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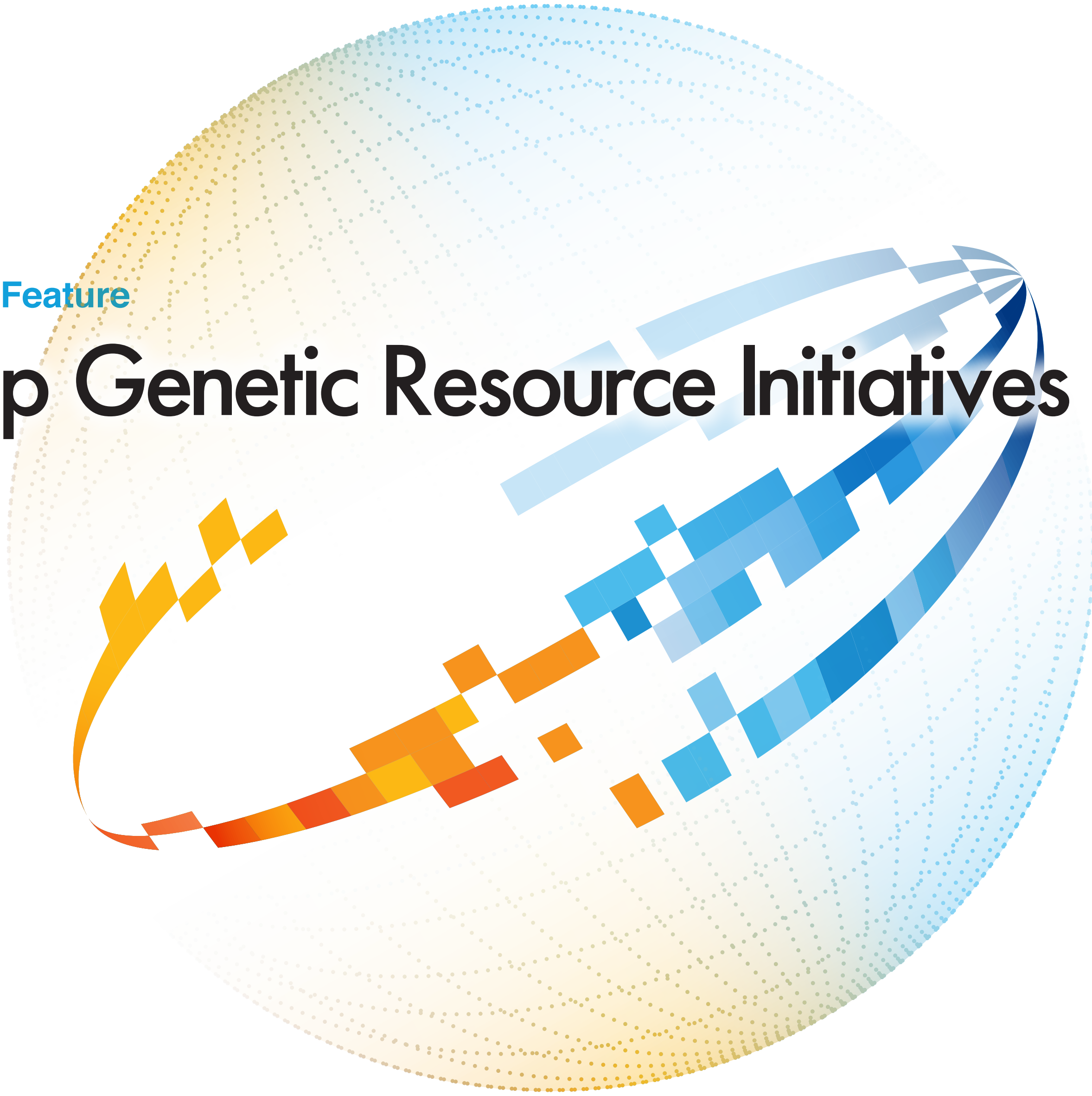
Special Feature

Crop Genetic Resource Initiatives



JIRCAS Japan International Research Center For Agricultural Sciences

In This Issue

Foreword

Special Feature

JIRCAS TODAY

Utilization of Time Capsules
—Insights for JIRCAS International Symposium 2024—

The theme of JIRCAS International Symposium 2024 is "Resilient Genetic Resources for Food Security in the Era of Global Boiling – Opportunities and Challenges for Conservation and Utilization." This theme was chosen because the crops that support our current food systems have become increasingly unable to adapt to the timing, intensity, and frequency of rain and drought resulting from changes in global mean air temperature, commonly referred to as climate change. Additionally, the occurrence of diseases and pests has led to a greater risk of significant crop damage. These issues have been reported worldwide, prompting us to focus on genetic resources as the topic of this special issue of the newsletter.

The climate and topography of the Earth have changed in various ways over its long history, and plants have similarly evolved in response to various environmental stresses. Only those plants that were able to adapt to their circumstances survived. Throughout this long period, plants faced biological stresses, such as herbivores and pathogens. Nonetheless, the plants we see today have survived due to various factors, such as accidental mutations in their genetic material, crossbreeding with related species, and the incorporation of genetic material from pathogens. Thus, the plants we see today bear the marks of their adaptation to past environments.

Our ancestors selected certain wild plants that were edible and domesticated them, laying the foundation for current crops. However, both domesticated crops and wild plants continue to be affected by environmental and biological stresses, providing ongoing opportunities for mutation. As a result, crops that are easier to cultivate and have higher utility have been selected, propagated, and utilized by many people. Moreover, modern breeding techniques, based on advances in genetics and breeding sciences, have led to the development of current crop varieties that can be cultivated in various environments and produce high yields using chemical fertilizers and pesticides. However, these crops are not fully adapted to the current environment, as mentioned earlier.

All living organisms may be considered time capsules, as they may carry evidence of their adaptation to the environment over many years in their genetic material. Especially for crops, wild relatives and long-standing indigenous varieties—rather than modern varieties developed using modern breeding techniques—must hold potential for developing varieties that can adapt to current and future global environments. Our urgent task is to identify useful genes in these unused genetic resources, which serve as time capsules, and utilize them to develop crops that are adaptable to the current global environment as well as to conserve those genetic resources.

In this newsletter, researchers from JIRCAS introduce how they utilize genetic resources to tackle the issues of biotic and abiotic stresses—using rice, quinoa, sugarcane, tropical fruits, and soybeans as examples—and discuss their visions for the future. I hope you find the articles interesting and enjoyable.

YANAGIHARA Seiji
Vice-President, JIRCAS

Crop Genetic Resource Diversity and JIRCAS' Activities

In retrospect, since the beginning of agriculture some 12,000 years ago, humans have selectively bred and domesticated thousands of genetic resources for food. Of the world's many crop genetic resources, it is estimated that over 5,500 species have been used by humans as food. Many breeders rely on crop genetic diversity to develop new varieties and help farmers in managing risk. However, for this process to be effective, genetic resources must be conserved and made available. The resilience and sustainability of the food system is highly dependent on crop genetic diversity.

Plants cannot move from one place to another, thus they have developed diverse phenological and stress resilience mechanisms to thrive in locally specific environments. Modern breeding practices, in turn, have favored the selection of high-yielding varieties with traits that enhance responsiveness to external inputs such as chemical fertilizers and pesticides, as well as adaptability to a wide range of environmental conditions. While this approach has facilitated the mass production of modern varieties (often grown under monoculture conditions) and provided cheap calories, it has also led to a reduction in genetic diversity with respect to traits such as high nutritional value and stress tolerance. It is estimated that in recent years, 50% of calorie intake has come from rice, maize, and wheat, and 75% from just 12 crops and 5 livestock species. Although this mass-production system has led to an increase in average per capita calorie intake, there has been a loss of crop species diversity worldwide, especially region-specific food and genetic resources.

Today, the global food system is facing climate change, extreme weather events, land and water resource constraints, biodiversity loss, soil degradation, market instability, and several other environmental and socio-economic crises. As global demand for food continues to rise, the pressure on the food system will only increase. In fact, in July 2023, as humanity experienced record-breaking global average temperatures, UN Secretary General António Guterres declared the end of the global warming era and the beginning of the global boiling era. By June 2024, highest monthly temperatures on record had been reported for 13 consecutive months. The recently published Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6) has predicted that the world will experience extreme events, including heat waves and flash floods, with increasing frequency and severity as anthropogenic climate change escalates. The agricultural sector, which already bears a significant burden with about 25% of climate-related loss and damage, would be particularly affected by such extreme climate events. The impact will be disproportionately felt by smallholder farmers in the Global South, while changing weather patterns could threaten global food security by disrupting growing seasons in key mid-latitude breadbasket regions. Improving the resilience of genetic resources is urgent to ensure food security in the face of these challenges.

Consequently, modern food systems have become increasingly vulnerable to emerging biotic and abiotic stresses, driving a vicious cycle of increasing dependence on external inputs to maintain productivity. To build resilient food systems in the era of global boiling, we need to conserve and restore the diversity of nutritiously rich genetic resources and harness their inherent resilience to biotic and abiotic stresses.

One such opportunity may lie in the utilization of climate-resilient food crops, including neglected and underutilized species (NUS), which are often highly nutritious. Accelerating the application of genetic diversity in crop breeding requires not only the conservation and use of genetic resources, but also a firm commitment by all parties and stakeholders to adhere to the principles of Access and Benefit Sharing (ABS).

As highlighted in this special issue, the Japan International Research Center for Agricultural Sciences (JIRCAS) has been carrying out research to develop crops that are resilient to various environmental shocks and stresses, with a special focus on rice and soybeans as major crops and quinoa as an orphan crop. At the same time, it has also been working on the dissemination and sharing of information, technology, and materials pertinent to tropical crop genetic resources through international and national collaborations and networks. Given these activities by JIRCAS and its partners, this newsletter aims to bring together stakeholders from the research, policy, administrative, and business sectors to identify and discuss opportunities and challenges in institutionalizing the conservation and utilization of resilient genetic resources, thereby ensuring food security amidst the challenges of the global boiling era.

FUJITA Yasunari
Program Director (Food), JIRCAS

IIYAMA Miyuki
Program Director (Information), JIRCAS

Exploring the History and Future of Quinoa: An International Collaborative Research Project Utilizing Genetic Resources and Genomic Information

Quinoa, a pseudocereal native to South America, has been cultivated for over 7,000 years; however, it has also been called an “orphan crop” and has not received much attention worldwide. Recently, quinoa has garnered significant attention due to its resilience as a crop capable of thriving in diverse environments and its high nutritional value. JIRCAS, expecting that quinoa will contribute to addressing global climate change and food issues, is conducting quinoa research projects in collaboration with domestic and international research institutes.

Peru and Bolivia are the two major quinoa-producing areas, although various strains suitable for different environments are cultivated throughout South America, from the coastal areas of Chile to the Andean highlands at altitudes of over 4,000 meters. Recently, in order to utilize the excellent characteristics of quinoa, attempts have been made to cultivate it in areas other than its native region, including Japan. It is hoped that new varieties of quinoa that can adapt to the climate and environment of each area and enable stable production will be developed. Meanwhile, even in the major quinoa-producing areas of South America, there is a demand for the development of new varieties with high quality and enhanced stress resilience to withstand the effects of recent climate change. The key to achieving this is the diverse genetic resources of quinoa and the information from their whole gene (genome) sequences, which determine the organism’s characteristics.

Because quinoa is partially allogamous, JIRCAS has established standard quinoa inbred lines (Photo 1). In 2016, we were the first in the world to decipher the draft genome sequence of quinoa using next-generation sequencing. We also analyzed the genetic diversity of quinoa based on the genomic information of more than 130 quinoa inbred lines. As a result, we were able to classify the genetic background of quinoa into three groups: northern highland, southern highland, and lowland types, and we were able to infer the history of domestication, which expanded the cultivation area while acquiring diverse characteristics. We have also pioneered a new experimental method for analyzing quinoa gene function and have established a world-leading quinoa research foundation.

Currently, JIRCAS is engaged in international collaborative research with Bolivia, the native land of quinoa, within the framework of the Science and Technology Research Partnership for Sustainable Development (SATREPS). This project, which consists of a research team in Japan with a track record in cutting-edge plant sciences and a research team in Bolivia engaged in quinoa research and technology dissemination locally, aims to develop and disseminate production technology to strengthen the resilience of quinoa by utilizing local genetic resources. As part of these activities, the teams have been working to protect the genetic resources of quinoa and its wild relatives with diverse characteristics (Photo 2). Additionally, we have been utilizing genomic information and other cutting-edge plant science knowledge to elucidate the mechanisms that give quinoa its excellent characteristics and build a foundation for efficient genomic breeding for improved varieties. These research results are expected to contribute to strengthening food security not only in Bolivia but also on a global scale.

OGATA Takuya
Biological Resources and Post-harvest Division

Photo 1. Quinoa cultivation in the greenhouse of JIRCAS. Each plant is covered with a breeding bag to prevent pollen from scattering and suppress cross-pollination.

Photo 2. A researcher explains about wild quinoa species cultivated at PROINPA, an agricultural research and extension organization in Bolivia.

Utilizing Wild Soybean Genetic Resources for Improvement of Cultivated Soybean Varieties

Wild soybean (Photo) is the ancestral species of cultivated soybean. This wild species is widely distributed across East Asia, including China, Japan, and the Korean Peninsula. Previous studies using molecular biological techniques have revealed that wild soybean possesses significantly higher genetic diversity at the DNA level compared to cultivated soybean. However, the potential utility of wild soybean in improving cultivated soybean has not been fully realized. Owing to its long-term adaptation to harsh natural environments, wild soybean is considered a valuable exotic genetic resource for enhancing biotic and abiotic stress tolerance in cultivated soybean.

To identify salt-tolerant soybean genetic resources, numerous wild soybean accessions were evaluated for their responses to salt stress at JIRCAS. Highly salt-tolerant wild soybean accessions such as “JWS156-1,” “JWS061,” and “GB102” were identified. Genetic studies located the salt tolerance gene on soybean chromosome 3. Utilizing DNA marker-assisted selection, this salt tolerance allele was successfully introduced into the salt-sensitive cultivated soybean variety “Jackson,” resulting in improved salt tolerance. Additionally, a wild soybean accession showing high alkaline tolerance was identified, with the corresponding alkaline tolerance locus located on chromosome 17. The alkaline tolerance allele identified in wild soybean holds promise as a new genetic resource for developing soybean varieties with enhanced tolerance to alkaline stress.

Wild soybean possesses certain unfavorable traits compared to cultivated soybean, such as small seed size, stem twining habit, and pod shattering, which impede the evaluation of its agronomic traits. To effectively uncover hidden superior genes in wild soybean, JIRCAS developed Wild Soybean Chromosome Segment Substitution Lines (CSSLs). This approach involves introducing small chromosome segments from wild soybean into a uniform genetic background of cultivated soybean, enabling precise evaluation of the effects of specific wild soybean genes.

Using these developed wild soybean CSSLs, a gene locus controlling the flowering time, designated as *qFT12.1*, was identified on chromosome 12. Flowering time is a critical trait affecting the adaptability and yield of soybean, and the identification of this flowering time locus might significantly contribute to the improvement of soybean adaptability and yield. Moreover, an allele named *qPro19* from wild soybean, responsible for increasing seed protein content, was discovered. Unlike other genes controlling seed protein content, *qPro19* enhances protein levels without reducing fat content, suggesting its potential contribution to improving soybean seed quality. Furthermore, the CSSLs facilitated the identification of a new gene locus controlling seed weight, termed *qSW12.1*, on chromosome 12, in addition to previously reported loci such as *qSW14.1* and *qSW17.1*. Notably, some lines within the wild soybean CSSLs exhibited higher seed weight and enhanced seed yield compared to their original cultivated soybean parent variety “Jackson,” indicating the presence of yield-enhancing genes derived from wild soybean. Current research efforts are focused on identifying these high-yield genes to further improve the seed yield of cultivated soybean varieties.

A substantial number of wild soybean genetic resources are currently preserved in genebanks across countries like China, the United States, and Japan, and are being utilized in genetic studies and the improvement of cultivated soybean. However, the preserved wild soybean accessions represent only a small fraction of the entire wild soybean population existing under natural conditions. In recent years, the natural habitats of wild soybean have been diminishing due to factors such as increased extreme weather events caused by climate change, urbanization, and the expansion of farmland and infrastructure, leading to a rapid decline in wild soybean natural populations. Consequently, valuable genes inherent in wild soybeans are being lost. Therefore, further efforts in the collection, preservation, research, and utilization of wild soybean growing in natural environments have become urgent and essential.

XU Donghe
Biological Resources and Post-harvest Division

Photo. Wild soybean plants (left) and seeds (right; the small black ones are wild soybean seeds)

Research on Rice Germplasm

Rice is a vital crop that serves as the staple food for a significant portion of the world's population. In Asia, in particular, the majority of people rely on rice as their primary food source. Rice cultivation is deeply rooted in the region's economy and culture, and it plays a crucial role in food security. However, rice production faces numerous challenges, including global warming and the growing demand for food driven by population growth. To address these challenges by utilizing improved varieties, the study and utilization of rice genetic resources is essential.

At JIRCAS, located in Tsukuba and Ishigaki, we introduce and preserve a diverse range of rice varieties and related wild species (Photo 1) from around the world through international collaboration. This preservation is crucial for protecting the diversity of varieties that possess resistance to various environmental conditions and pests. For example, we store varieties that can thrive in low-fertility soils or withstand salt damage, securing the stability of food production by preserving varieties with essential genes for future environmental changes.

The introduced genetic resources are cultivated and thoroughly studied for their characteristics, such as rice yield, brown rice quality, heading date, and resistance to salt damage and diseases (Photo 2). This allows us to understand which varieties are best suited to specific environmental conditions. Proper management of these genetic resources forms the foundation for their future utilization, particularly in discovering resources with resistance to climate change and emerging pests, which is critical for future food production.

For the useful traits discovered in these studies, genetic analysis is conducted to identify the genes responsible for these traits. The results of genetic analysis provide vital information for efficiently selecting varieties with valuable traits during breeding. Based on these genetic analyses, we develop breeding materials with beneficial traits and apply them in crop improvement.

As global warming progresses and extreme weather and natural disasters become more frequent, food production is becoming increasingly unstable. In this era, the diversity of genetic resources, not only for rice but also for other crops, is key to enhancing the resilience of food production. By utilizing diverse genetic resources, we can minimize the impact of extreme weather and pests, ensuring a stable food supply. At JIRCAS, we are working on research and development of rice production in collaboration with national agricultural research and extension systems (NARES) partners such as Vietnam, Laos, Bangladesh, Indonesia, Cambodia, the Philippines, and Zambia, as well as international research organizations such as IRRI and AfricaRice.

SAITO Hiroki, KUNIYOSHI Daichi, and KOBAYASHI Nobuya
Tropical Agricultural Research Front

Photo 1. Wild species of rice (*Oryza longistaminata*) growing in Zambia

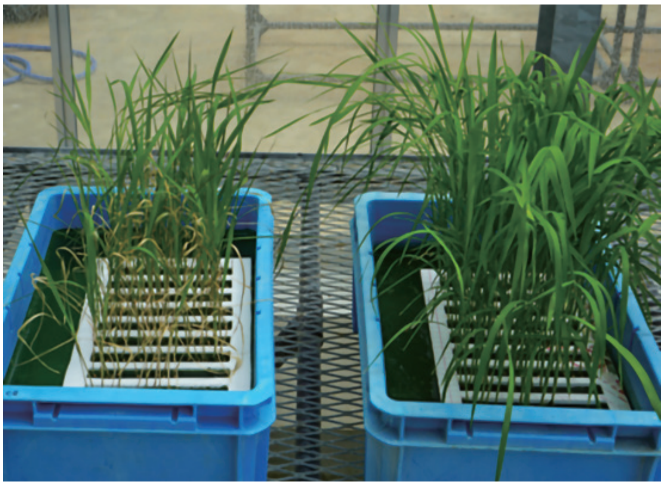


Photo 2. Screening rice germplasm for salinity tolerance

Sugarcane Improvement Using Wide Crossing with Diverse Wild Genetic Resources

Sugarcane (*Saccharum* L.) is grown in over 90 countries, primarily in tropical and subtropical regions, and boasts the world's largest production volume with approximately 1.9 billion tons. Its continuous ratooning ability, which allows the stalks to regenerate from underground stubbles after the above-ground parts are harvested, results in lower production costs by eliminating the need for yearly replanting. Sugarcane also uniquely accumulates high concentrations of sucrose in the stalks, contributing to approximately 80% of the world's sugar and 40% of its bioethanol production. Additionally, in recent years, there has been a rise in the production of biochemical products such as bioplastics made from sugars and electricity generated from bagasse, the fibrous residue left after sugarcane juice is extracted. Therefore, sugarcane plays a crucial role in increasing the production of sugar, bioenergy, and biochemicals to meet the needs of the growing world population and achieve a decarbonized society. While further improvements in sugarcane productivity are expected, there are concerns about stagnation in sugarcane improvement as well as the negative impacts of climate change on production. Thus, expanding genetic diversity and introducing useful traits through breeding use of underutilized wild genetic resources have become critical challenges for improving productivity and resilience to environmental stress.

JIRCAS has focused on using wild genetic resources for sugarcane improvement, specifically the wild sugarcane (*S. spontaneum* L.) with superior ratooning ability and *Erianthus* (*Erianthus* spp.) with deep roots and excellent drought adaptability (Photo 1). Breeding technologies for these resources are being developed at the Tropical Agriculture Research Front of JIRCAS. Additionally, genetic resource collection and evaluation and variety development through breeding use of the resources have been conducted through international collaborative research with Thailand, where we have collected over 300 accessions of wild sugarcane and more than 150 accessions of *Erianthus* genetic resources. These resources have been evaluated for productivity under multiple ratoon cultivation during the dry season, and promising breeding materials have been selected. Subsequently, these selected materials have been crossed with sugarcane to develop a new variety.

In the use of wild sugarcane for sugarcane improvement, interspecific hybrids were selected, focusing on sugar and bagasse yields in multiple ratoon cultivation. As a result, we have developed the new sugarcane variety, 'KK4,' which can produce approximately 1.5 times more bagasse due to its higher fiber content while maintaining a similar sugar yield as conventional varieties. In 2023, the Department of Agriculture in Thailand adopted 'KK4' as a recommended variety. With 'KK4' endorsed as the recommended variety, the Department of Agriculture has established a system for producing seed canes for commercial use. Furthermore, in Japan, we have developed 'Harunoogi,' a variety with excellent sugar and bagasse productivity in multiple ratoon cultivation, in collaboration with the National Agriculture and Food Research Organization. In the use of *Erianthus*, we have developed intergeneric hybrids and shown that its deep root characteristics can be introduced into sugarcane through intergeneric crossing to further improve sugarcane productivity and adaptation to adverse environments (Photo 2). We have also selected new breeding materials with superior ratooning ability even during the severe dry season in Thailand. These novel breeding materials worldwide are expected to be used for future sugarcane improvement.

The world is currently facing the need for substantial increases in food and renewable energy production under climate change, along with achieving sustainable agricultural production with low environmental impact. To address these challenges, the use of underutilized wild genetic resources in crop improvement is essential. We believe that sugarcane has the potential for further improvement due to its unique ability to produce hybrids with various wild genetic resources. By leading the breeding of sugarcane using wild genetic resources, we aim to realize sustainable, high-yield production of sugars and fibers, thus contributing to global food and energy production and achieving a carbon-neutral society.

TERAJIMA Yoshifumi
Tropical Agriculture Research Front

Photo 1. Wild sugarcane (left) and *Erianthus* (right) genetic resources collected in Thailand

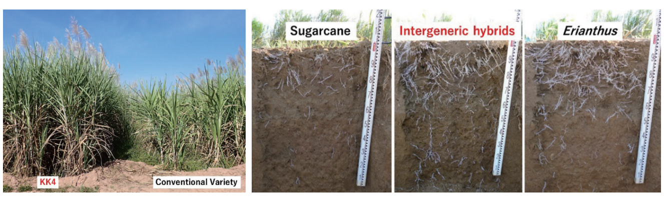


Photo 2. Growth of 'KK4' in the ratoon crops (left) and root distribution of intergeneric hybrids between sugarcane and *Erianthus*

Utilizing the Diversity of Tropical Fruit Tree Genetic Resources

In Asia, the world's largest producer of tropical fruit trees, a diverse array of tree species and varieties are cultivated in various growing environments. These trees play an important role as sources of vitamins and other nutrients, and they provide significant income for small farmers and agricultural products for export markets. Although there are many native cultivars in each region, a few major varieties dominate cultivation, leading to an extremely limited number of economically grown varieties overall. Systematic conservation of genetic resources is essential to counteract the loss of diversity as native cultivars are replaced by these major varieties.

Mango (*Mangifera indica*) is considered to have originated in the areas from India to the Malay Peninsula. As a representative tropical fruit, it is widely cultivated in tropical and subtropical regions of the world, and is the world's second-largest tropical fruit tree in terms of production (banana and pineapple are the first and third, respectively). More than 70% of the world's production occurs in Asia, including India, the largest producer (approximately 25 million tons, FAO 2021). It is said that there are more than 1,000 mango varieties in the world. However, unlike bananas and pineapples, there has been no organized effort to develop plantations, systematic breeding, or cultivation techniques. As a result, there is a diverse range of preferred characteristics and varieties produced in each country and region. In Japan, approximately 3,500 tons of mangoes are produced annually, mainly in Okinawa, Miyazaki, and Kagoshima prefectures, but in terms of varieties, the mangoes grown in Japan are practically monocultural, with the 'Irwin' variety accounting for over 90% of domestic production. JIRCAS maintains about 100 mango varieties, mainly from widely distributed sources around the world, and is currently conducting variety characterization and evaluation (Photo 1). Diversification of mango varieties is expected not only to stimulate demand and increase consumption, but also to help address the instability in flowering and fruiting seen both in Japan and overseas, which is thought to be caused by climate change and global warming in recent years, through appropriate variety selection.

Passion fruit (*Passiflora edulis*) production in Japan is about 500 tons per year, which is small compared to other crops, but it is the third most produced tropical fruit in Japan after pineapple and mango. In Japan, there has been concern about the effects of global warming on the environment, ecosystems, and agriculture. Taking advantage of the possibility of increasing the cultivation areas of tropical crops due to global warming, we can contribute to food diversification by introducing tropical crops. Passion fruit is an herbaceous vine that can flower and bear fruit in the first year after seedlings are planted, making it an easy crop to introduce to farmers compared to other tropical fruits. However, it is difficult for passion fruit, which is native to the relatively cooler regions of the South American highlands, to flower and set fruit under recent extremely hot summer conditions in Japan. The development of varieties that take advantage of heat-tolerant genetic resources (Photo 2) could lead to an expansion of the passion fruit growing and harvest periods and could contribute to the promotion of passion fruit production and consumption in the future.

In recent years, unstable flowering and fruiting, which may be caused by climate change (e.g., global warming, low or high rainfall, etc.), have become difficult to deal with using existing cultivars. To address these issues, it is necessary to diversify varieties based on the evaluation of the characteristics of indigenous varieties, which have been underutilized until now, and to stabilize production through cultivation techniques. Instability in flowering and fruiting is a major factor that affects the yield and harvest period of many fruit trees. Addressing these issues through both varietal and cultivation methods will make a technological contribution to the local market, and the results can be used not only overseas but also domestically. In addition, the establishment of an appropriate seedling management and distribution system that utilizes variety identification technology is essential for the certification of superior varieties as export items and the creation of high value-added products.

YAMANAKA Shinsuke
Tropical Agriculture Research Front

Photo 1. Diverse mango genetic resources maintained in JIRCAS

Photo 2. Flower of a heat-tolerant passion fruit relative (*Passiflora alata*)

JIRCAS TODAY

【Research Highlights】

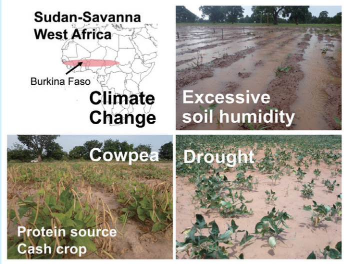
Estimation of the Impacts of Climate Change on Cowpea, an Important Crop in the Semi-Arid Regions of West Africa, through a Yield Prediction Model
—Highlighting the dual challenge of excessive soil humidity and drought—

A collaborative research initiative involving JIRCAS, the National Agriculture and Food Research Organization (NARO), the National Institute for Environmental Studies (NIES), the University of Tokyo, and the Institute for Environmental and Agricultural Research of Burkina Faso (INERA) conducted a study on cowpea – an important protein-source and cash crop in West Africa. The research used detailed data from field trials to improve the accuracy of yield predictions, particularly under both conditions of drought and excessive soil humidity. Cowpea yield variations until the mid-century were estimated by applying the yield prediction model to climate prediction data, such as the latest Coupled Model Intercomparison Project (CMIP6) for global climate change prediction and the extensive large ensemble climate simulation database (d4PDF).

The results indicate that, although drought is expected to persist in semi-arid regions of West Africa, the damage is projected to decrease. Conversely, an increase in rainfall days is anticipated, exacerbating yield reduction due to excessive soil humidity.

Traditional yield prediction models are often based on data from crop trials conducted in regions with minimal environmental stresses, limiting their applicability primarily to developed countries. In developing regions like Africa, the lack of detailed field trial data hampers the validation and improvement of yield prediction models, creating challenges in developing models that accurately capture Africa's complex agricultural conditions and predict the impact of impending climate change on crop production.

The findings of the study, indicating an increase in rainfall in the semi-arid regions and an escalation of damage to cowpea from excessive soil humidity, will provide new insights into the impact of climate change on food production in impoverished African regions. They also serve to stimulate countermeasures such as the development of new varieties tolerant not only to drought but also to excessive soil humidity.



The results of this research have been published in the international scientific journal *Agricultural and Forest Meteorology* (November 20, 2023 JST).

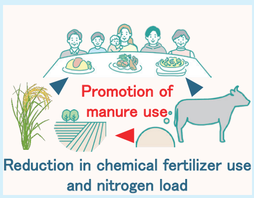
Visualizing the Impact of Nitrogen Load Reduction on Tropical Islands through the Food Nitrogen Footprint
—Scenario of resource-recirculating agriculture and livestock industry for 30% reduction of chemical fertilizer

JIRCAS, in collaboration with the National Agriculture and Food Research Organization (NARO), has made a breakthrough in visualizing the impact of reducing nitrogen loading in food systems on tropical and subtropical islands.

Recent fluctuations in the prices of chemical fertilizers, food, and feed have had a significant impact on agriculture worldwide. This impact is particularly pronounced in tropical and subtropical islands that rely heavily on imports. These regions face challenges due to the underutilization of local organic resources rich in nutrients such as nitrogen. These resources often contribute to nitrogen loading in the environment, leading to negative impacts on coastal coral reefs and marine ecosystems.

The study focuses on Ishigaki Island in Okinawa Prefecture, a subtropical island known for its vibrant agricultural and livestock industries. It aimed to assess the nitrogen load of the island's entire food system, including imported food and feed as well as exported food. The study also explored scenarios for achieving a 30% reduction in chemical fertilizer use, which is a goal of the Sustainable Food Systems Strategy, MIDORI, by maximizing the use of livestock manure on farmland. The results showed that by utilizing 70% of cattle manure on farmland, nitrogen inputs to crop production could be maintained even with a 30% reduction in chemical fertilizer use, ultimately reducing total nitrogen emissions (nitrogen load) on Ishigaki Island by 18%.

The active use of organic resources from the food system on farmland, combined with reduced use of chemical fertilizers, not only increases agricultural productivity but also contributes to environmental protection. The food nitrogen footprint applied in this study holds promise for similar tropical and subtropical island regions. It aligns with the United Nations Sustainable Development Goals (SDGs) and the Sustainable Food Systems Strategy, MIDORI, and is expected to aid in the development of strategies to address the recent volatility in chemical fertilizer prices.



The results of this research have been published in the electronic edition of *Environmental Research Letters* (July 11, 2023 JST).

JIRCAS TODAY

【Research Highlights】

Clarifying the Mechanism of Starch Accumulation in Old Palm Trees —Toward the realization of a sustainable palm industry that contributes to environmental impact reduction—

A joint research group from JIRCAS and Universiti Sains Malaysia (USM) has found that the amount of starch and sugars contained in old oil palm trees is greatly influenced by the growth conditions of the palm and the environmental conditions of the plantation.

Oil palms are cut down and left on plantations at the end of their life. These abandoned trees not only become sources of greenhouse gases but also promote the growth of pathogens, hindering the growth of new seedlings. On the other hand, old palm trees contain starch and sugars, which are seen as promising sustainable resources for bioethanol and bioplastics.

In this study, we used transcriptome analysis to clarify the factors that affect the starch content in palm trunks. The results showed that excessive production of infection-specific proteins (PR proteins) in palm trunks during pathogen attacks inhibits the synthesis and accumulation of starch. It was also suggested that when the growth conditions of the palm and the plantation environment deteriorate, the plant's immune system activates, suppressing starch accumulation.

The findings of this research elucidate the impact of environmental degradation on the starch content in old palm trees and pave the way for the development of cultivation management techniques that promote starch accumulation. This makes it possible to efficiently recover old palm trees from plantations and use their starch as a raw material for high-value-added products. Ultimately, repurposing what has previously been considered waste into a valuable resource can help mitigate greenhouse gas emissions and improve the health of plantations. This circular approach is expected to significantly contribute to achieving a sustainable palm oil industry.

The results of this research have been published in the electronic version of *Industrial Crops and Products* (June 7, 2024 JST).

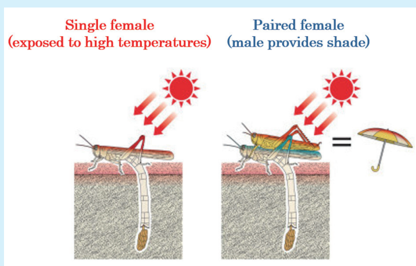
Elucidating the Egg-Laying Behavior of Desert Locusts Adapted to the Desert —Males act as "parasols" to protect females during egg-laying under high temperatures—

JIRCAS, in collaboration with the Mauritanian National Center for Desert Locust Control, has clarified the daytime egg-laying behavior of adult desert locusts in harsh desert environments characterized by extremely high temperatures.

Field surveys conducted in the Sahara Desert revealed that many adult locusts lay eggs in groups at night. However, some females delayed laying their eggs and did so during the day when surface temperatures approached lethal levels (over 50°C), periods when most animals refrain from activity. In these high-temperature conditions, males were found riding on the backs of many egg-laying females, and when the body surface of the locusts was measured using a thermographic camera, it was found that they maintained lower body temperatures than the ground surface. This suggests that the males on the backs of females function as "parasols," allowing the females to lay eggs while avoiding excessive heat.

In addition to having a high physiological tolerance to elevated temperatures (approximately 55°C), the males' role as "parasols" implies that locusts can lay eggs during times when most animals cannot remain active due to the extreme heat.

From a pest control perspective, paired locusts engaged in mass egg-laying stay in the same spot for several hours, which increases the efficiency of pesticide application. By applying this ecological understanding of locust behavior, it is anticipated that pest control can be conducted with minimal pesticide use, taking into account environmental and health considerations.



The results of this research have been published in the electronic version of *Ecology* (September 15, 2024 JST).

JIRCAS TODAY

【Event Report】

Bolivia Symposium: The Charms of Salar de Uyuni, Quinoa, and Llamas

On Monday, May 20, 2024, JIRCAS and the Embassy of the Plurinational State of Bolivia in Japan held the "Bolivia Symposium: The Charms of Salar de Uyuni, Quinoa, and Llamas" at the Japan Science and Technology Agency (JST) Tokyo Headquarters Annex. This hybrid gathering was recognized as a commemorative event for the 110th anniversary of the establishment of diplomatic relations between Japan and Bolivia and the 125th anniversary of Japanese immigration to Bolivia.

In the first session on "Quinoa and Llamas," Dr. Rolando Gregorio Oros Martínez (General Manager of the PROINPA Foundation) introduced the "Diversity and Charm of Andean Crops," Dr. Giovanna Rocio Almanza Vega (Professor at San Andrés University) presented the "Functionality of Quinoa and Bolivian Quinoa Cuisine," and Dr. NAGATOSHI Yukari (Project Leader at JIRCAS) discussed the "SATREPS Super Food Bolivia Project: The Charms of Quinoa."

In addition, in light of the fact that 2024 is the International Year of the Camel, the Bolivian Ministry of Foreign Affairs screened a video about camelids (llamas, alpacas, guanacos, vicuñas, etc.), explaining their importance to local communities and to Bolivia's economy and food security. This was followed by Dr. TOUKURA Yuji (Manager of Human Resource Development at Obihiro University of Agriculture and Veterinary Medicine), who spoke about "Camelids in South America – Llamas and Vicuñas." Dr. YANAGIHARA Seiji (Vice-President of JIRCAS) closed Session 1 on behalf of the organizers.

In the second session, Ms. Natalia Fernanda Salazar Balderrama (Charge d'Affaires ad interim of the Embassy of the Plurinational State of Bolivia in Japan) introduced Bolivian tourism and culture, and attendees had the opportunity to taste quinoa dishes and enjoy live performances of Andean folklore music.

A video of the event is available on the "JIRCAS channel" on YouTube.

JIRCAS Mail Magazine (English) Registration Guidance

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Errata

There were errors in the ISSN of JIRCAS Newsletter Nos. 91–96.
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