

JIRCAS Newsletter

for
INTERNATIONAL COLLABORATION



A quinoa field at the Salar de Uyuni (Uyuni Salt Flats) lakeshore in Bolivia (Photo by Yasunari Fujita)

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Important Crops for a Balanced Nutrition

Currently, one in nine people in the world, or more than 800 million people, do not have enough food or access to food to enable them to live healthy and active lives. Among them, more than 200 million people live south of the Sahara Desert in Africa (Sub-Saharan Africa). In these areas, soils with low fertility are widely distributed, rainfall is unstable, and many are trapped in chronic poverty. In recent years, extreme weather events such as droughts have occurred frequently due to climate change. Therefore, it is difficult to secure sufficient amounts of food of appropriate quality to ensure stable nutrition.

We at JIRCAS are working on the development of technologies for stable agricultural production under adverse environments in developing regions, including the tropics, with the aim of enhancing agricultural productivity and improving nutrition. Therefore, we have positioned “Food Security in Africa” as the flagship project under the “Stable Agricultural Production” program, and we are studying the development of sustainable technologies to increase agricultural productivity and food security in the region. For instance, under the ‘Rice production enhancement’ sub-theme of the project, we are developing breeding materials with improved nutrition uptake and smart fertilizer management technologies, and we are verifying the cultivation technologies and combining them in African environments.

However, nutrition and food behavior is biased toward the production of staple foods such as rice. In order to get a proper balanced nutrition (i.e., to grow physically and maintain good health), every meal should include the five essential nutrients in addition to providing enough calories. In developing regions including Africa, there is a deficiency not only in calories but also in nutritional elements such as protein, vitamin A, iron, zinc, and calcium. For this reason, nutrient disorders such as stunted growth in children (i.e.,

they are short for their age) are occurring. In other words, in order to improve food and nutrition in developing regions such as Africa, we need to tackle not only quantitative but also qualitative problems. In the Food Security in Africa Project, in addition to increasing rice production to improve calorie-based diets, we also conduct research on the utilization of genetic resources of cowpea and yam, which are two important regional crops with high nutritional value in West Africa, and on crop-livestock integration to improve dairy productivity.

In this special issue, researchers in charge of various food crops under the Stable Agricultural Production Program will introduce our research studies on various crops that can supply nutrients such as proteins, vitamins, and minerals, which are otherwise difficult to achieve from major staple crops such as rice.

The uses of these crops vary from region to region. Hence, the leaders of the Food Security in Africa Project will first introduce the various crops that are consumed in Africa. Then, the researchers in charge will introduce the researches on cowpea and yam, which the project focuses on. About 90% of these crops are produced in West Africa. Cowpea is an important protein and mineral source, while yam is a staple food in the area. They contain abundant vitamins and minerals besides carbohydrates.

Next, a researcher of the Environmental Stress-tolerant Crops Project will introduce our research on quinoa, a pseudocereal native to the Andean Region of South America. The main quinoa-producing countries are Peru and Bolivia, accounting for over 90% of total world production. It has excellent adaptability to adverse environments, is nutrient-rich, and provides nutritional balance. It has also been adopted as a space food by NASA and has been drawing attention as a super crop.

Finally, a researcher of the Food Value Chain Project under the Value-adding Technologies Program will introduce her research on buckwheat. It is expected to add high value to the Asian product.

Various crops have varying degrees of importance to people in different areas, and the nutrients that are obtained from these crops cannot be compensated by relying only on staple foods. I hope that we recognize the importance of research to make effective use of such crops and bring further improvements.

Kazuo Nakashima
Program Director
Stable Agricultural Production



Important crops for a balanced nutrition
 From left to right: Sorghum and pearl millet (Niger), cowpea and yam (Nigeria), and quinoa (Bolivia)
 (Photographers: Yasunari Fujita for quinoa and Satoru Muranaka for others)

Crops Grown and Eaten in Africa

Africa is the world's second largest continent, next only to Asia. It lies between latitudes 37°N and 34°S and longitudes 51°E and 17°W, and the climate varies according to area. Thus, there are places that might be suitable for cultivation of crops, places that are unsuitable, and places that may not grow anything at all. Accordingly, it raises questions about the kind of crops that are cultivated in such environments and the type of food that are eaten in the region.

Bananas are usually grown in hot and wet areas. In places where there is water available from rivers or where it rains a lot, people cultivate (and eat) paddy rice. On the other hand, in places that are not so close to the rivers or places that get little rain or where water cannot be stored in the soil to grow rice, people grow wheat, barley, maize, etc. to eat. These crops can bring good yield if they are grown in fertile soil, with optimum fertilizer application and intensive pest management. However, African environments are generally poorly suited for cultivating the abovementioned crops. In places that are prone to droughts due to unstable rainfall or infertile land, people grow minor crops such as sorghum, Siberian millet, finger millet, teff, French millet, Kodo millet, pearl millet, foxtail millet, and fonio. Cassava is also suitable in infertile soils and is often used for food. Cowpea, bambara beans, and yam are also commonly cultivated as food crops.

In addition to knowing what crops to cultivate and how to grow them under such environments, another important issue to tackle is how to prepare the harvested

crops for consumption. People prepare and eat rice simply by boiling or by frying cooked rice (fried rice). However, wheat is crushed and steamed as “couscous,” or milled (ground into flour) and baked as bread. Maize is also milled, kneaded, and prepared with hot water or put into a steamer (steamed pudding). Cooked rice, couscous, and kneaded maize are topped with stew or sauce made from a variety of vegetables, meat, or fish. Minor cereals such as Siberian millet, finger millet, etc. are cooked after milling. Beans are served as a staple food (by boiling) and as a side dish (by boiling, mashing, and pan frying). The leaves of cassava or cowpea are used as a vegetable in soups. Yams are simply boiled or fried and eaten directly, or pounded to a paste and served together with stew. As you can see, there are various crops that can be grown, and there are many ways of cooking to diversify people's diets in Africa. Minor crops, other than rice, maize, and wheat, play very important roles in this regard. We cannot put our research focus on all crops; however, we can focus on some crops and hope to make contributions toward diversifying the diets of Africans and enlivening the busy dining table of African families.

Seiji Yanagihara

Biological Resources and Post-harvest Division

Tetsuji Oya

Crop, Livestock and Environment Division



'Banku' made from fermented maize flour



'Injera' baked using teff flour

Cowpea: An Important Regional Crop in West Africa

Cowpea (*Vigna unguiculata* (L.) Walp) is a major grain legume that originated in Africa (Fig.1). With its agronomical characteristics such as tolerance to low soil fertility, high temperature, and drought, cowpea have been widely cultivated both as food and cash crop especially in Sub-Saharan Africa. Cowpea grain contains 15-25% protein and several vitamins, minerals, and dietary fiber. Cowpea is an important and less expensive food alternative for consumers whose animal protein diet is beyond their purse. It can complement staple cereals and starchy tuber crops to contribute to more nutritionally balanced diets in the region. Cowpea grains and cowpea flour are used to make home meals such as stews, soups, bean cakes, and paste fritters (Fig. 2). The leaves and immature seed pods can also be consumed. Moreover, cowpea farming provides cash income not only as dry seeds but also as fodder.

Breeding can play an important role in enhancing the functions of cowpea as food and cash crop. Hence, our project focuses on generating necessary scientific information toward the development of breeding programs for cowpea varieties that suit consumers' preferences in the target regions. The target of breeding is to improve not only the agronomical characteristics but also the grain quality, nutritional value, color, size, and softness, suiting various requests that are linked with regional subcultures. Effective breeding requires the use of genet-

ic resources to produce varieties that are endowed with the desired features. However, that kind of information, especially on the quality or nutrient content of genetic resources, is very limited. Nevertheless, we have been able to identify genetic diversity in physical, nutritional/antinutritional, and functional properties of cowpea grain. The obtained results were organized into an open access "EDITS-Cowpea" database (<https://www.jircas.go.jp/en/database/edits-cowpea>) that enables all cowpea breeders and researchers to identify the potential germplasm resources to use to facilitate their work. We are also aiming to develop more rapid and simpler techniques of evaluating agricultural and grain qualities of cowpea, and gathering information to settle clear breeding targets. We expect our data will help advance cowpea breeding and contribute to the development of varieties that suit the demands of farmers as well as consumers in Africa.

Mariko Shono
Tropical Agriculture Research Front

Satoru Muranaka
Research Strategy Office



Fig. 1. Cowpea seeds in a wide array of distinct shapes, sizes, and colors.



Fig. 2. Cowpea cooked in many different ways

Yam: An Important Regional Crop in West Africa

Yam (*Dioscorea* spp.) is a tuber crop widely cultivated in Africa, Asia, Oceania, and South America. This traditional staple crop is very important for regional food security and income generation especially in West Africa. More than 54 million tons (>95% of global production) of yam are produced in West African countries. Of the *Dioscorea* species, white Guinea yam (*D. rotundata*) are extensively grown for human consumption in West Africa, a region where yam is a crop of great economic and cultural importance for the people. However, yam breeding is constrained by the crop's inherent attributes, including a long growth cycle and low multiplication ratio, in addition to a poor understanding of genetic diversity and the underdevelopment of evaluation techniques for important traits.

JIRCAS has been working on international research collaborations on the development of genetic tools and utilization of yam genetic resources and its application for breeding. This would improve productivity and quality and help toward achieving regional food security and enhancing the income generation capacity of small farmers. Through research collaborations, we have recently analyzed whole genome sequencing of *D. rotundata* for accumulation and utilization of genetic information, which would enable us to identify the genetic regions in

the genome and clarify the roles of genes of interest without laborious conventional genetic analyses. Also, for the evaluation of the genetic diversity of yam genetic resources, DNA markers that detect variations at DNA level conveniently have been developed, and are being utilized for evaluating diversity and selecting representative diverse genetic resources

Based on these research activities, we are currently accumulating data and information about important agronomic and tuber quality traits and developing evaluation methods using the genomic tools and materials that have been developed and selected.

The knowledge, information, and technology from our current activities will be transferred to our collaborative partners, such as the International Institute of Tropical Agriculture (IITA), and to national breeding programs of West African countries and relevant projects on yam. We hope the outcomes of our research activities will accelerate the efficient use of genetic diversity to produce new varieties thereby increasing productivity and regional food security.

Shinsuke Yamanaka

Tropical Agriculture Research Front



Photos: Yam tubers being sold at the market (left) and cooked into “pounded yam,” a famous traditional food (right)

Quinoa: An Amazing Superfood/Pseudocereal

Quinoa, a grain native to the Andean Region in South America, is a pseudocereal crop of the annual Amaranthaceae family, which also includes spinach and sugar beet. As of now, Bolivia and Peru are the major quinoa-producing countries. Quinoa is rich in a wide range of minerals, vitamins, nutritional fibers, natural antioxidants, and high-quality protein and does not contain gluten. Quinoa grows well under harsh soil and climatic conditions and exhibits great tolerance to soil salinity, drought, and frost. Because of the great nutritional value of quinoa seeds and leaves and the high adaptability of quinoa plants to marginal environments, quinoa is viewed as an important crop with the potential to contribute to global food security by the Food and Agriculture Organization of the United Nations (FAO). Moreover, the National Aeronautics and Space Administration (NASA), USA, considers quinoa as an optimal food source for astronauts on long-term space missions in isolated conditions.

Quinoa has been cultivated in the Andes for more than 5,000 years. Although quinoa cultivation was forbidden during the Spanish Conquest of South America in the sixteenth century, farmers and researchers are trying to cultivate quinoa in over 50 countries today. However, the molecular mechanism underlying quinoa's outstanding nutritional profile and great tolerance to

environmental stresses, such as drought, high salinity, and low temperature, is not well understood due to its genetic heterogeneity caused by outcrossing based on carrying two kinds of flowers on the same plant and its genome complexity derived from allotetraploidy (i.e., quinoa has four sets of chromosomes that originated from two different species). To overcome these problems, our joint research team, which includes JIRCAS, Kyoto University, Kazusa DNA Research Institute, Ishikawa Prefectural University, and Actree Co., established an inbred and standard quinoa accession, Kd, suitable for molecular analyses, and provided the draft genome sequence of the quinoa accession using an optimized combination of high-throughput next generation sequencing on the PacBio RS II and Illumina Hiseq 2500 sequencers. Based on these data, we constructed the free-access Quinoa Genome DataBase (QGDB; <http://quinoa.kazusa.or.jp>). Thus, these findings will provide insights into the mechanisms underlying agronomically important traits of quinoa, and would enable us to develop more productive and useful varieties required to enhance global food security.

Yasunari Fujita

Biological Resources and Post-harvest Division



Fig. 1. Quinoa cultivation near Uyuni Salt Flat in Bolivia



Fig. 2. Quinoa sold at the market in Puno near Lake Titicaca in Peru

Development of Efficient Processing and Utilization Technologies for Buckwheat towards Food Value Chain Formation

Buckwheat is cultivated in many countries and on every continent. Although it is considered an underutilized crop, it is of significant economic importance in several countries. There are two main species, common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*F. tataricum* Gaertn.), which are widely produced throughout the world (Photo 1). These crops were domesticated and first cultivated in a southwestern province of China, and from there spread to the east in Central Asia, Tibet, Korea and Japan, and to the west in India, Middle East, Europe and then to the United States. Its long history of utilization and economic importance has been recorded in many ancient books as well as paintings such as “Buckwheat Harvest, Summer,” Jean-Francois Millet’s 19th century artwork depicting Barbizon Village in France. These historical records show that buckwheat was deeply rooted in peasant societies and informs us about the cultivated region’s natural environment, climate, and livelihood.

Buckwheat is utilized in various ways, depending on the different cultures of several countries (Photo 2). They are almost always consumed as noodles in Japan and Korea, but in European countries they are used as wheat flour for making pastas, gnocchis, cakes, breads, cookies, and galettes. In some European and former Soviet republic countries, they are also consumed as whole grains in meal dishes like kashas, minced meats, and short pastas. This indicates that buckwheat, due to its unique processing characteristics (i.e., good milling and easy-to-dehull qualities), can be produced into both flour and grains. Furthermore, in the mountainous areas of Yunnan and Sichuan Provinces in China where it originated, and in neighboring areas like Nepal, they utilize not only the grains but also the whole plant, including common and tartary buckwheat as well as the perennial species *F. cymosum*. The leaves, flowers, stems, and roots are consumed as vegetables and herbal tea, fermented into alcohol and vinegar, and used in traditional medicine.

Buckwheat cultivation has managed to carry on to the present day in many countries because of the crop’s two main benefits such as agronomic abilities and nutritional values. In terms of their favorable agronomic characteristics, these crops adapt to severe environmental conditions such as drought, low soil fertility, and high altitudes (e.g., in mountainous areas from Asia to Europe) where other crops cannot grow easily. It is a relatively low-demanding crop and has the ability to tolerate environmental stresses such as water deficiency, diseases, insects, and ultraviolet radiation; consequently, it is often used in organic farming systems and as an emergency crop around the world. In terms of nutritional benefits, it is a great source of essential nutrients, such as proteins, vitamin B₁ and B₂, ash, and fiber, compared with other major crops. Buckwheat is also popular as a source of healthy food and medicine. It contains rutin and querce-

tin, and it reduces activity of the angiotensin-converting enzyme, which is known to strengthen capillary walls. The rutin content of tartary buckwheat flour, especially, is about 100 times higher than that of common buckwheat. These functions are useful not only for rural areas but also for urban areas all over the world.

However, despite these clear benefits, only a few research studies have been devoted to processing technologies that would fully utilize the potential and functionality of various buckwheat species, same with other minor crops. “Quality growth” is a priority issue in the post-2015 development agenda, hence we must aim at both quantity and quality to promote healthy diets from sustainable food systems. A new viewpoint has been brought forward, which cites the need to develop a nutritional food value chain based on the local food production system. JIRCAS has started collaborative studies with Northwest A&F University (NAFU) China in 2016 to develop technologies for the effective use of a minor crop’s functionality. NAFU, a key collaborator located in Southwest China, is close to the origins of many minor crops including buckwheat species. It keeps a huge collection of genetic resources of minor crops originating in Asia. Through these collaborative researches, we will try to do advanced evaluation and develop utilization technologies for buckwheat species.

Kaori Fujita

Biological Resources and Post-harvest Division



Photo 1. Buckwheat flowers

Left : Common buckwheat (*F. esculentum* Moench)

Right: Tartary buckwheat (*F. tataricum* Gaertn.)



Photo 2. Local utilization of buckwheat

Left: making noodle (Yulin, China)

Upper right: kasha (Russia)

Lower right: noodle (Yulin, China)

The Institute of Environment and Agricultural Research, Burkina Faso

Burkina Faso, which means “nation of noble people” in local language, is a landlocked country located in the southern Sahara Desert, with a land area of 270,000 km² and 180 million inhabitants. Eighty percent of the population is engaged in agriculture, the productivity of which, however, is very low. The Institute of Environment and Agricultural Research (INERA, headquartered in Ouagadougou) is the national research organization tasked to solve various issues related to agriculture. Although it is relatively small scale with only 226 researchers, it has branches in five different agro-ecological regions where they conduct locally specific research. Each researcher assigned to a branch, at the same time, belongs to one of four research departments, namely, crop production, environment and forestry, animal production, and natural resource management/ production system, and they conduct research activities under the department’s instruction.

On September 9, 2014, INERA and JIRCAS signed a Memorandum of Understanding (MOU) aimed at conducting extensive international collaborative researches. Under the MOU, two collaborative researches started during the 4th Medium to Long-term Plan (FY 2016-2020). One is the development of an intensive watershed management model aimed at soil conservation as well as agricultural productivity improvement (Africa watershed management project), and the other is the development of fundamental breeding technologies to utilize the genetic diversity of cowpea, an important crop in the country (Food security in Africa project; Regional crop utilization). The above two projects are being conducted mainly at the Saria Branch in the Central Region. In addition, a new research has started this year (2017), aiming to develop a new fertilizer utilizing nationally produced rock phosphate in Burkina Faso. Furthermore, the possibility of extension is also being evaluated. This project is conducted within the framework of Science and Technology Research Partnership for Sustainable Development (SATREPS) in collaboration with Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST). These SATREPS activities will be developed not only at the Saria Branch but also at the Farako-ba Branch in the Western Region as well as

the Kouare Branch in the Eastern Region.

JIRCAS has never before conducted three different projects with one national institute at the same time. It clearly indicates the importance of INERA to lead agricultural development in Burkina Faso. Accordingly, in order to accelerate mutual understanding and relationship reinforcement between JIRCAS and INERA as well as to strengthen linkages among the three projects, JIRCAS invited an INERA representative and all project coordinators to JIRCAS in March 2017 to hold a joint seminar, titled “INERA-JIRCAS collaborative research for sustainable agricultural development in Burkina Faso.” This seminar was quite beneficial in understanding the function of each organization as well as in sharing information on the project contents.

Although the abovenamed projects are three different projects, they are all JIRCAS projects for INERA. Therefore, it is quite important to strengthen linkages among the projects and to establish a highly efficient collaborative research system for further project activities in the field.

Fujio Nagumo *Crop, Livestock and Environment Division*



Group photograph at the MOU signing ceremony in September 2014



INERA staff taking photographs to measure plant coverage rate in cowpea

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