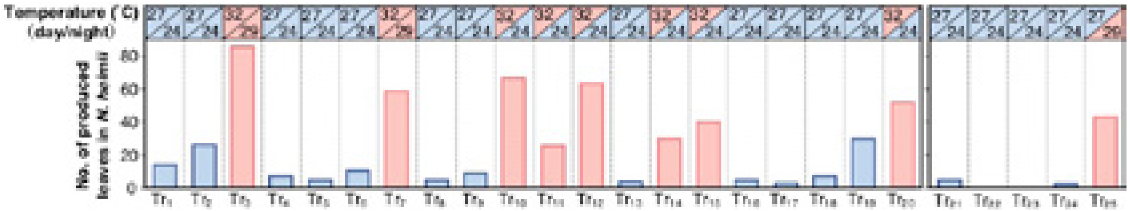


Fig. 3. Relationship between temperature and leaf production in the growth chamber
The growth chamber experiment was conducted using 50 individuals of *N. heimii*. Tr_x indicates ~3-week temperature treatment. The experiment from Tr_{21} was conducted as a separate experiment. The temperatures in upper and lower triangles indicate daytime (7 AM to 7 PM) and nighttime (7 PM to 7 AM) temperatures, respectively.

Thus, to test the effect of temperature on the timing of leaf production, we applied Convergent Cross Mapping (CCM) to the observation result. CCM is a mathematical framework to analyze causal relationships between time-series data. The CCM analysis showed that estimation skill from leaf to temperature data (cross-map skill: 0.20) was higher than that of surrogate data (cross-map skill: 0.18), suggesting a causal relationship between temperature and leaf production. The growth chamber experiments showed that leaf production was significantly increased by small increments (5˚C) in daytime or nighttime temperature from baseline temperature (daytime: 27˚C, nighttime: 24˚C) (Fig. 3). These results indicate that temperature is a regulator of leaf production.

Because our results showed that temperature affects the growth of dipterocarp saplings, if we grow the saplings in the nurseries under different temperature regimes, their growth would be varied. Thus, the establishment of multiple nurseries in different temperature conditions would diversify the supply time of good planting materials, which will contribute to a stable supply of planting materials and sustainable timber production of dipterocarps.

(M.J. Kobayashi, N. Tani, K.K.S. Ng [Forest Research Institute Malaysia], S.L. Lee [Forest Research Institute Malaysia], N. Muhammad [Forest Research Institute Malaysia])

TOPIC 8

Development of models for estimating mangrove aboveground biomass at regional scale

Mangroves are unique ecosystems developed in brackish water areas where plants are exposed to physiologically stressful conditions such as high-salinity and anaerobic environments (Fig. 1). Recently, the huge amount of carbon stocks in mangroves have been the focus of studies due to its relevance to climate change, and mangroves have been recognized as very important for storage of blue carbon, which is carbon sequestrated in marine ecosystems. To evaluate the ability of mangroves to sequestrate carbon, biomass estimation over wide regions is essential. In general, biomass estimation is conducted with remote sensing techniques, such as the airborne Light Detection and Ranging (LiDAR) system, to measure average canopy height, which is then converted to biomass using models developed by field researchers. However, models for converting canopy height to biomass were scarce for mangroves in Southeast Asian regions. Therefore, we developed a mangrove model for Asian regions based on field studies conducted at mangroves in the Philippines, Indonesia, and Japan.

Fig. 1. Mangroves inundated with brackish water
Photo taken at a study site in the Philippines

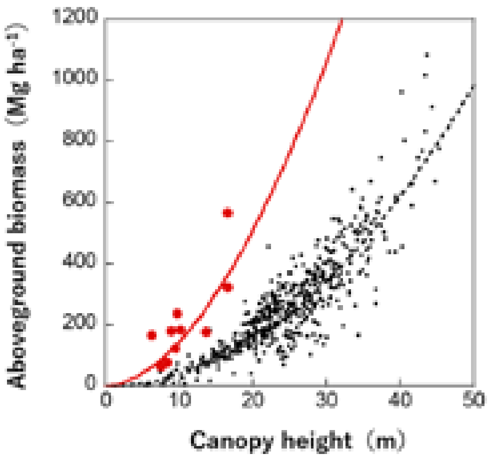


Fig. 2 Relationships of aboveground biomass to canopy height
Red dots and black dots mean mangroves and terrestrial forests, respectively. The solid red line and dashed black line mean regression models for mangroves (the present study) and terrestrial forests (Saatchi et al. 2011 in *PNAS*).

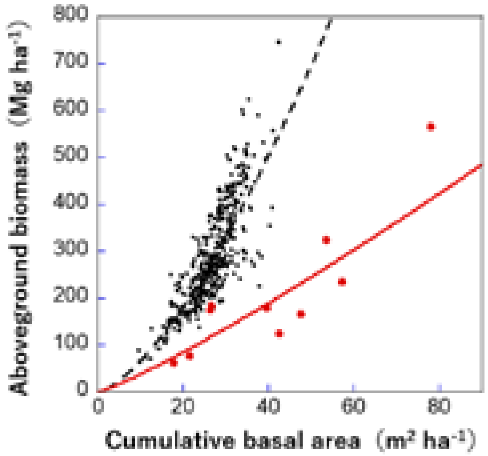


Fig. 3. Relationships of aboveground biomass to cumulative basal area
Red dots and black dots mean mangroves and terrestrial forests, respectively. The solid red line and dashed black line mean regression models for mangroves (the present study) and terrestrial forests (Mitchard et al. 2014 in *Global Ecol. Biogeogr.*).

Our results confirmed that the relationships of aboveground biomass (AGB) to average canopy height for upper-canopy trees showed apparent differences between terrestrial tropical forests and mangroves, where mangroves showed approximately four times higher AGB specific to the canopy height than that of terrestrial forests (Fig. 2). On the other hand, the cumulative basal area *BA* was approximately two times higher in mangroves than in terrestrial forests (Fig. 3). Thus, the high AGB specific to canopy height can be partly explained by their unique characteristics having higher tree density of thick stem trees. Finally, we successfully proposed a common mangrove model for Asian regions as $Y = 2.25X^{1.81}$ (R^2 = 0.66), where Y and X are AGB in Mg ha^{-1} and the average canopy height in m, respectively.

The developed model for estimating AGB with canopy height can be applied for evaluating the carbon stock of mangroves in Asian regions with remote sensing techniques. It should be noted, however, that the developed model cannot be applied to open-canopy mangroves. Furthermore, the developed model tends to underestimate AGB for large forests whose AGB > ca. 400 Mg t ha^{-1}.

(R. Suwa, R. Rollon, G. M. G. Albano, A. C. Blanco [University of the Philippines], S. Sharma [Malaya University], M. Yoshikai, K. Nadaoka [Tokyo Institute of Technology], K. Ono [Forestry and Forest Products Research Institute, Japan], N.S. Adi, R. N. A. Ati, M. A. Kusumaningtyas, T. L. Kepel [Ministry of Marine Affairs and Fisheries, Indonesia], R. J. Maliao, Y. H. Primavera-Tirol [Aklan State University, Philippines])

TOPIC 9

Use of a filamentous green alga (*Chaetomorpha* sp.) and microsnail (*Stenothyra* sp.) as feed at an early stage of intensive aquaculture promotes profitability of giant tiger prawn

Shrimp is a major export item; hence, high Penaeidae shrimp production in intensive aquaculture systems contribute to the economic development of shrimp-producing countries. However, decreasing shrimp productivity and profitability have been reported owing to a deterioration in artificial feed quality and the soaring prices of artificial feed. Following a series of research activities on Penaeidae aquaculture in Southeast Asian countries, JIRCAS was able to develop a simple, low-cost, and sustainable technique to boost productivity, feed efficiency, and profitability of the giant tiger prawn. The aim of this study was to verify the profitability of giant tiger prawn grown in an innovative aquaculture system, in which a filamentous green alga (*Chaetomorpha* sp.) and microsnail (*Stenothyra* sp.) are cultured together during early stage and freely consumed as supplementary live feeds in intensive aquaculture ponds.

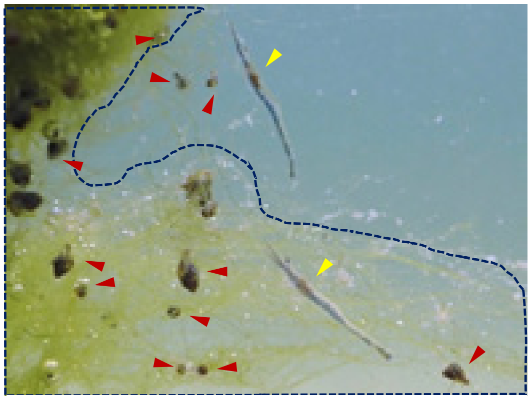


Fig. 1. Post-larvae (Total length: ~9 mm, yellow arrows), *Chaetomorpha* sp. (area within dark blue broken line) and *Stenothyra* sp. (red arrows)

Fig. 2. Sorting operation at a shrimp broker company for giant tiger prawn produced from this study

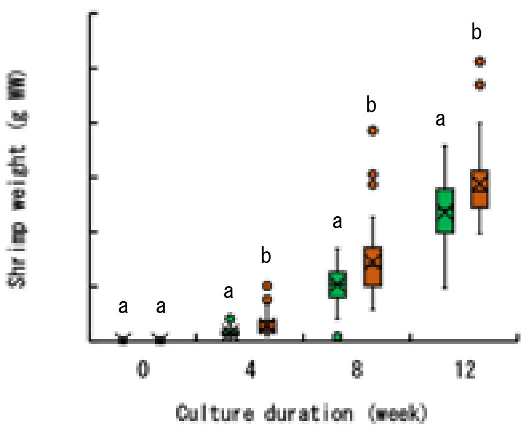


Fig. 3. Changes in wet weight of giant tiger prawn under control (green) and treatment (orange) conditions

Different lowercase letters within the same sampling week indicate a significant difference between treatments (Mann–Whitney U-test, $p < 0.05$, adjusted via the Bonferroni correction for multiplicity)

Post-larvae (mean wet weight: 2 mg, mean total length: 9 mm) of giant tiger prawn were released and cultured at a density of approximately 33 individuals m^{-2} in outdoor concrete ponds (9 m×9 m×1.2 m) at King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand, under either control (fed only artificial feed, n = 3) or experimental (fed artificial feed and benthic organisms, n = 3) conditions (Fig. 1) until they reached marketable size (15 weeks) (Fig. 2, Table 1). Compared with the control group of giant

Table 1. Results of the 15-week giant tiger prawn aquaculture experiment in a concrete pond at KMITL

	Control (n = 3)	Experimental treatment (n = 3)
Growth and productivity		
Final mean individual shrimp weight (g WW)	16.0 ± 0.61	18.2 ± 1.07 *
Total shrimp production (kg WW)	33.0 ± 1.8	43.9 ± 0.5 *
Feed intake and efficiency		
Apparent *Chaetomorpha* intake (kg WW)	—	6.81 ± 1.45
Apparent *Stenothyra* intake (kg WW)	—	1.96 ± 0.05
Apparent artificial feed intake (kg WW)	61.0 ± 3.2	72.0 ± 3.8 *
Feed efficiency (%)	54.1 ± 1.8	61.1 ± 4.0 *
Costs and profitability		
Artificial shrimp feed costs (USD) (a)	83.55 ± 4.45	98.59 ± 5.24 *
Miscellaneous costs (USD) (b)	—	12.11 ± 0.00
Shrimp sales (USD) (c)	155.73 ± 10.27	215.97 ± 4.37 *
Balance between shrimp sales and costs (USD) (c-a-b)	72.18 ± 7.55	105.27 ± 3.02 *

Values are shown as mean ± standard deviation from triplicate data. Superscript labels within the same row indicate significant difference (t-test, $p < 0.05$). Feed efficiency (%) is calculated as 100 × weight gain / Feed amount intake. Common costs between mono-culture and co-culture such as water charges, electric fees, labor, culture materials, etc. are omitted in order to easily compare the profitability results.

tiger prawn, the experimental group significantly improved in terms of productivity (33%), feed efficiency (12%), and profitability (46%) when provided ~8% green alga to total feed consumption and ~2% microsnail to total feed consumption at an early stage of culture. The individual shrimp weight became significantly higher in the experimental treatment ponds (median: 1.12 g, mean: 1.44 g) than those in the control ponds (median: 0.70 g, mean: 0.80 g) at week 4. The technique developed in this study will help enhance productivity, feed efficiency, and profitability in intensive giant tiger prawn aquaculture operations.

From these results, it is expected that this can be applied to Penaeidae intensive aquaculture management systems other than those for giant tiger prawn. Both green alga, *Chaetomorpha* sp., and microsnail, *Stenothyra* sp., were all consumed within 1–2 months due to active grazing by the giant tiger prawn. These two benthic organisms could be propagated for longer periods in shrimp culture ponds for higher productivity, feed efficiency, and profitability.

(I. Tsutsui,
D. Aue-umneoy [King Mongkut's Institute of Technology Ladkrabang])

TOPIC 10

Development of conventional biological indices for evaluation and management of blood cockle fishing/aquaculture grounds

The blood cockle, *Tegillarca granosa* (Fig. 1), is an especially important fisheries resource for Southeast Asia. It is rich in minerals and vitamins, and is an indispensable ingredient in traditional dishes to improve nutritional balance of the local people. These days, production of blood cockle in Southeast Asia is seriously decreasing because of environmental deterioration in the coastal areas where their habitats are. Therefore, appropriate management of the fishing and aquaculture grounds as well as technical measures to recover the bivalve resources are required. For that purpose, easy and economical monitoring techniques are needed to evaluate long- and short-term changes in the bivalve's living environment.

To monitor the condition of the fishing/aquaculture grounds of blood cockle continuously, we developed simple biological indices which can be obtained easily by local fishers. We modified the conventional sharpness index in bivalve shell profiles (shell width / shell length) and applied it to blood cockle to examine its growth conditions. The adjusted sharpness index was deduced from the allometric equation to remove size dependency in the conventional sharpness index (Fig. 2A, Eq. 1). It could be used for blood cockle samples of mixed sizes to detect growth difference between groups from different origins (Fig. 3) to evaluate habitat suitability. For example, a trend in increasing adjusted sharpness index in the same fishing ground suggests environmental deterioration is in progress, causing the growing of the inhabiting blood cockle worse. Thus, we may recommend changing the location of fishing /aquaculture grounds. On the other hand, we examined a new method to estimate the condition factor (soft tissue weight / total wet weight) quickly (Fig. 2B, Eq. 2). We found that shell width can be used as a good estimator of shell weight. The soft tissue weight can be calculated as total wet weight of the bivalve minus total shell weight. In this manner, the condition factor could be calculated from total wet weight and shell width without opening the cockles. A trend in decreasing the condition factor suggests the soft tissue of the blood cockle is getting thinner. Thus, we may recommend harvesting the cockles sooner.

The adjusted sharpness index and the estimated condition factor would provide powerful tools to

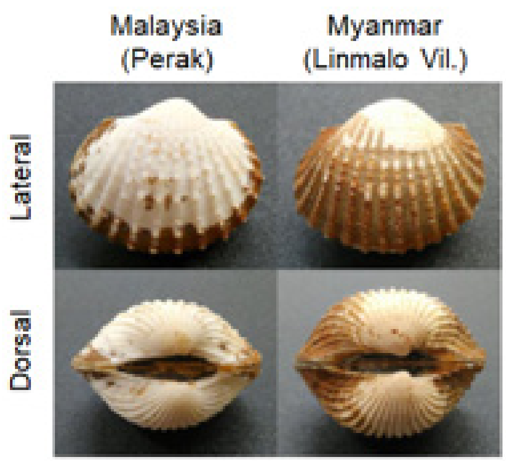
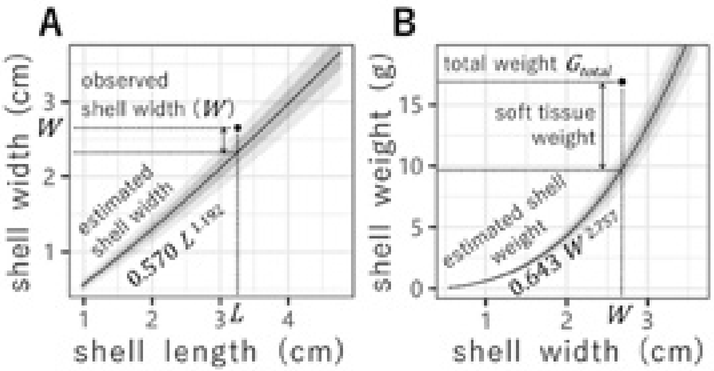


Fig. 1. Blood cockles, *Tegillarca granosa*, collected from Perak, Malaysia (left) and from Linmalo Village, Myanmar (right)



$$SI_{adj} = \frac{W - 0.570L^{1.192}}{L} \quad \text{... Eq. 1}$$

$$CF = \frac{G_{total} - 0.643W^{2.757}}{G_{total}} \quad \text{… Eq. 2}$$

SI_{adj}: Adjusted sharpness index, W: Shell width (cm),

L: Shell length (cm), CF: Condition factor, G_{total}: Total wet weight

Fig. 2. Scatter plots to estimate equations for the adjusted sharpness index (A) and the condition factor
Each plot was superimposed with the allometry curve (black line) and 68% (light grey) and 95% (grey) prediction intervals.

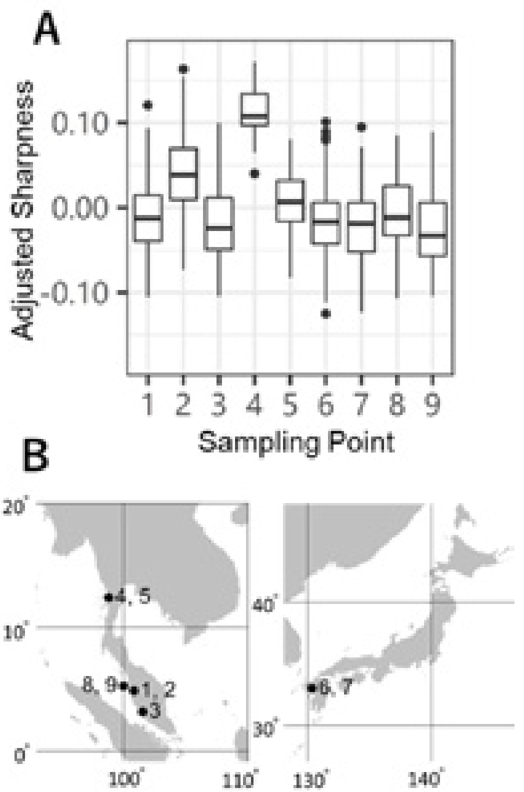


Fig. 3. Adjusted sharpness indices of blood cockles (A) from sampling points (B)

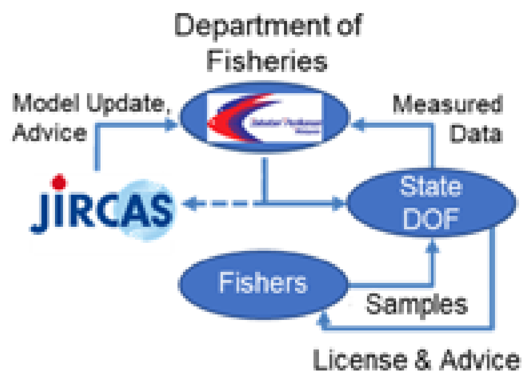


Fig. 4. Schematic model to monitor and manage blood cockle fishing/aquaculture grounds in Malaysia

monitor long- and short-term growth conditions of blood cockles, and to evaluate the condition of its fishing/aquaculture grounds indirectly. The developed biological indices would provide fisheries authorities scientific evidence to make recommendations for blood cockle fishery management. The developed indices can be calculated easily by measuring only three body size variables — length, width, and total weight — using simple tools such as calipers and weighing scales, therefore even fishers can utilize them. JIRCAS has worked together with our counterpart in Malaysia to construct a data collection and monitoring scheme for the management of blood cockle fishing/aquaculture grounds (Fig. 4).

(H. Saito [Fisheries Technology Institute], H. W. Teoh [China-ASEAN College of Marine Sciences, Xiamen University, Malaysia])

Program D
Information Analysis

“Collection, analysis and dissemination of information for grasping trends of international agriculture, forestry and fisheries”

Program D (Information Analysis) collected, analyzed, and disseminated information on current developments and trends in international agriculture, forestry and fisheries that will guide the identification of research priorities and the development of strategic research agendas. The program consisted of the following major research activities, namely, the evaluation of the global food supply-demand and nutrition balance; the collection and dissemination of the latest information on global agricultural research agendas; and the implementation of the goal-oriented basic research projects.

The global food supply-demand and nutrition balance research project covered country-level case studies and scenario analyses based on the foresight model of global food supply-demand, with the aim of identifying and guiding areas where intervention is needed to improve the food and nutrition security situation of vulnerable populations. Some highlights of the analyses implemented during fiscal year 2020 are briefly described below. As the COVID-19 pandemic triggered concerns over the deterioration of global food and nutrition security among the most vulnerable populations in developing countries, we got actively engaged in communication, through publishing a series of online articles and making presentations at online events. For the foresight study, an ex-ante impact assessment was performed to evaluate the financial impacts of technologies that JIRCAS typically develop. For example, scenario analyses were conducted with an economic model to evaluate the impacts of introducing soybean rust-resistant varieties in Latin American countries. The results indicated that the adoption of new varieties could contribute not only to global food security by securing stable outputs thus averting hikes in global prices, but also to planetary health by substantially reducing the use of chemical pesticides.

Under Program D, JIRCAS actively participated in international initiatives and forums to discuss research and policy agendas to contribute to global food and nutrition security. For the fiscal year 2020, however, almost all physical gatherings for those initiatives and forums were cancelled, postponed, or instead held online due to the escalation of the COVID-19 pandemic and corresponding movement restrictions. Program D indeed took advantage of the increase in demand for latest information on global issues, especially the impacts of the pandemic on the functioning of global food systems as well as drivers affecting the climate crises and biodiversity loss, by exploring new modes of information dissemination. For example, JIRCAS International Symposium 2020, commemorating its 50th anniversary, was held online while featuring the timely topic of the post-COVID 19 agricultural research agendas of the global food system, attracting 365 people (including 81 abroad, more than double compared with the previous years). The Research Strategy Office team also regularly uploaded a series of timely articles, with links to the latest news on global topics such as climate change, food and nutrition security, and JIRCAS research activities, to the ‘Pick Up’ site of JIRCAS HP. Between April 2020 and the end of January 2021, more than 220 articles were uploaded, attracting 100,000 views over the 10-month period, highlighting JIRCAS’s role in Information Analysis.

Lastly, Program D oversaw the implementation of goal-oriented basic research projects, which feature novel research ideas whose outcomes are expected to yield technological innovations and promising business opportunities in the agriculture and food industries. The following five research projects were implemented under joint research schemes with Japanese and/or foreign research institutions. They include: 1) the characterization of rice germplasms collected by and introduced from the International Rice Research Institute (IRRI) with the aim of developing superior breeding materials; 2) the evaluation of functional components of a non-conventional yeast, 3) the comparative genetic analysis of shrimps and locusts to develop gene discovery systems, 4) the investigation of shrimp ovarian growth systems to enhance efficiency and sustainability of seed production, and 5) the improvement of environmental adaptability of tropical fruit species, including mango and passion fruit. Over the five years, all the five projects made significant achievements which are expected to lead to immediate social outcomes or future innovations. For example, the development of genetic materials/ varieties [ex. 1) a rice variety suitable for domestic Awamori production] and agronomy practices [ex. 5) a simple virus-free technology for passion fruits] can not only benefit farmers but may also contribute to furthering Japan’s policy goals and developing the country’s agriculture sector. The result of experiments to ferment a non-conventional yeast with cassava pulp suggested dual effects of revitalizing immune systems and tranquilizing inflammation, indicating the possibility of developing effective supplements [2], while the genome sequence analyses succeeded in identifying key genes controlling, for example, polyphenism in locust [3]. Some of the technologies, such as that to promote shrimp ovarian growth, have attracted substantial interests both from domestic and foreign private companies, prompting JIRCAS to set up a platform to utilize its intellectual properties and set up joint ventures [4].

Training and Invitation Programs

Information Events

Invitation Programs at JIRCAS

To establish and maintain its role as an international research center, JIRCAS has implemented several invitation programs for foreign researchers and administrators from counterpart organizations. These invitation programs are designed to facilitate the exchange of information and opinions on agriculture, forestry, and fisheries research, and their implementation and administration simultaneously provide an opportunity to strengthen research ties among scientists and administrators in participating countries, mostly in developing regions. However, due to the global outbreak of the 2019 novel coronavirus (COVID-19) from the beginning of 2020, all invitation programs scheduled by JIRCAS for FY 2020 were canceled. Moreover, the completion of some invitation programs that were carried over from FY 2019 were delayed, and all kinds of business trips have remained closed or canceled from FY 2020 up to now, marking the first time in the history of JIRCAS that all training and invitation programs for the entire financial year were canceled. Below is a brief description of JIRCAS's invitation programs spanning FYs 2019 and 2020.

Administrative Invitation Program

Under the Administrative Invitation Program, JIRCAS invites administrators and managers from counterpart organizations to its Tsukuba premises to engage in discussions and reviews of ongoing research to ensure that the collaborative projects run efficiently. This invitation program exposes the current activities of JIRCAS and other MAFF-affiliated National Research and Development Agencies (NRDAs) to the administrators. It also provides opportunities to exchange information and opinions concerning policymaking and project design at the administrative level, thus contributing to a deep and mutual understanding for improving international collaboration. A total of twenty-one (21) visits to JIRCAS occurred during FY 2019 under this program. Unfortunately, the Administrative Invitation Program for FY 2020 was canceled due to the COVID-19 pandemic.

Counterpart Researcher Invitation Program

The Counterpart Researcher Invitation Program provides invitations for periods of up to six months to researchers engaged in collaborative work with JIRCAS research staff. Generally, counterparts conduct in-depth research at JIRCAS, at other MAFF-affiliated NRDAs, at prefectural research institutes, or national universities. This invitation program aims to enhance the quality of research conducted overseas and facilitate exchanges of individual research staff between JIRCAS and the counterpart institutions. A total of fifty-two (52) researchers were invited under this program during FY 2019. In response to COVID-19, the Counterpart Researcher Invitation Program for FY 2020 was canceled as well.

Project Site Invitation Program

Since 2007, JIRCAS has been carrying out the Project Site Invitation Program. The purpose of this invitation program is to invite researchers from developing countries to the project sites where JIRCAS researchers are engaged in JIRCAS-funded collaborative research projects on various research themes related to the projects. A total of fourteen (14) researchers were invited to implement their programs during FY 2019. However, because of the global pandemic, the Project Site Invitation Program for FY 2020 was also canceled.

Fellowship Programs at JIRCAS

JIRCAS Visiting Research Fellowship Program

The current JIRCAS Visiting Research Fellowship Program began in FY 1992 with the launching of the JIRCAS Visiting Research Fellowship Program at Okinawa, where researchers are invited to do research on topics relating to tropical agriculture for a period of one year at the Tropical Agriculture Research Front (TARF, formerly Okinawa Subtropical Station). In October 1995, a similar program (JIRCAS Visiting Research Fellowship Program at Tsukuba) began implementation at JIRCAS's Tsukuba premises, aiming to promote collaborative research activities that address various problems confronting countries in developing regions. In FY 2006, these fellowship programs were modified and combined. In FY 2019, a total of five (5) researchers were selected and invited to conduct research at JIRCAS HQ in Tsukuba; however, the invitation was not announced for Okinawa. The FY 2019 program was originally scheduled to finish in September 2020 but due to the COVID-19 pandemic and international travel restrictions, it was extended by JIRCAS for an additional six (6) months (until March 31, 2021). On March 10, 2021, all five fellows presented their final research outputs and received their JIRCAS Fellowship completion certificates from the president of JIRCAS. Finally, all JIRCAS fellows and their families returned safely to their home countries by the end of March 2021. However, the announcement for JIRCAS Fellowship Program FY 2020 was not issued as JIRCAS was in the final year of the 4th Medium to Long-term Plan and because of the COVID-19 pandemic.

JIRCAS Visiting Research Fellowship Program at Tsukuba (October 2019 - March 2021)

No	Name	Institution/Organization	Research Theme	Duration
1	Xiang Gao	Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, PR China	Functional link between leaf NRA (nitrate reductase activity) and BNI-capacity in sorghum	Oct. 12, 2019 - Mar. 31, 2021
2	Zhumei Du	College of Grassland Science and Technology, China Agricultural University, PR China	Development of preparation techniques of fermented TMR with feed resources in Africa	Oct. 01, 2019 - Mar. 31, 2021
3	Giriraj Kumawat	ICAR-Indian Institute of Soybean Research, India	Identification and function analysis of genes controlling root development in soybean	Oct. 01, 2019 - Mar. 25, 2021
4	Luciano Nobuhiro Aoyagi	Soybean Research Center, Brazilian Agricultural Research Corporation (Embrapa Soybean), Brazil	Characterization of new soybean lines pyramided with resistance genes against Asian soybean rust disease	Oct. 01, 2019 - Mar. 31, 2021
5	Sirilak Baramee	Department of Biology, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Thailand	Establishment of biological simultaneous enzyme production and saccharification (BSES) process using *Herbivorax saccincola* A7 and *Clostridium thermocellum*	Oct. 14, 2019 - Mar. 18, 2021

JIRCAS Visiting Research Fellowship Program at Project Sites

This fellowship program has been implemented since May 2006 in collaboration with research institutions located in developing countries where collaborative research is being carried out by JIRCAS researchers. This program aims to promote the effective implementation of ongoing collaborative research at the project sites with the participation of local research staff. Through this fellowship program, JIRCAS also intends to contribute to the capacity-building of the collaborating research institutions. In FY 2019 and FY 2020, no invitation was released for the Project Sites Program.

For inquiries on the JIRCAS Visiting Research Fellowship Program, please contact the International Relations Section (IRS) (Tel. +81-29-838-6336; Fax +81-29-838-6337; e-mail: irs-jircas@ml.affrc.go.jp)

Other Fellowships for Visiting Scientists

The Visiting Researcher Program of JIRCAS considers scientists who have an excellent record of research achievements and are involved in conducting overseas research on agriculture, forestry, and fisheries in tropical and subtropical regions under overseas research institutions or universities. In FY 2019, JIRCAS accepted one visiting researcher from Jilin University, China. However, as with other invitation programs, the Visiting Researcher Program for FY 2020 was also canceled due to COVID-19.

Lastly, the Government of Japan sponsors a postdoctoral fellowship program and a researcher exchange program for foreign scientists through the Japan Society for the Promotion of Science (JSPS). The program places post-doctoral and sabbatical fellows in national research institutes throughout Japan according to research theme and prior arrangement with host scientists, in periods of one month to three years. Fellowships can be undertaken in any of the ministries of Japan, and many fellows are currently working at various NRDAs affiliated with MAFF.

Visiting Researcher Program (April 2020 to March 2021)

Name	Institution/Organization	Research Theme	Duration
Dequan Liu	College of Plant Science, Jilin University, PR China	Identification and cloning of genes controlling several important agronomic traits genes in soybean	Nov. 29, 2019 - Nov. 29, 2021

JSPS Postdoctoral Fellowship Program for Overseas Researchers (April 2020 to March 2021)

Name	Institution/Organization	Research Theme	Duration
Getnet Dino Adem	University of Tasmania, Australia	Functional characterization of candidate genes for PUE and mining their allelic variants in rice	Jul. 18, 2018 - Aug. 17, 2020
Patrick Enrico Hayes	University of Western Australia, Australia	Optimising the allocation of phosphorus fractions in rice to improve nutrient-use efficiency	Jul. 18, 2018 - May 01, 2020
Md Asaduzzaman Prodhan	Department of Primary Industries and Regional Development, Australia	Dissecting the genetic basis of root vigor: applications for improving rice for a changing world	May 12, 2019 - Feb. 06, 2021

Workshops

JIRCAS-FFTC International Workshop on "Applicable Solutions Against Rice Blast in Asia"

The International Workshop "Applicable Solutions Against Rice Blast in Asia" co-organized by JIRCAS and the Food and Fertilizer Technology Center (FFTC) was held on September 18, 2020. Due to the influence of COVID-19, it was held as an online conference with JIRCAS as the main venue. The workshop focused on discussions on the recent advancement in rice blast research, the achievements of the Rice Blast Research Network conducted by JIRCAS since 2006, and the direction of future research using those research results and genetic resources.

This workshop was the first large-scale online international conference of JIRCAS, with 100 online participants and 16 on-site participants from 18 countries and regions. In the opening ceremony, JIRCAS President Masa Iwanaga and FFTC Director Su-San Chang expressed the importance of rice blast research and the significance of this workshop on behalf of the organizers. Then, the director of International Research, Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries (MAFF), Mr. Hiroshi Honjo, emphasized the role of joint research on cross-border pests and expressed his expectations for the workshop.

In the keynote address, Dr. Yoshimichi Fukuta of JIRCAS gave an overview of the International Rice Blast Research Network and introduced the genetic resources that can be used for future research. The presentation also tackled the importance of the differential system in elucidating the pathogenicity of blast races and resistance of rice cultivars, elimination of highly pathogenic blast races using genetic diversity, breeding materials with partial resistance gene, and the use of multiline varieties which could lead to the development of control technologies that meet the needs of farmers.

In the first session on international differential variety and characterization of resistance genes, the presentations focused on evaluation and designation method for rice blast fungus race using monogenic lines as differential variety set (Institute of Agrobiological Sciences, NARO), development and characterization of international differential varieties for blast disease (JIRCAS), and genetic improvement for resistance using partial resistance genes (Aichi Agricultural Research Center). In the panel discussion, it was pointed out that the differential system should consist of a set of differential varieties without any additional major resistance gene in the genetic backgrounds and a set of standard differential blast isolates with a wide pathogenicity, and that the introduction of a partial resistance gene could be effective as one approach for development of durable protection system in rice.

In the second session, representatives from FFTC member countries such as Malaysia, South Korea, Thailand, and Taiwan reported on the current state of blast disease and variations in blast races. The importance of using the differential varieties jointly developed by the International Rice Research Institute (IRRI) and JIRCAS has been reconfirmed, and the virulence gene analysis has revealed a low frequency of isolates capable of infecting the resistance gene *Pi9*(t) based on the research results from Thailand and Taiwan.

In the third session, representatives from the countries participating in the International Rice Blast Research Network gave reports on blast studies using the differential system. The presentations focused on genetic variations of blast races and rice varieties in each region as well as the development of breeding materials using partial resistance genes. The discussion confirmed the high risk of developing pathogenic strains in the *Pik* locus multiple alleles. On the other hand, it was confirmed that there were a few pathogenic strains against the multiple alleles of the *Piz* locus, especially *Pi9*(t). However, a panelist stated that the outbreak of blast race virulent to *Pi9*(t) has been already found in India. In addition, it was confirmed that the Standard Material Transfer Agreement (SMTA) etc. could facilitate to exchange breeding materials with partial resistance gene and that future joint research will be developed in consideration of commercial profit sharing.

In the closing address, FFTC Deputy Director Akira Hasebe expressed the summary of the entire workshop and the importance of promoting continuous research and announced plans such as publication of presentations and proceedings of the workshop.

Proceedings regarding this workshop can be downloaded from the FFTC website (https://www.fftc.org.tw/en/publications/main/2301).

Screenshot of online participants after the workshop

International Symposiums, Workshops, and Seminars, FY 2020			
1	4th Joint Coordination Committee (JCC) Meeting for the SATREPS project "Breakthrough in nutrient use efficiency for rice by genetic improvement and fertility sensing techniques in Africa"	September 17, 2020	Held online
2	JIRCAS - FFTC International Rice Blast Workshop titled "Applicable solutions against rice blast in Asia"	September 18, 2020	Held online
3	5th Technical Coordinating Committee Meeting for the "Project on Establishment of fertilizing crop cultivation promotion model using Burkina Faso phosphate rocks"	October 22, 2020	Held online
4	2nd Joint Coordination Committee (JCC) Meeting for the SATREPS project "Sustainable Replantation of Oil Palm by Adding Value to Oil Palm Trunk through Scientific and Technological Innovation"	October 27, 2020	Held online
5	JIRCAS 50th Anniversary International Symposium 2020: The role of international collaboration in agricultural research to address challenges in the post-COVID-19 global food system	November 10, 2020	Held online
6	JIRCAS - CSSRI Collaborative Research Seminar 2021: Low-cost shallow sub-surface drainage technology (Cut-soiler) for mitigating salinization	March 12, 2021	Held online
7	Final Project Meeting for the "Development of intensive watershed management models for soil erosion-prone areas in Sub-Saharan Africa"	March 18, 2021	Held online
8	Study Meeting for the draft manual on "Issues concerning crop-livestock integration"	March 31, 2021	Held in Manhiça District, Maputo, Mozambique (JIRCAS researchers participated via video message)

Appendix

Publishing at JIRCAS

English

1) JARQ (Japan Agricultural Research Quarterly)

Vol. 54 No. 3, No. 4

Vol. 55 No. 1, No. 2

2) Annual Report 2019

3) JIRCAS Newsletter No.89, No.90

4) JIRCAS Working Report No. 91, No. 92

5) 50th Anniversary —Achievements from the Past and Expectations for the Future —

Japanese

1) Kōhō JIRCAS Vol. 6, Vol. 7

2) JIRCAS News No.89, No.90

3) Kenkyū Sōsyo No.25

4) Kokusainōkensōritsu50syūnenkinenshi—kokusainōrinsuisangyōkenkyū50nen —

Refereed Journal Articles 2020-2021

Program A

Afzal, M.R., Zhang, M.X., Jin, H.Y., Wang, G.M., Zhang, M.C., Ding, M., Raza, S., Hu, J., Zeng, H.P., Gao, X., Subbarao, G.V.* and Zhu, Y.Y.* (2020) Post-translational regulation of plasma membrane H^+-ATPase is involved in the release of biological nitrification inhibitors from sorghum roots, *Plant and Soil*, 450:357-372, DOI: 10.1007/s11104-020-04511-6.

Aizaki, H.*, Furuya, J., Sakurai, T. and Mar, S.S. (2021) Measuring farmers' preferences for weather index insurance in the Ayeyarwady Delta, Myanmar: a discrete choice experiment approach, *Paddy and Water Environment*, DOI: 10.1007/s10333-020-00838-z.

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Cai, Y.M.*, Du, Z.M., Yamasaki, S., Jethro, D.B. and Man, N. (2020) Chemical composition, characteristics concerned with fermentative quality and microbial population of ensiled pearl millet and sorghum stover in semi-arid West Africa, *Animal Science Journal*, 91:e13463, DOI: 10.1111/asj.13463.

Hirano, A.* (2021) Effects of climate change on spatiotemporal patterns of tropical cyclone tracks and their implications for coastal agriculture in Myanmar, *Paddy and Water Environment*, DOI: 10.1007/s10333-021-00842-x.

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Leon, A.*, Minamikawa, K., Izumi, T. and Chiem, N.H. (2020) Estimating impacts of alternate wetting and drying on greenhouse gas emissions from early wet rice production in a full-dike system in An Giang Province, Vietnam, through life cycle assessment, *Journal of Cleaner Production*, 285:125359, DOI: 10.1016/j.jclepro.2020.125309.

Maeda, K.*, Nguyen, V.T., Suzuki, T., Yamada, K., Kudo, K., Hikita, C., Le, V.P., Nguyen, M.C. and Yoshida, N. (2020) Network analysis and functional estimation of the microbiome reveal the effects of cashew nut shell liquid feeding on methanogen behaviour in the rumen, *Microbial Biotechnology*, DOI: 10.1111/1751-7915.13702.

Matsumoto, N.*, Nobuntou, W., Punlai, N., Sugino, T., Rujikun, P., Luanmanee, S. and Kawamura, K. (2020) Soil carbon sequestration on a maize-mung bean field with rice straw mulch, no-tillage, and chemical fertilizer application in Thailand from 2011 to 2015, *Soil Science and Plant Nutrition*, DOI: 10.1080/00380768.2020.1857660.

Minamikawa, K.*, Kodama, M. and Hayashi, H. (2021) Effect of cashew nut shell liquid on rice growth and methane emission from paddy soil, *Soil Science and Plant Nutrition*, DOI: 10.1080/00380768.2021.1887710.

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Underline indicates researcher at JIRCAS.
* Corresponding author

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Fourth Medium to Long-Term Plan of the Japan International Research Center for Agricultural Sciences

March 31, 2016 (Revision: March 26, 2019)

The Japan International Research Center for Agricultural Sciences (JIRCAS) has been helping improve technologies for agriculture, forestry, and fisheries in tropical and subtropical areas, as well as in other overseas developing regions (hereinafter referred to as “developing regions”), by performing technical trials and research.

During the First Medium-Term Goal period (FY 2001 to 2005), JIRCAS worked on research and development (R&D) for the sustainable development of agriculture, forestry, and fisheries, as well as on the expansion of international research exchanges and networks, taking into account both domestic and overseas situations, such as the adoption of the United Nations Millennium Development Goals for the eradication of poverty and hunger in the world.

During the Second Medium-Term Goal period (FY 2006 to 2010), JIRCAS created a multilateral collaborative research system, promoted collaborative research with world-class research organizations led by the Consultative Group on International Agricultural Research (CGIAR), established a dynamic research system, and implemented major research projects. In FY 2008, JIRCAS took over international activities from the dissolved Japan Green Resources Agency and strengthened its field activities.

During the Third Medium-Term Goal period (FY 2011 to 2015), a program/project scheme was developed for three principal research areas: environment and natural resource management; stable food production; and livelihood improvement of the rural population. In addition, flagship projects to which research resources were intensively allocated were set up to promote research. Furthermore, systems were developed to strengthen the process of disseminating research results and ensuring the safe management of experimental materials.

On the basis of the outcomes of JIRCAS’s commitments and in accordance with the Basic Plan for Agriculture, Forestry and Fisheries Research (determined at the meeting of the Agriculture, Forestry and Fisheries Research Council on March 31, 2015), three principal research areas have been identified for the Medium to Long-Term Goal period, namely: (1) development of agricultural technologies for sustainable management of the environment and natural resources in developing regions; (2) technology development for stable production of agricultural products in the tropics and other adverse environments; and (3) development of high value-adding technologies and utilization of local resources in developing regions. Resources will be allocated to these research areas on a priority basis, and innovations in research management will be promoted to maximize R&D outcomes. To best understand the needs and seeds of technological development in developing regions and to promote R&D in line with Japan’s policy, JIRCAS will strengthen its capability related to the collection, analysis, and dissemination of information on international agriculture, forestry, and fisheries.

Through this series of activities, JIRCAS, as Japan’s only research institution mandated to carry out comprehensive international research in agriculture, forestry, and fisheries, is committed to strengthening the framework of collaboration with related organizations and to play a key role in R&D targeting developing regions. In this way, it will help solve global food problems and sophisticate Japan’s research in agriculture, forestry, and fisheries.

I. Improving the Quality of Operations, Including Maximizing R&D Outcomes

JIRCAS will promote and evaluate the following five operational items as individual segments:

i. Promotion of research planning and partnership [1 to 5]

ii. Development of agricultural technologies for sustainable management of the environment and natural resources in developing regions [6(1); Attachment 1]

iii. Technology development for stable production of agricultural products in the tropics and other adverse environments [6(1); Attachment 2]

iv. Development of high value-adding technologies and utilization of local resources in developing regions [6(1); Attachment 3]

v. Collection, analysis, and dissemination of information to understand trends in international agriculture, forestry and fisheries [6(2)]

(Note) Notations within the above square brackets indicate subsections relevant to each item of operation.

<Promotion of research planning and partnership >

1. Promotion of research in line with government policy and enhancement of the PDCA (Plan, Do, Check, Action) cycle

(1) Strategic promotion of research in line with government policy

a) JIRCAS will identify research subjects and research promotion measures and will promote R&D strategically in consideration of the following issues: the need for technical improvement of agriculture, forestry, and fisheries in developing regions; the international situation; the need to contribute to government policy; the need to sophisticate Japan's research on agriculture, forestry, and fisheries; and ripple effects of R&D outcomes on technological improvement.
b) If JIRCAS, through its R&D, obtains technology seeds and findings useful to companies and producers in Japan, it will actively provide information and local support toward commercialization.
c) JIRCAS will manage the progress of research topics by preparing a process sheet stipulating the specific goals of each fiscal year before the start of research.
d) JIRCAS will evaluate research subjects adequately and rigorously, with the involvement of external experts, in accordance with the progress of the Medium to Long-Term Plan.
e) JIRCAS will pursue the approach of selection and concentration of research in light of the results of these evaluations and changes in social circumstances and will review, change, enhance, or terminate research subjects as necessary.

(2) Evaluation of the agency as a whole and allocation of resources

a) JIRCAS, as a whole agency, will develop a mechanism to conduct adequate self-evaluation and checking of the state of project management and the progress of research and will strengthen its PDCA cycle by reviewing plans adequately in light of the results of this evaluation and checking. Evaluation will be conducted according to the evaluation items and indexes specified by the Ministry of Agriculture, Forestry and Fisheries.
b) On the basis of the evaluation results, JIRCAS will develop and manage a system to allocate research resources such as budget amounts and personnel adequately to promote research activity. Effective incentives will be given to research personnel at the discretion of the President, and the research environment will be improved.
c) To further promote the Medium to Long-Term Plan, JIRCAS will make vigorous efforts to obtain external research funds, such as funds for commissioned projects and competitive funds.
d) The results of evaluations by the competent minister, and other findings, will be reflected adequately in the project management on a timely basis.

2. Promotion and enhancement of collaboration and cooperation between industry, academia, and government

a) JIRCAS will enhance collaboration and coordination with international organizations, domestic and international research institutes, extension organizations, universities, and private companies and will actively promote the exchange of information and staff.
b) In accordance with government strategies such as the Global Food Value Chain Strategy (developed on June 6, 2014 by the Committee for Global Food Value Chain Strategy), JIRCAS will use research networks to strengthen domestic and international collaboration.
c) JIRCAS will strengthen its cooperation in the use of technology seeds and human resources with such organizations as the National Agriculture and Food Research Organization (NARO) (including sections in charge of international collaboration), the Forestry and Forest Products Research Institute, and the Japan Fisheries Research and Education Agency.
d) By using the locational advantage of the Tropical Agriculture Research Front, JIRCAS will cooperate in the Genebank Project, NARO and a breeding study conducted by NARO, as well as in research projects conducted by other research organizations, to help advance agriculture, forestry, and fisheries in Japan.

3. Strategic promotion of intellectual property management

(1) Development of basic policy on intellectual property management

The basic policy on intellectual property management to promote the social implementation of R&D outcomes in developing regions will be reviewed in consideration of the Ministry of Agriculture, Forestry and Fisheries' Intellectual Property Strategy 2020 (issued on May 28, 2015 by the Ministry of Agriculture, Forestry and Fisheries) and the Policy on Intellectual Property in Research in Agriculture, Forestry and Fisheries (decreed by the Agriculture, Forestry and Fisheries Research Council on February 23, 2016).

(2) Promotion of social implementation of R&D outcomes through intellectual property management

a) A system of intellectual property management applicable to a series of processes from the planning stage of R&D to the stage after the completion of R&D will be developed and managed.
b) With goals that include using R&D outcomes as global public goods in developing regions, JIRCAS will study methods of obtaining the intellectual property rights for, preserving the confidentiality of, and disclosing R&D results; it will also study the policy of licensing. It thus aims to improve the speed of social implementation of research results and will pursue the smooth management of intellectual property.
c) On the basis of the basic policy on intellectual property management, JIRCAS will take the actions necessary for strategic management of intellectual property.

4. Enhancement of social implementation of R&D outcomes

(1) Publication of R&D outcomes

The outcomes of R&D will be published through research highlights, academic journals, and academic conferences. On such occasions, due consideration will be given to the possibility of obtaining intellectual property rights to research results and the need to preserve confidentiality.

(2) Promotion of technology dissemination

a) JIRCAS will quickly disseminate research results by converting them into databases and manuals; research results will be presented in forms available to farmers, companies, and extension organizations.
b) JIRCAS will collaborate with the relevant organizations to disseminate research results in countries and regions where the results may be utilized.
c) To promote the practical utilization of R&D results and create innovations through commercialization, JIRCAS shall, and if necessary, provide support, human resources, and technical assistance to parties who will use or pursue the application of these R&D results in business activities, in accordance with the Act on Activation of Science, Technology and Innovation (Act No. 63 of 2008). JIRCAS will appropriately implement the abovementioned support and assistance upon formulating the necessary rules according to the guidelines on contributions etc. of the National Research and Development Agency (Director General for Science, Technology and Innovation Policy, Cabinet Office, January 17, 2019).

(3) Enhancement of public relations activities

a) JIRCAS will develop and implement publicity strategies to make its activities known to the public and increase its name recognition in Japan and other countries.
b) JIRCAS will disseminate information by using various media and opportunities, such as press releases, interviews, publication of journals and email magazines, and participation in external exhibitions.
c) JIRCAS will effectively disseminate information adapted to research areas and will target end-users through locally held workshops and explanatory meetings.

(4) Interactive communication with the public

a) JIRCAS will promote effective, interactive communication by holding symposiums and seminars and arranging educational tours and technical consultations.
b) JIRCAS will actively conduct outreach activities such as participating in external exhibitions and science café events and offering visiting lectures, in addition to making its facilities open to the public, in order to gain public feedback and increase public understanding of its activities.
c) JIRCAS will seek the understanding of residents in the areas targeted by research through cooperation with research partners and local governments in these target areas.

(5) Understanding and publication of medium to long-term ripple effects of R&D outcomes

a) JIRCAS will conduct follow-up surveys systematically regarding the main R&D outcomes it has achieved since becoming an incorporated administrative agency. It will publicize the survey results on its web site and by other means.
b) JIRCAS will disseminate information through its web site and by other means to make it widely known to the public that its R&D outcomes and activities have helped advance agriculture and society in Japan and developing regions.

5. Reinforcement of ties with government departments and other organizations

a) JIRCAS will closely exchange information with the relevant administrative departments to respond to their needs at various stages, from the design of research to the dissemination and commercialization of research results. JIRCAS will invite the relevant administrative departments to annual meetings to discuss the research results.
b) On request from administrative departments, JIRCAS will cooperate in conducting emergency operations, holding liaison conferences and symposiums, and dispatching experts.
c) On request from national and local governments, organizations, or universities, JIRCAS will perform analyses and appraisals that require its highly specialized knowledge and are difficult for other bodies to perform.
d) JIRCAS will welcome participants and trainees from other national research and development agencies, universities, national and public institutions, the private sector, and overseas organizations so as to develop human resources and raise technical standards.
e) As an organization that performs comprehensive research on agriculture, forestry, and fisheries, JIRCAS will dispatch its staff to committee meetings and conferences held by related international organizations and academic associations and will cooperate in other activities on request.

<Research work>

6. Promotion of research work (experiments, research, investigations)

(1) Focused areas and direction of research

a) JIRCAS will focus on the research subjects listed in the Attachment in consideration of the need for technical improvement of agriculture, forestry, and fisheries in developing regions, the international situation, the need to contribute to government policy, the need to sophisticate Japan's research on agriculture, forestry, and fisheries; and ripple effects of R&D outcomes on technological improvement.
b) JIRCAS will exchange information and develop systems of collaboration with relevant organizations in Japan and abroad and will promote effective international joint research in collaboration with developing regions, developed countries, international research organizations such as CGIAR, private organizations (including NGOs), and international research networks.
c) JIRCAS will further strengthen its alliances with other national research and development agencies in the field of agriculture, forestry, and fisheries and will effectively promote collaborative research utilizing research resources owned by the relevant organizations.

(2) Collection, analysis and dissemination of information for grasping trends of international agriculture, forestry and fisheries

a) To help solve global food and environmental problems, JIRCAS will analyze the current status of food supply and demand, nutritional improvement, and food systems in foreign countries and will forecast the future—and analyze the ripple effects—of research results.
b) To contribute to agriculture, forestry, and fisheries R&D in developing regions and to Japan's policies, such as the development of a global food value chain, JIRCAS will collaborate with the relevant organizations in Japan and abroad and will dispatch personnel to focus areas. It will collect and organize information and materials related to the international food situation and to agricultural, forestry, and fishery industries and rural areas in a regular, institutional, and systematic manner, and it will supply this information widely to researchers, administrative agencies, and companies in Japan and abroad.
c) To strengthen the systematic exchange of information among relevant organizations in Japan, JIRCAS will manage the Japan Forum on International Agricultural Research for Sustainable Development (J-FARD).
d) JIRCAS will promote goal-oriented basic research by using Presidential incentive expenses and other means.
e) In promoting goal-oriented basic research, JIRCAS will, in principle, abide by the Basic Plan for Agriculture, Forestry, and Fisheries Research and will choose research subjects in consideration of the significance and effectiveness of its own involvement. In addition, JIRCAS will focus on the future potential of pioneering research, including the creation of technology seeds leading to innovation and the development of new research areas through the combination of different research disciplines. Furthermore, JIRCAS will evaluate the progress of research and will take the necessary management actions, such as modification of the method of research or termination of research topics.

II. Efficient Business Management

1. Cost reduction

(1) Reduction in costs such as general and administrative expenditures

Administrative operations implemented by operational grants will be reviewed and efficiency will be further promoted. Average annual reduction targets are at least 3% with respect to the previous year for general and administrative expenditures (excluding personnel expenditures), and at least 1% with respect to the previous year for research expenditures.

(2) Streamlining of procurement

a) JIRCAS will develop a Procurement Streamlining Plan, including quantitative targets and specific indexes, by the end of June each fiscal year. It will implement the plan consistently and will conduct a self-evaluation of the plan's performance at an implementation evaluation session each fiscal year.
b) JIRCAS will maintain fairness by clarifying the reasons for adopting free contracts (e.g., when only one company can provide a special item) and extending unit-price contracts. It will try to procure items for R&D rapidly.
c) JIRCAS will collaborate with NARO to improve efficiency by conducting joint procurement and sharing tender price information.

2. Review and improvement of efficiency in organization and operations

(1) Restructuring of organization and operations

a) JIRCAS will review its organization and operations flexibly toward achieving the Medium to Long-term Goal and strengthening the PDCA cycle.
b) JIRCAS will promote the computerization of operations by, for example, improving the corporation's information systems. It will improve efficiency by using a TV conference system and Information and Communication Technology (ICT).
c) Through the above efforts, JIRCAS will optimize personnel arrangement and operations.

(2) Integration of research facilities and equipment (plan of facilities and equipment)

Planned renovation and upgrading of facilities essential to research promotion will be primarily implemented for research facilities and equipment, which are classified into three categories as follows on the basis of their age-related condition and the research prioritization of JIRCAS: facilities that will not be conducive to research promotion without renovation and upgrading; facilities that will hamper the progress of research without renovation owing to their severe age-related condition; and facilities required to be renovated by law or regulations. Increased use of such facilities will be promoted.

[Attachment] Directions related to research and investigations

The following research works were conducted until the end of FY 2020.

1. Development of agricultural technologies for sustainable management of the environment and natural resources in developing regions

To cope with increasingly serious global problems such as climate change and environmental degradation, which affect Japan substantially, JIRCAS will develop technologies in cooperation with local research organizations. It will disseminate and establish technologies through verification tests in farm fields and collaboration with local extension organizations. These works will be implemented in developing regions, mainly in Asia and Africa. More specifically, the following priority research projects will be carried out.

To reduce greenhouse gas emissions in agriculture, JIRCAS will develop a water-saving irrigation method and a system to reduce methane generation through integration of cropping and livestock farming and will evaluate its carbon budget. JIRCAS will also address the issues of flooding and other extreme phenomena and climate change, including warming, and will develop technologies to mitigate the damage associated with such issues. [Importance: high][1]

In river basins where precipitation is unstable and vegetation is being degraded, and in areas where soil degradation and other soil problems are becoming serious, JIRCAS will develop technologies to sustain stable crop yields from the perspectives of breeding, cultivation, and soil and water control and will present a model for technological dissemination.

For the effective use of nitrogen fertilizer and the reduction of nitrous oxide emissions from agricultural land, JIRCAS will develop breeding materials utilizing the biological nitrification inhibition function.

2. Technology development for stable production of agricultural products in the tropics and other adverse environments

To enhance food production and improve nutritional status in Africa and other parts of the world, JIRCAS will conduct technological development and verification trials in cooperation with local organizations and will prepare manuals and commentary articles in tropical areas and other developing regions where potential crop productivity is not fully exploited owing to adverse conditions such as droughts and low fertility. In addition, JIRCAS will promptly disseminate the technologies it develops to breeders, government departments, and farmers. More specifically, the following priority research projects will be carried out.

In Africa, JIRCAS will develop technologies to utilize the diversity of food crop genetic resources; crop breeding materials of high productivity adapted to the planting environment and those materials adapted to local preferences; and crop production and livestock raising technologies that effectively utilize organic materials, water, and other local resources. [Importance: high][2]

JIRCAS will develop basic technologies for producing high-yield crops adaptable to adverse conditions such as low fertility, drought, and salt damage. It will also develop pioneering breeding materials, as well as technologies for their evaluation and utilization in the field in developing regions.

To control migratory plant pests and transboundary diseases that can spread and invade Japan, JIRCAS will work on pest control based on the epidemiology of migratory pests and vectors, and will develop technologies to prevent their invasion and spread. In addition, JIRCAS will develop disease-resistant varieties by using the research networks it has developed.

3. Development of high value-adding technologies and utilization of local resources in developing regions

In Asian areas where development needs are increasing along with economic growth, JIRCAS will use diverse regional resources and will develop new high value-adding technologies. In this way, it will support rural development by pursuing environmentally friendly and sustainable agriculture, forestry, and fisheries; help increase the incomes of farmers in developing regions; and contribute to the Global Food Value Chain Strategy promoted by Japan. More specifically, the following priority research projects will be carried out.

To secure high-quality products and develop food value chains, JIRCAS will develop a way of evaluating potential high value-added products of agriculture, forestry, and fisheries and will develop the processing and distribution technologies needed to add high value. In addition, JIRCAS will work on enhancing value addition by clarifying consumer needs and improving distribution systems. [Importance: high][3]

To establish agriculture, forestry, and fisheries in a sustainable, resource-recycling way, JIRCAS will develop technologies for saccharification from unused biomass resources such as agricultural waste and will promote their advanced use. JIRCAS will also develop technologies for the sustainable production and use of diverse resources to produce high value-added products in semi-mountainous areas. It will develop technologies for the development and maintenance of forest resources, technologies for the production of high value-added wood products, and technologies for improving the productivity of forest plantations in harmony with ecosystems. Moreover, JIRCAS will develop efficient aquaculture technologies and will utilize aquatic resources in harmony with ecosystems with the aim of sustainable consumption of aquatic resources.

In these efforts, JIRCAS will use international research networks, collaborate with Japanese and local private sectors, and promote systematization and transfer of technologies. Furthermore, JIRCAS will prepare technical manuals and exhibit technologies for dissemination among farmers and will provide information for technology transfer to local processors and distributors.

<Descriptions of importance>

[1] [Importance: high] According to the Fifth Assessment Report of the IPCC, adaptation to climate change may exceed a limit in the future, and a combination of effective adaptation measures and mitigation measures will promote a resilient society and sustainable development. In this regard, it is very important to take action in developing regions, where agriculture contributes to a large proportion of the economy.

[2] [Importance: high] As outlined in Goal 2 of the sustainable development goals (SDGs), i.e., to “end hunger, achieve food security and improved nutrition, and promote sustainable agriculture,” it is very important to solve the food problems in Africa, where large populations are deficient in nutrients and agricultural productivity is low.

[3] [Importance: high] Because the Global Food Value Chain Strategy indicates that we need to develop a food value chain that adds high value in agriculture, forestry, and fisheries, it is very important to help increase farmers’ incomes through this effort.

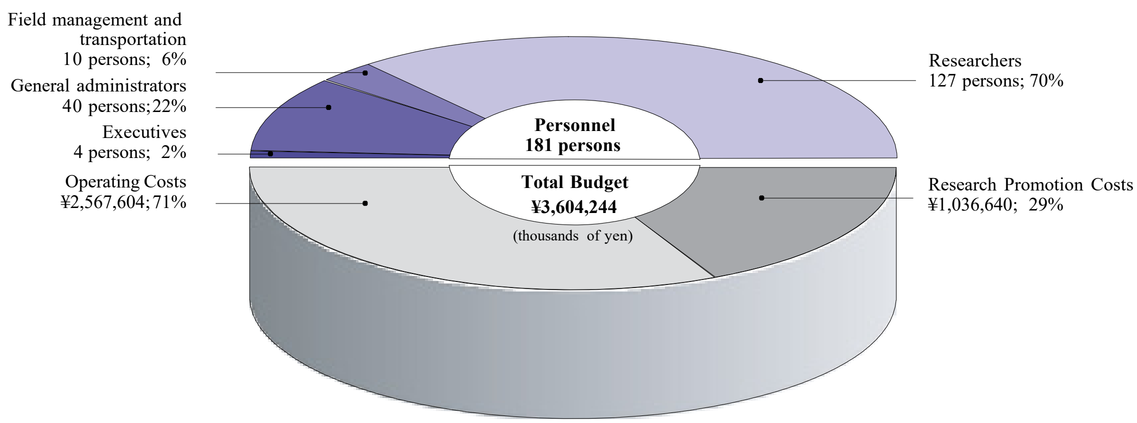
Financial Overview

Fiscal Year 2020

	thousands of yen
TOTAL BUDGET	**3,604,244**
OPERATING COSTS	**2,567,604**
Personnel (181)	2,234,156
President (1), Vice-President (1), Executive Advisor & Auditor (2)	
General administrators (40)	
Field management (10)	
Researchers (127)	
* Number of persons shown in ( )	
Administrative Costs	333,448

RESEARCH PROMOTION COSTS	**1,036,640**
Research and development	739,050
Overseas dispatches	108,040
Collection of research information	111,285
International collaborative projects	58,728
Fellowship programs	19,537

Budget FY 2020 (Graph)



Members of the External Evaluation Committee

Members of the JIRCAS External Evaluation Committee

Hiroto ARAKAWA	Former Advisor, Sumitomo Corporation
Hiroko ISODA	Deputy Director/Professor, Alliance for Research on the Mediterranean and North Africa, University of Tsukuba
Toshihiko KOMARI	Science Advisor, Agri-Bio Research Center, Biotechnology Research Laboratories, Kaneka Corporation
Shin-ichi SHOGENJI	Dean/Professor, Faculty of Agricultural and Food Sciences, Fukushima University
Hisayo YASUDA	Attorney-at-law, Yasuda International Law Office

JIRCAS Staff in FY 2020

President

Masa Iwanaga

Vice-President

Osamu Koyama

Auditors

Teruyoshi Kumashiro
Mari Inoue

Research Strategy Office

Miyuki Iiyama, Director

Research Coordinator
Norihito Kanamori, Plant Molecular Biology

Regional Coordinator
Shotaro Ando, Representative of Southeast Asia Office (Thailand)

Senior Researcher
Sakiko Shiratori, Agricultural Economics

Program Directors

Satoshi Tobita, Program A: Environment and Natural Resource Management
Kazuo Nakashima, Program B: Stable Agricultural Production
Yukiyo Yamamoto, Program C: Value-adding Technologies

Research Planning and Partnership Division

Masayoshi Saito, Director

Research Planning and Management Office
Tomohide Sugino, Head

Research Planning Section
Hiroshi Ikeura, Head

Research Management Section
Mie Kasuga, Head
Katsunori Kanno, Intellectual Property Expert

Communications Advisor
Baltazar Antonio

Field Management Section
Takashi Komatsu, Field Operator
Hiroyuki Ishiyama, Field Operator

Research Support Office
Noriaki Nishimura, Head

Research Coordination Section
Koichi Iioka, Head
Toshiki Kikuchi, Coordination Subsection Head
Daisuke Abe, Overseas Travel and Invitation Program Subsection Head
Gen-ichiro Hanaoka, Overseas Travel and Invitation Program Subsection Officer
Kenji Iwasa, Overseas Affairs Subsection Head
Misaki Ohashi, Overseas Affairs Subsection Officer

Research Support Section
Takashi Kamura, Head
Koichi Fuse, Budget Subsection Head
Takayuki Yamamoto, Support Subsection Head

Information and Public Relations Office
Kazuo Nakamoto, Head

Senior Researcher
Masaki Morishita, Rural Development

Public Relations Section
Kazuhiko Okada, Head

International Relations Section
Keisuke Omori, Head

Publications and Documentation Section
Akira Hirokawa, Head
Hiromi Miura, Information Security Expert
Takanori Hayashi, Information Management Expert
Shota Miyai, Information System Subsection Officer

Administration Division

Hiroshi Miyamoto, Director

General Affairs Section
Takashi Oosato, Head
Takeshi Usuku, General Affairs Assistant Head
Jun Yatabe, Personnel Management Assistant Head
Gaku Takeda, Personnel Subsection Expert
Hitomi Ogamino, Welfare Subsection Officer
Noriko Osonoe, Personnel Subsection 1 Officer
Kumi Ehara, Personnel Subsection 2 Head

Accounting Section
Tadao Yatabe, Head

Kiyoyuki Sunaoka, Accounting and Examination Assistant Head
Takashi Ichimi, Procurement and Asset Managing Assistant Head
Ryoichi Mise, Financial Subsection Head
Shoko Yoshida, Accounting Subsection Officer
Aki Tamura, Audit Subsection Officer
Yumekazu Yano, Procurement Subsection 1 Head
Mizuha Furukawa, Procurement Subsection 2 Officer
Takehito Kato, Supplies/Equipment Subsection Officer
Tadahisa Akiyama, Facilities Subsection Head

Administration Section (Tropical Agriculture Research Front)
Kengo Uemura, Head
Hiroe Nagatomo, General Affairs Subsection Head
Maretomo Fujimoto, Accounting Subsection Head

Risk Management Office

Masato Oda, Head

Compliance Management Section
Yuma Sukegawa, Management Subsection Officer

Safety Management Section
Masakazu Yamada, Head

Audit Office

Yoshihiro Saito, Head

Rural Development Division

Soji Shindo, Director

Sub Project Leaders
Naoki Horikawa, Hydrology
Taro Izumi, Rural Development

Senior Researchers
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Kazuhisa Kouda, Agricultural Engineering
Shinji Hirouchi, Agricultural Engineering
Koichi Takenaka, Rural Development Forestry
Mamoru Watanabe, Rural Development
Naoko Oka, Agriculture Water Management
Haruyuki Dan, Rural Development
Shutaro Shiraki, Rural Development
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Katsumi Hasada, Rural Development
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Researcher
Fumi Okura, Irrigation and Drainage

Social Sciences Division

Jun Furuya, Director

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Shunji Oniki, Agricultural Economics
Akira Hirano, Geographic Information Systems
Eiichi Kusano, Agricultural Economics

Researchers
Kensuke Kawamura, Remote Sensing and Grassland Ecology
Toru Sakai, Remote Sensing and GIS
Rie Muraoka, Agricultural Economics
Junji Koide, Agricultural Economics
Ai Leon, Environmental Impact Assessment

Biological Resources and Post-harvest Division

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Project Leaders
Masayasu Kato, Plant Pathology
Seiji Yanagihara, Rice Breeding
Akihiko Kosugi, Molecular Microbiology
Kazuhiko Nakahara, Food Chemistry
Xu Donghe, Plant Molecular Genetics

Sub Project Leader
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Satoru Nirasawa, Food Functionality
Yasunari Fujita, Plant Molecular Biology
Tadashi Yoshihashi, Food Science
Yoshinori Murata, Applied Microbiology
Naoki Yamanaka, Plant Molecular Genetics
Kyonoshin Maruyama, Plant Molecular Biology
Mitsuhiro Obara, Plant Physiology and Genetics
Takamitsu Arai, Molecular Microbiology
Toshiyuki Takai, Crop Science and Genetics
Jun-ichiro Marui, Molecular Microbiology
Yukari Nagatoshi, Plant Molecular Biology
Toshiaki Kondo, Molecular Ecology
Kaori Fujita, Crop Science and Food Engineering

Researchers
Kotaro Iseki, Crop Science and Breeding
Shimpei Aikawa, Applied Microbiology
Takuya Ogata, Plant Molecular Biology
Takeshi Kashiwa, Plant Pathology

Kazuhiro Sasaki, Plant Breeding and Genetics
Ken Hoshikawa, Horticulture Science
Junnosuke Otaka, Natural Products Chemistry
Park Cheolwoo, Plant Breeding and Genetics
Yasufumi Kobayashi, Plant Molecular Biology

Crop, Livestock and Environment Division

Seishi Yamasaki, Director

Project Leaders
Naruo Matsumoto, Soil Fertility and Nutrient Cycling
Keiichi Hayashi, Soil Management

Sub Project Leaders
Tetsuji Oya, Crop Science
Satoru Muranaka, Plant Physiology

Senior Researchers
Cai Yimin, Animal Science
Guntur V. Subbarao, Crop Physiology and Nutrition
Matthias Wissuwa, Physiology and Genetics
Youichi Kobori, Entomology
Kazunori Minamikawa, Biogeochemistry
Koki Maeda, Environmental Science, Manure Management and Microbial Ecology
Yasuhiro Tsujimoto, Crop Science
Hidetoshi Asai, Crop Science
Kenta Ikazaki, Soil Science
Fujio Nagumo, Soil Science

Researchers
Satoshi Nakamura, Soil Science
Tetsuro Kikuchi, Biogeochemistry
Kotaro Maeno, Entomology
Sarr Papa Saliou, Soil Microbiology
Mizuki Matsukawa, Plant Protection
Tomohiro Nishigaki, Soil Science
Andressa C. S. Nakagawa, Crop Science
Miwa Arai, Soil Ecology and Soil Science
Satoshi Ogawa, Agronomy
Yoshiaki Ueda, Plant Physiology and Genetics

Forestry Division

Hiroyasu Oka, Director

Senior Researchers
Naoki Tani, Forest Genetics
Gaku Hitsuma, Physiological Ecology and Silviculture
Akihiro Imaya, Soil Science
Rempei Suwa, Forest Ecology

Researcher
Masaki Kobayashi, Tree Molecular Biology

Fisheries Division

Osamu Abe, Director

Project Leader
Shinsuke Morioka, Fish Biology

Senior Researchers
Marcy N. Wilder, Crustacean Biochemistry
Toru Shimoda, Marine Chemistry
Isao Tsutsui, Aquaculture
Masaya Toyokawa, Marine Planktology
Tomoyuki Okutsu, Aquatic Animal Physiology
Ryogen Nambu, Benthic Biology
Tatsuya Yurimoto, Aquatic Biology
Bong Jung Kang, Aquatic Animal Physiology

Tropical Agriculture Research Front

Hide Omae, Director

Project Leaders
Shotaro Ando, Soil Science
Takeshi Watanabe, Soil Chemistry

Senior Researchers
Tatsushi Ogata, Pomology
Shinsuke Yamanaka, Molecular Biology
Takuma Ishizaki, Plant Molecular Biology
Yoshifumi Terajima, Sugarcane Breeding
Shin-ichi Tsuruta, Molecular Genetics
Toshihiko Anzai, Irrigation and Drainage

Researchers
Hiroki Saito, Rice Breeding and Molecular Genetics
Ken Okamoto, Agricultural Engineering
Hiroshi Matsuda, Tropical Pomology
Masakazu Nakayama, Vegetable Crop Science
Hiroo Takaragawa, Crop Science

Technical Support Office
Kunimasa Kawabe, Head
Hirokazu Ikema, Machine Operator
Masato Shimajiri, Machine Operator
Masakazu Hirata, Machine Operator
Yasuteru Shikina, Machine Operator
Toshihiko Takemoto, Machine Operator
Masashi Takahashi, Machine Operator
Masahide Maetsu, Machine Operator
Takaya Shinmori, Machine Operator

The Japanese Fiscal Year and Miscellaneous Data

The Japanese Fiscal Year and the Annual Report 2020

The Japanese fiscal year is defined as the period of fiscal activity occurring from April 1 through March 31 of the following year. Thus, Fiscal Year (FY) 2020 covers the period from April 1, 2020 through March 31, 2021.

The Annual Report 2020 summarizes the full extent of JIRCAS activities that occurred during this period. The subsequent Annual Report will detail events and programs from April 1, 2021 through March 31, 2022 (FY 2021).

Buildings and campus data

Land	(units: m^2)
Tsukuba premises	109,538
Okinawa Tropical Agriculture Research Front	294,912
Total	404,450

Buildings	(units: m^2)
Tsukuba premises	10,766
Okinawa Tropical Agriculture Research Front	9,485
Total	20,251

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