ISSN 0919-8822
March 2015
No.74

JIRCAS Newsletter *for* INTERNATIONAL COLLABORATION

JIRCAS International Symposium 2014, Akihabara Convention Hall, Tokyo, Japan

In This Issue

JIRCAS
JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES

JIRCAS International Symposium 2014

JIRCAS International Symposium 2014

Opening Remarks : Masa Iwanaga (President, JIRCAS)

Welcome Statements : Hirotsugu Amamiya (Director General, Agriculture, Forestry and Fisheries Research Council Secretariat, MAFF)

JIRCAS International Symposium 2014 entitled “Soil Environment and Crop Production: Toward Stable Crop Production in Developing Regions” was held in Tokyo on November 28, 2014. The symposium was organized by Japan International Research Center for Agriculture Sciences (JIRCAS) and co-organized by the Japanese Society of Soil Science and Plant Nutrition, with the kind support of the Research Council Secretariat of the Ministry of Agriculture, Forestry and Fisheries and the National Institute for Agro-Environmental Sciences as well as Japan Forum on International Agricultural Research for Sustainable Development.

Climate change and rising food prices are still serious problems in many parts of the world. For this reason, recognizing the increasing importance of technology development is a key to increased productivity and stable production of agricultural products in the tropics and other unstable environments. This approach would help reduce malnutrition in developing regions and improve global food security.

Solutions to problems related to soil environment, soil health and fertilizer, which are indispensable for crop production, are urgently needed, particularly in areas like Africa where unstable environments that limit productivity are widely distributed. We recognize that tracking these problems is an urgent matter, following Tokyo International Conference on African Development (TICAD V) of 2013 and ahead of the United Nation’s declaration of 2015 as the International Year of Soils.

In this symposium, topics focusing on the improvement of nitrogen and phosphorous use efficiency as well as countermeasures against salinity were discussed by researchers and specialists in a comprehensive manner, not only from the aspect of soil science or plant nutrition but also from that of crop breeding or crop improvement.

There were two keynote speeches: Dr. Dar explained important issues related to soil in developing regions and showed examples of programs for addressing them in his speech entitled ‘Sustainable intensification through improved soil health in smallholder agriculture’; Dr. Kosaki presented a theoretical clarification of issues on soil from the viewpoint of soil science and their application to agriculture in developing regions in his speech entitled ‘Soil degradation: Challenge to achieving human security’.

Session 1 (Improvement of crop productivity in infertile soils) was divided into two parts: The first half focused on nitrogen issues while the second half highlighted phosphorus issues.

The first half of Session 1 began with the speech ‘Overview on soil fertility and crop production in SSA’ (Dr. Bationo), followed by 'Nitrogen use and efficiency in East Asian agriculture - A step towards application in Africa' (Dr. Mishima), 'N2Africa: Delivering biological nitrogen fixation (BNF) technologies to African small-scale farmers for enhancing soil fertility and legume production' (Dr. Karanja), and 'Biological Nitrification Inhibition (BNI) - Potential for reducing nitrification and N_2O emissions from agricultural systems' (Dr. Subbarao).

The second half of Session 1 commenced with the topic 'Soybean yield is affected by previous crops and mycorrhizal fungal colonization under no P fertilizer condition -A Japanese study with applicability to developing regions-' (Dr. Isobe), followed by 'Agricultural use of indigenous phosphate rocks in Sub-Saharan Africa' (Dr. Tobita), and 'Pup1 and beyond: New ideas, traits and genes for higher phosphorus efficiency' (Dr. Wissuwa).

Session 2 (Mitigation of soil salinity problems) opened with a speech titled ‘Sustainable technologies for crop production under salt-affected soil in India’ (Dr. Sharma), followed by two speeches: ‘Soil salinization and its mechanism in checkdam farmlands in the Loess Plateau, China’ (Dr. Shimizu) and ‘Genetic improvement of salt tolerance in soybean’ (Dr. Xu).

The last part of the symposium was allotted for the General Discussion, whose main focus was the collaboration between soil science and crop breeding. There were several comments, for example, on the importance of recognizing soil diversity in different regions or on the selection of suitable technologies by comparing them under different environments in different specialized areas.

The proceedings of this symposium including the transcribed speeches and discussions will be made available at JIRCAS’s web site.

This issue of JIRCAS Newsletter not only presents the outline of the symposium but also focuses on JIRCAS’s research outputs as presented at the symposium. Furthermore, related research activities such as the genetic approach of nitrogen use efficiency in rice, cultivation improvement for increasing rice yield in Africa, and countermeasures against salinization in Uzbekistan are herein described by JIRCAS researchers.

Takeshi Kano
Program Director
Stable Food Production Program

Symposium Summary (Keynote Speeches, Session1, Session2, General Discussion)

Keynote Speeches

The Keynote Session of JIRCAS International Symposium 2014 featured two distinguished guests who delivered lectures from different points of view -- one on technology improvement in the field and the other on scientific understanding.

Dr. William Dollente Dar, director general of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), one of the leading research centers of the Consultative Group of International Agricultural Research (CGIAR), delivered the first speech, titled “Sustainable Intensification through Improved Soil Health in Smallholder Agriculture.” He explained how appropriate resource management can contribute to poverty alleviation, and introduced some results of ICRISAT research in India and other areas, on the development of farmer-centric water and soil management strategies as well as climate-smart cropping and cultivation systems. Furthermore, Dr. Dar stressed the importance of connecting research results with income increase to a wider range of small-scale farmers by showing some successful cases. Lastly, he enumerated the ‘drivers of success’ for sustainable intensification and proposed taking further steps, including the need to change dietary habits, toward resolving global food problems.

Dr. Takashi Kosaki, professor at Tokyo Metropolitan University, gave the second speech, titled “Soil Degradation: Challenge to Achieving Human Security.” He explained the theoretical background of soil degradation and the significance of anthropogenic sources from the viewpoint of soil science, which he cited in his capacity as president of the Japanese Society of Soil Science and Plant Nutrition. In his lecture, several study results that pursue scientific solutions to the soil erosion problem, such as the relationship between soil carbon content and soil water dynamics in a wheat-producing area in Kazakhstan, Central Asia, soil erosion and recovery cycle in slash and burn cultivation in Northern Thailand, and the prevention technology for wind soil erosion in dry land of West Africa, were highlighted. Finally, Prof. Kosaki mentioned the need for “ethics” in soil-human relationships and reiterated the significance of the International Year of Soils.

Osamu Koyama
Director
Research Strategy Office

William Dollente Dar (Director General, International Crops Research Institute for the Semi-Arid Tropics)

Takashi Kosaki (Professor, Faculty of Urban Environmental Sciences, Tokyo Metropolitan University)

Session 1: Improvement of crop productivity in infertile soils

Soil fertility is one of the most important issues affecting crop production under diverse soil environments. Session 1 of JIRCAS International Symposium 2014 tackled this issue, with a focus on technologies for the improvement of crop production in infertile soils.

First, Dr. Andre Bationo, president of Action for Integrated Rural Development (AIRD), presented an overview of soil fertility and crop production in Sub-Saharan Africa (SSA), where the land is most threatened by multiple problems. In his presentation, Dr. Bationo used statistical data to show a declining trend in soil fertility in SSA. He proposed the adoption of integrated soil fertility management (ISFM) technologies, backed by sound policies as well as financial and institutional support services to stimulate the increase in food production.

Andre Bationo (President, Action for Integrated Rural Development, Ghana)

Shin-ichiro Mishima (Senior Researcher, National Institute for Agro-Environmental Sciences)

Nancy K. N. Karanja (Professor, Faculty of Agriculture, University of Nairobi)

Guntur Venkata Subbarao (JIRCAS)

Katsunori Isobe (Associate Professor, Nihon University)

Matthias Wissuwa (JIRCAS)

Subsequent presentations in Session 1 were comprised of 6 technology issues divided into two parts: one about nitrogen (N) and another about phosphorus (P).

Dr. Shin-ichiro Mishima, senior researcher at the National Institute of Agro-Environmental Sciences (NIAES), Japan, was the first speaker for the N part. He talked about N budget estimation in agricultural systems, citing the survey results in China and Japan. He also mentioned its application to SSA.

Biological nitrogen fixation (BNF) is a substantial source of N in leguminous crops, therefore technologies associated with BNF contribute to soil N balance and productivity of various cropping systems. In this context, Dr. Nancy K. N. Karanja, professor at the University of Nairobi, Kenya, introduced the successful activities of “N2Africa,” a megaproject for technical promotion of BNF in SSA countries.

The third speaker for the N group was Dr. Guntur Venkata Subbarao, senior researcher at JIRCAS. He talked about biological nitrification inhibition (BNI), a mechanism in the soil that suppresses nitrification through unique chemical substances produced by some crops and pastures. He showed possible technologies for the efficient utilization of fertilizer N in various agricultural systems incorporating such plant genotypes.

For the P part, first speaker Dr. Katsunori Isobe, associate professor at Nihon University, Japan, lectured about the significant effect of arbuscular mycorrhizal fungi (AMF) on plant P acquisition. From past experiences in the fields of Japan, an appropriate crop rotation system shall be proposed to enhance AMF not only in Japanese fields but also in P-deficient SSA soils.

The next presenter, Dr. Satoshi Tobita, division director at JIRCAS, introduced research activities utilizing indigenous phosphate rocks (PRs) to improve soil P fertility in SSA. PRs are relatively abundant in the African continent, and he showed positive data that Burkina Faso PRs were effective in improving the yield of lowland rice in rain-fed and irrigated ecologies.

The final presentation of Session 1 was delivered by Dr. Matthias Wissuwa, senior researcher at JIRCAS. He explained his work with an international network on the *Pup1* gene, which confers P deficiency tolerance in rice plants as well as genetic improvement of root and crop efficiency in P uptake and P utilization.

In summary, Session 1 considered key technologies for the improvement of crop productivity in infertile soils. These beneficial technologies will be harnessed by 1) analyzing and understanding nutrient flow/balance in agricultural systems, 2) enhancing soil fertility at prices affordable to local farmers, and 3) improving nutrient uptake/ utilization efficiency in crops.

Satoshi Tobita and Naruo Matsumoto
Crop, Livestock and Environment Division

Session 2: Mitigation of soil salinity problems


Dinesh Kumar Sharma (Director, Central Soil Salinity Research Institute, India)


Katsuyuki Shimizu (Lecturer, Faculty of Agriculture, Tottori University)


Donghe Xu (Senior Researcher, JIRCAS)

Soil salinity is one of the most serious soil degradation problems in the world. Salt-affected soils are generally classified into two main categories: saline and sodic (alkaline). Saline soils are soils with high amounts of soluble salts. The accumulated salts include sodium, potassium, magnesium, calcium, chloride, and sulphate. In sodic soil, sodium accumulates as crystalized $NaHCO_3$ or Na_2CO_3, with pH values between 8.5 and10.

Topics related to soil salinization were discussed at JIRCAS Symposium 2014 (Session 2: Mitigation of soil salinity problems). Dr. Dinesh Kumar Sharma, director of the Central Soil Salinity Research Institute (CSSRI), introduced “Sustainable technologies for crop production under salt-affected soil in India”; Dr. Katsuyuki Shimizu, lecturer at Tottori University, discussed “Soil salinization and its mechanism in check-dam farmlands in the Loess Plateau, China”; and Dr. Donghe Xu, senior researcher at JIRCAS, presented “Genetic improvement of salt tolerance in soybean.”

Dr. Sharma’s lecture described CSSRI’s development and standardization of several location-specific technologies for the reclamation and management of saline and sodic soils. These included interventions in the farming system approach in canal command areas and its effects on reducing the negative impacts of water logging and sodicity. He also spoke about the development of strategies for crop production through efficient, balanced, and integrated use of inputs. Sodic soil land reclamation technology through chemical amendments and breeding of salt-tolerant crop varieties were also regarded as important technologies.

Dr. Shimizu’s topic explained soil salinization in a check-dam system. He noted the construction of a check-dam as one of the most effective measures for conserving soil and water around the Loess Plateau in China. He also described that after the reservoir was filled with sediments, a flat land was formed and utilized as a farmland. However, soil salinization was observed in check-dam farmlands. He reported that rising groundwater level in the farmland, rather than soil texture, was the main cause of soil salinization as indicated by field experiments.

Dr. Donghe Xu’s presentation concluded the session by enumerating the following approaches -- quantitative trait locus (QTL) analysis, map-based cloning and whole-genome-sequencing -- as useful tools for identifying the gene related to saline or sodic tolerance.

Mariko Shono
Tropical Agriculture Research Front

General Discussion

Participants at the 2014 JIRCAS Symposium engaged in a lively exchange of views during General Discussion, which focused on the collaboration between soil science and crop breeding. Several comments related to this year’s theme were received as mentioned below.

- Scientists in different specialist areas need to work together in multidisciplinary teams to holistically address the issues discussed in this symposium. Scientists have to bring convergence amongst different actors such as policy makers, extension workers or farmers involved in the impact chain.
- The BNI research is a very good model of cooperation between plant nutrition and plant breeding. The linkage can generate big synergies and give us a good solution or a breakthrough to deal with 'climate change', not only in the adaptation area but also in mitigation measures.
- The genetic approach to nitrogen use efficiency in rice has attracted attention among researchers. The gene has already been introduced into “mega-varieties” in Asia and Africa.
- It is necessary to fully describe the aims and objectives of any research activity. Any ecosystem should be viewed as a whole so that in the end the synergy effects can lead to greater impacts.
- It is very important to recognize the variability or variation in terms of soil characteristics and the environment. Under certain conditions, a kind of package made of a particular soil type, crop variety or farming system may be highly appropriate and useful on one site but may not be applicable or be able to solve problems on another site. The second choice or the third choice in one place can be the first choice in other places.
- Actual collaboration depends on the selection of scientists. The role of the institution is also important to ensure collaboration.
- A good example of collaboration among different specialist areas is shown by one of the CGIAR (Consultative Group on International Agricultural Research) research centers, AfricaRice, which is currently implementing the ‘rice sector development hubs’. After the breeder develops the varieties, the agronomist immediately evaluates the performance of such varieties by phenotyping and characterization. A linkage structure or mechanism representing specific environments is important because technology always needs to adapt to local conditions.

Takeshi Kano


Takeshi Kano (JIRCAS)


Satoshi Tobita (JIRCAS)


Naruo Matsumoto (JIRCAS)


Kazuhiro Suenaga (JIRCAS)


Mariko Shono (JIRCAS)


General Discussion

Biological Nitrification Inhibition (BNI) and its Potential for Reducing Nitrification and N_2O Emissions from Agricultural Systems

Modern crop production has become a human-centric ecosystem, driven largely by the massive infusion of industrially fixed-nitrogen (N) and becoming high-nitrifying due to accelerated soil nitrifier activity. Nearly 95% of the reactive-N that enters these agricultural systems goes through rapid nitrification and nitrate becomes the dominant inorganic-N source for crop uptake and assimilation. Accelerated nitrification rates in agricultural soils have resulted in a decline in nitrogen use efficiency (NUE) since the advent of Green Revolution. Nearly 70% of the N fertilizer applied globally to agricultural systems (about 175 Tg N) is lost through NO_3^- leaching and gaseous emissions by denitrification, harming ecosystems and human health. This amounts to an annual economic loss of US$ 90 billion.

Nitrous oxide (N_2O) is the most powerful greenhouse gas with global warming potential 300 times that of CO_2. The primary drivers of N_2O production and emission are nitrification and denitrification in the soil, with nearly 75% of global N_2O emissions coming from agricultural systems. Nitrous oxide emissions from agricultural systems are increasing and projected to reach 19 Tg by 2100, a near doubling from present level. Hence, there is an urgent need to develop next-generation technologies to reduce N_2O emissions from agricultural systems as IPCC has set a target to cut global greenhouse gas emissions by 80% by 2100.

Biological nitrification inhibition (BNI) is a plant function where nitrification inhibitors are released from root systems to suppress soil nitrifier activity and reduce nitrification potential of agricultural soils (Figure 1). With the recent developments in *in-situ* measurement of nitrification inhibition, it is now possible to characterize BNI function in plants. Tropical pasture grasses belonging to *Brachiaria* sp. have the highest capacity to produce nitrification inhibitors from their extensive root systems, and indeed are model systems to understand the implications on reducing N_2O emissions and nitrification potential of agricultural soils. The nitrification inhibitor released from *Brachiaria* sp. root systems has been discovered and identified as 'Brachialactone', a cyclic diterpene with a unique 5-8-5-membered ring system and a γ-lactone ring. The release of BNIs from root systems is a highly regulated plant function, triggered and sustained by the availability of ammonium in the root environment. The physiological consequences associated with the uptake of NH_4^+, such as activation of H^+ pumps in the plasmalemma and acidification of the rhizosphere, facilitate the release of BNIs. Moreover, the release of BNIs from roots is a localized phenomenon, mostly confined to parts of the root system where NH_4^+ is present; this ensures a relatively high concentration of BNIs in soil microsites where nitrifiers are active, often associated with the presence of NH_4^+. In addition to the presence of NH_4^+ in the root zone, the rhizosphere pH may also influence the release of BNIs from roots. Recent results suggest that sorghum plants do not release BNIs from their roots in the presence of NH_4^+ when rhizosphere pH is >7.0; optimum rhizosphere pH for the release of BNIs from plant root systems appears to be between 5.0 to 6.0, suggesting that BNI function will be most effective in light-textured soils with pH of 6.0 or less. The effectiveness of BNI function in suppressing nitrifier activity, soil nitrification and N_2O emissions has been demonstrated from field studies using *Brachiaria* sp. pasture grasses that have varying levels of BNI-capacity in root systems.

The concept of BNI function was introduced in 2006, and is gaining increasing attention and traction due to its potential for reducing nitrate leaching, N_2O emissions and improving NUE in production agriculture. The primary focus of JIRCAS's mission on BNI research is to develop a conceptual frame work, generate research tools/methods, and identify/develop genetic stocks with BNI-trait to facilitate genetic improvement of BNI-capacity in major food and feed crops. Several CGIAR research centers collaborate with JIRCAS using *Brachiaria* sp. pasture grasses, sorghum and wheat as model systems for BNI research. JIRCAS and CIAT (International Center for Tropical Agriculture) are jointly working for developing low-nitrifying production systems in Ianos (Colombia) and Cerrados (Brazil) through exploitation of high-BNI *Brachiaria* pastures. The low-BNI capacity maize production can be benefitted by integrating production systems with high-BNI-capacity *Brachiaria* pastures, gaining increasing attention in the region. Development of genetic markers for sorgoleone release (a major nitrification inhibitor released from sorghum roots) is another important research area where ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) is participating. CIAT also participates in developing genetic markers for brachialactone production and release in *B. humidicola* to breed for high-BNI capacity *Brachiaria* pastures. Transferring the high-BNI-capacity from *Leymus racemosus* (a wild relative of wheat) to cultivated wheat through chromosome engineering, is the focus of ongoing collaboration with CIMMYT (International Maize and Wheat Improvement Center). A paradigm shift is needed to move away from an inherently inefficient NO_3^--centric nutrition and move towards NH_4^+-centric crop nutrition. The genetic exploitation of BNI function has the potential to facilitate the development of low-nitrifying and low-N_2O-emitting agricultural systems to benefit both agriculture and environment.

G.V. Subbarao[1], Y. Ando[1], T. Yoshihashi[2] and K. Nakahara[2]
[1]Crop, Livestock and Environment Division
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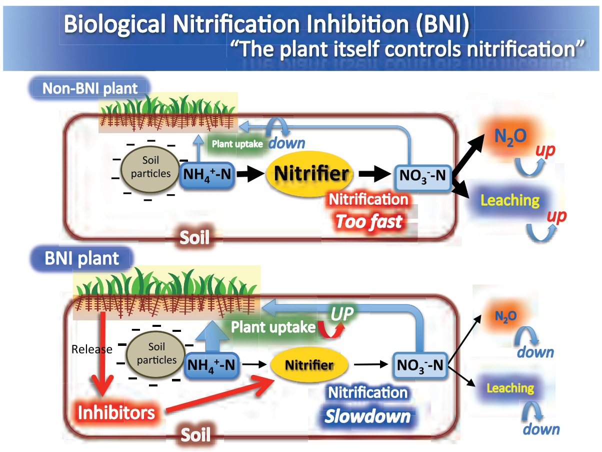

Figure 1. A schematic representation of biological nitrification inhibition (BNI) interfaces with the nitrogen cycle in agricultural soils. Non-BNI plants may accelerate nitrifier activity and make soil nitrification faster resulting in nitrogen losses from NO_3^- leaching and N_2O emissions. BNI-plants, in contrast, will suppress nitrifier activity by releasing inhibitors from root systems and will slow down soil nitrification and improve nitrogen use efficiency by reducing NO_3^- leaching and N_2O emissions.

Agricultural Use of Indigenous Phosphate Rocks in Sub-Saharan Africa

Phosphorus (P) is an essential nutrient for crop growth and production. In Sub-Saharan Africa (SSA), soil P deficiency is one of the most serious constraints to crop yield. This shortfall has resulted from the high P fixation capacities of highly weathered acidic soils in SSA, spreading throughout a range of agricultural lands, from upland to lowland fields. To cope with P deficiency in SSA farmlands, resource-poor farmers have to look for alternative sources because commercial water-soluble P fertilizers are expensive and in short supply.

Indigenous phosphate rock (PR) deposits are found in several places in the African continent, and are recognized as cheaper alternative sources of P for local agricultural production. Currently, PR consumption comprises merely 2.8% in Africa whereas the production is 28% of the world total. Hence, it is important to study the chemical and physical properties of local PRs in order to develop appropriate methods for its effective utilization. PRs mined in SSA, however, with its low water solubility, are generally considered less effective especially when directly applied onto the fields.

It is therefore worthwhile to evaluate the effectiveness of PRs in SSA where agricultural systems differ in terms of crops and environmental conditions (soil and climate). The JIRCAS Team, in collaboration with researchers from counterpart institutes in Ghana and Burkina Faso, evaluated the PRs originating from Burkina Faso (BPR). On-farm experiments in Ghana showed that directly-applied BPR had a positive effect on the growth and yield of lowland rice in irrigated (Equatorial forest zone/ Kumasi) and rainfed (Guinea savanna zone/ Tamale) ecologies (Figure 1). Same results were reproduced in an on-farm experiment in a rainfed lowland rice system in Burkina Faso.

Continuous experiments have been conducted in the same fields of Ghana to examine the residual effects of BPR applied in the previous season. Although the residual effects were observed in all farmers' fields in the Equatorial zone, they were site-dependent in the Savanna zone. BPR could be utilized as a delayed-release P fertilizer in most lowland rice fields in Ghana and even in supposedly similar rice ecologies of neighboring countries. From participatory studies in the rural communities of Ghana, most farmers expressed interest in the use of BPR (if available) as its acceptability was 100%, although accessibility is still 0% at this moment (Photo 1).

To increase the solubility of BPR, several processing technologies have been examined, with due consideration to the feasibility concerns of farmers and the community. Low-temperature calcination (at around 300°C) is expected to increase the solubility of BPR, hence the material could be incorporated into the charring process to make biochar (from rice straw and husks, sawdust and other organic resources) as it can locally attain the temperature. Additionally, biological acidulation during the composting process to make farmyard manure (from various sources of organic matter) could be promising, as it generates heat and organic acids and helps solubilize the incorporated BPR.

The "Soil Fertility Improvement Manual," which explains these technologies in detail, has already been issued in Ghana and will soon be published in neighboring countries for reference and future application.

Satoshi Tobita, Satoshi Nakamura, Monrawee Fukuda & Fujio Nagumo
Crop, Livestock and Environment Division

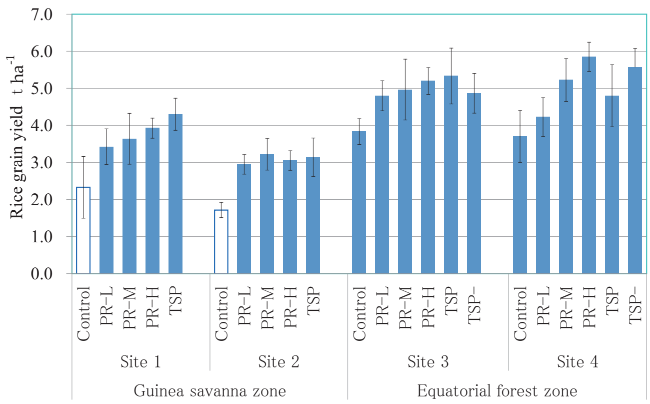

Figure 1. Rice grain yield in farmers' fields of Guinea savanna zone (Sites 1 and 2) and Equatorial forest zone (Sites 3 and 4) in Ghana, as affected by the application of Burkina Faso Phosphate Rock (PR) at the rate of 67.5 (L), 135 (M) and 270 kg-P_2O_5 ha^{-1} (H), as well as chemical fertilizer with 270 (TSP) and 60 kg-P_2O_5 ha^{-1} (TSP-Rec)

Photo 1. Participatory training/study workshop in a farming community around Tamale, Ghana, to assess the affordability of indigenous materials including phosphate rock

Pup1 and Beyond: New Ideas, Traits and Genes for Higher Phosphorus Efficiency

Phosphorus (P) is an essential macro-element for all living cells and therefore crucially important for crop production. It has been estimated that insufficient plant-available P constrains plant growth on more than 5.7 billion ha of land worldwide. P deficiency can be overcome by P fertilizer application but given that high-quality phosphate rock, the source of P fertilizers, is a non-renewable and increasingly limited resource, it is foreseeable that P-fertilizer prices will further increase, putting P fertilizers out of reach of most resource-poor farmers in developing countries. It has therefore been suggested to increase efforts to develop crop cultivars with enhanced P efficiency.

Selection of modern varieties has typically been performed in standardized, high fertility conditions with a primary focus on yield. This could have contributed to the loss of plant genes associated with efficient nutrient acquisition strategies and with adaptations to soil-related stresses that many traditional varieties maintained. It will therefore be crucial to reintroduce traits and genes associated with efficient P acquisition and utilization into elite crop cultivars.

One successful project recently identified the *OsPSTOL1* gene enhancing P uptake from low-P soils at the Pup1 locus. Molecular markers diagnostic of the superior *OsPSTOL1* allele have been identified and shared with breeding partners throughout Asia and Africa, enabling them to conduct their own marker-assisted selection program with locally preferred varieties. Under P deficiency sensitive varieties exhibit delayed root development, which further reduced the amount of P taken up, whereas *OsPSTOL1* helps tolerant plants to overcome this reduction in root development (Figure 1) and thus enhances overall root size.

While root size is generally considered one of the most important traits to maintain P uptake and thus overcome P deficiency, other complementary traits exist that have so far not received much attention. For example, certain genotypes may induce changes in the soil around their roots that enhance P availability, leading to higher root efficiency (RE = increased P uptake per unit root) or they may possess higher internal P utilization efficiency (PUE) that enables them to produce more biomass per unit P taken up (Fig. 1).

After screening diverse panels of rice gene bank accessions, we identified new donor varieties with superior RE and PUE. Furthermore, we have associated genotypic differences within these panels to phenotypic variation for RE and PUE and identified novel loci enhancing each trait. These loci are now being investigated for the presence of candidate genes and molecular markers. The ongoing genetic and physiological characterization of underlying genes and mechanisms suggests more efficient genotypes have altered gene structures for a gene affecting RNA turnover within the plant cell. RNA constitutes the biggest pool of plant P and is thus crucially linked to P efficiency. A second candidate gene for PUE is likely to affect cellular P compartmentation between physiologically active and inactive P pools.

While such studies will enhance our understanding of how P efficiency traits are regulated, our main aim is to use novel P efficiency loci and alleles in rice breeding and for this purpose crosses between globally important but inefficient rice cultivars and our new donors for superior RE and PUE have been made. Selection within this material will be conducted jointly with our partners in Asian and African rice-growing countries.

Matthias Wissuwa
Crop, Livestock and Environment Division

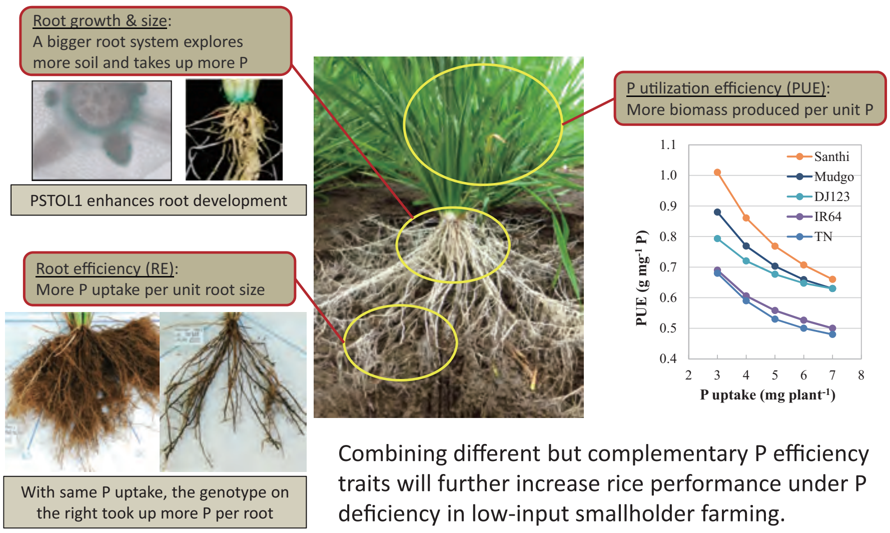

Figure 1. Complementary P efficiency traits that enhance overall performance of rice in P deficient fields. Better root growth as conferred by the *PSTOL1* gene enhances P uptake because a larger soil volume is explored by roots. The aim in breeding is to combine *PSTOL1* with additional traits such as root efficiency and PUE to further improve P uptake and subsequent growth under sub-optimal P supply.

Genetic Improvement of Salt Tolerance in Soybean

Salt-affected soils significantly reduce land value and productivity. Soil salt and related problems generally occur in arid or semi-arid climates, where rainfall is insufficient to leach soluble salts from the soil. Salt stress can also occur on irrigated land, particularly when irrigation water of marginal quality is used. About 7% of the earth's land and 20% of irrigated lands are affected by salt stress.

Salt-affected soils are generally classified into two main categories: saline and sodic (alkaline). Based on the Soil Map of the World by FAO/UNESCO, salt-affected soils cover a total area of 831 million ha, of which 397 million ha are saline and 434 million ha are sodic (FAO, AGL 2000).

Soybean [*Glycine max* (L.) Merr.] is the world's primary crop source for protein and oil, providing 68% of world protein meal consumption and 28% of world vegetable oil consumption. This legume crop is generally regarded as a salt-sensitive crop compared with other crops such as wheat, rice, and cotton. However, salt stress problem occurs in some soybean production areas (Photo 1). Genetic improvement of salt tolerance is therefore essential for maintaining sustainable production in areas where soybean growth is threatened by salt stresses.

Saline stress reportedly inhibits soybean germination and growth, nodule formation, and seed yield. Previous studies have revealed that there was a great genetic variation for saline tolerance in soybean, and that several soybean germplasm were identified to be saline-tolerant, suggesting that development of soybean varieties with high saline tolerance is feasible and would provide an efficient way to improve soybean production in a saline stress environment.

To identify soybean germplasm with higher saline tolerance, we evaluated more than 600 soybean accessions, including wild soybean (*Glycine soja* Sieb. & Zucc.), in a greenhouse condition using salt-water flooding method. The soybean plants were treated with 150 mM NaCl water solution for about four weeks. Based on screening of a large number of soybean germplasm from different countries, several soybean genotypes with high saline tolerance, such as the Brazilian soybean cultivar FT-Abyara, the Chinese soybean cultivar Jindou 6, and the Japanese wild soybean accession JWS156-1, were identified. Quantitative trait locus (QTL) analysis with four mapping populations derived from crosses between these tolerance lines and sensitive cultivars revealed a major saline-tolerant QTL on soybean chromosome 3 flanked by SSR markers Sat_091, Satt255, Satt339, and Satt237. The QTL accounted for 31.3-68.7% of the total variance for saline tolerance in the mapping populations. The tolerance alleles in the progenies were contributed by the tolerant accessions.

Recently, DNA marker-assisted selection (MAS) has been recognized as an efficient way to accelerate the development of new, more productive, and better-adapted cultivars. MAS is particularly useful for breed selection and for assessing saline tolerance, which is difficult to evaluate because salt concentrations typically show either a horizontal or vertical gradient across a field. Using MAS method, we developed near isogenic lines (NILs) for the saline tolerance QTL. Field test in a salt-affected soil revealed that all the lines that harbored the saline tolerance allele showed significant higher saline tolerance than the lines that had the sensitive allele at the QTL. The saline tolerance gene could greatly increase soybean grain yield in a saline field condition (Photo 2). To identify the gene conferring saline tolerance at this locus, map-based cloning approach was employed, and a causal gene *qNaCl3* underlying the QTL on chromosome 3 was isolated. The successful isolation and characterization of the saline tolerance gene might contribute to the sustainability of soybean production in saline areas by introducing it into local soybean varieties either by DNA marker-assisted selection or gene transformation methods.

Photo 1. Soybean growth inhibited by salt stress (Hebei Province, China)

Saline tolerance line　　　Saline sensitive line

Photo 2. Performance of the developed saline tolerance soybean line (left) and the sensitive soybean line (right) grown under salt stress conditions (Miyagi Prefecture, Japan)

In the case of sodic tolerance, previous studies mainly focused on iron deficiency caused by high soil pH, and several QTLs associated with iron deficiency were reported. In our study, a wild soybean accession was identified to show sodic tolerance at the seedling stage, and a significant QTL for sodic tolerance was detected on chromosome 17. Further fine-mapping analysis narrowed down the sodic salt tolerance QTL in a 3.3 cM region between markers GM703907-Satt447. These studies demonstrated that salinity and sodic tolerances were controlled by different genes in soybean. DNA markers closely associated with these QTLs can be used for marker-assisted selection to pyramid tolerance genes in soybean for both saline and sodic stresses.

Donghe Xu
Biological Resources and Post-harvest Division

Developing Rice Breeding Technologies for Improved Nitrogen Use Efficiency

Nitrogen deficiency is common in almost all soils worldwide. Nitrogen largely affects plant photosynthesis and hence is a limiting factor in rice yield. Supplementation of deficient nutrients by fertilizer application to rice fields typically leads to higher yields. However, nearly 70% of nitrogen fertilizer is not absorbed by rice. Additionally, nitrogen content is low in African soils. Enhancing nitrogen uptake from fertilizer and soils is therefore important toward a suitable rice production system that is also in harmony with the environment.

A genetic approach to nitrogen use efficiency (NUE) analysis is difficult as it is affected by many environmental factors. One effective way to solve this problem is to analyze NUE-related traits and use them as indicators. For example, the weight of a plant grown in various conditions is selected as a promising indicator and subsequently a number of quantitative trait locus/loci (QTL/QTLs) are identified. This signifies the importance of indicators in identifying QTLs for NUE.

Generally, root lengths are longer in plants grown in nitrogen-deficient conditions and shorter in plants grown in nitrogen-sufficient conditions. Root elongation in response to nitrogen deficiency is considered a phenomenon arising from the active uptake of diluted nitrogen. I hypothesized that longer roots at any nitrogen concentrations (i.e., deficient to sufficient) would be beneficial to NUE. Before QTL mapping, a reliable growth condition was established to evaluate root length of seedlings in response to changes in nitrogen concentrations. Using this method, it was proven that an Indica rice variety, Kasalath, grew longer roots over a wide range of nitrogen concentrations. Furthermore, a causal QTL for longer root, designated as *qRL6.1*, was identified and the corresponding DNA markers were developed for a molecular breeding program. Preliminary yield trials revealed that Kasalath *qRL6.1* enhanced nitrogen uptake and grain yield, at least in the genetic background of Koshihikari.

We, in collaboration with Africa Rice Center, are currently working on the introduction of Kasalath *qRL6.1* into mega varieties for Asia and Africa. Field testing of the prospective lines is planned for the future. We are going to develop technologies for NUE in combination with breeding and cultivation techniques.

Mitsuhiro Obara

Biological Resources and Post-harvest Division

Photo 1. A line (center) produced by introducing Kasalath *qRL6.1* (right) into Koshihikari (left). Plants were grown for 16 days in hydroponic condition supplied with moderate concentration of nitrogen.

(Photo by Mitsuhiro Obara)

Agronomic Approach for Increasing Rice Productivity in Africa

One major constraint to crop production in Sub-Saharan Africa (SSA) is the extremely low amount of nitrogen (N) input. Nitrogen, a part of chlorophyll that is responsible for photosynthesis, is the most important macronutrient for crop growth. According to FAOSTAT (http://faostat.fao.org/), N-fertilizer consumption increased 30-fold, from 0.18 million tonnes to 5.22 million tonnes per year, in Southeast Asia in the four decades since 1961 -- a period known as the ‘Green Revolution’ -- during which the region achieved substantial increases in rice yield. On the other hand, current N-fertilizer consumption in SSA has remained constant at around 0.6 million tonnes per year despite having nearly 10 times as much farmland area as Southeast Asia. Further input of nitrogen together with water is highly necessary in order to meet crop growth demands and to improve rice productivity in SSA.

However, it is also a fact that the capacity to invest in fertilizer inputs and irrigation infrastructure is still limited particularly for smallholder farmers in SSA. Given these circumstances, our project aims at developing low-input techniques for rice production in a floodplain environment that is naturally endowed with relatively rich alluvial soils and adequate access to water.

A model site was selected in a floodplain area along the White Volta River, and we have identified that both N-supplying capacity of soils and length of water-logging period can be quantitatively estimated by measuring the distance to ‘water reservoirs’ (i.e., logarithmically increased with proximity to ‘water reservoirs’). Here, ‘water reservoirs’ indicates standing water areas (such as main river and backswamps) throughout the seasons. This finding was achieved using a multilateral approach that integrates satellite imagery analysis, ground survey of water dynamics, soil chemical analysis, and phytometric pot experiments.

Also, field experiments in virgin floodplain areas revealed that rice yields as well as responses to N application became greater as it approached ‘water reservoirs’. River floodplain occupies an estimated 30Mha in SSA, the majority of which is currently underutilized for agricultural production. Rice is better adapted to seasonal flooding compared with upland crops such as maize, therefore efficient use and management of the floodplain environment should expectedly contribute to improved rice production in SSA.

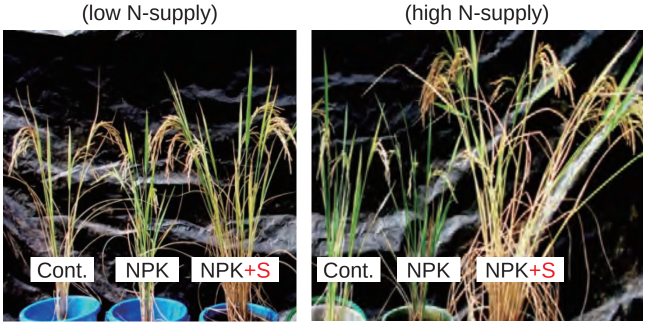

Fig. 1. Soil-derived and fertilizer nitrogen can be more efficiently utilized for rice production with sulfur application.

Photo 1. Farmers evaluate fertilizer management techniques through multiple-village cooperation. (Counterparts weigh grain samples at Tolon in Northern Ghana.)

Furthermore, pot experiments using floodplain soils combined with different fertilizer elements indicated that sulfur (S) application would substantially increase soil-derived N and external N use efficiency for rice production (Fig. 1). As exemplified in this S-deficient case, various types of nutrient elements apart from N should be considered for enhancing rice productivity since the soils are highly weathered in many parts of SSA. Our recent study had identified that silica (Si) deficiency was widespread in local farmers’ fields in SSA and that the probability of Si deficiency can be increased with abundant N fertilizer application. Rice increases resistance to biotic and abiotic stresses by accumulating large amounts of Si, and therefore Si is another element to be considered.

Based on our studies, we suggest the following three steps to efficiently improve rice yield under limited external inputs and highly weathered soils in SSA: 1) select relatively productive land areas for rice production in terms of N-supplying capacity of soils and water availability such as floodplain lowlands, 2) elucidate deficient nutrient elements apart from N (e.g., S and Si) in the selected land areas, and 3) develop management practices against nutrient deficiency in any of these elements. A fertilizer management practice using S-containing ammonium sulfate is currently tested as a cooperative activity among multiple villages in Northern Ghana, including floodplain areas.

Yasuhiro Tsujimoto
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Research on Measures against Salinization in Uzbekistan

Salinization causes farmland damage including reduced agricultural productivity as can be observed in the irrigated lands of arid or semi-arid zones. In addition to dissolved salts in irrigation water, salts are also accumulated on the ground surface after evaporation of groundwater and thus worsening the situation. The rise of groundwater levels, with the salts moving up towards the surface layer through capillary action, is caused by excessive irrigation or malfunctioning drainage systems.

In the river basins of Amu-darya and Syr-darya flowing into Aral Sea, Central Asia, a large scale irrigation project has been implemented starting from the 1960s. Expansion of irrigated agriculture focused on cotton, wheat, and paddy rice cultivation. Consequently, groundwater levels in the region rose steadily due to excessive irrigation, leakage from irrigation canals, and lack of drainage management, etc. Accumulation of salt on the surface layer resulted to decreased crop yields and land abandonment.

To cope with this problem, JIRCAS implemented a research project to develop measures against salinization in Uzbekistan, which has the largest salinized area in Central Asia. The research, conducted in cooperation with Uzbekistan's Ministry of Agriculture and Water Resources (MAWR) and the Farmers' Council (FC; formerly the Farmers' Association), was started in 2008 after obtaining subsidy from the Ministry of Agriculture, Forestry and Fisheries of Japan.

A number of salinity mitigation measures, such as repairing irrigation canals, cleaning drainages, and leading the farmers in leaching activities to wash out the accumulated salts from the field, were implemented by the national government. However, farmers continued using excessive amounts of irrigation water, rendering the measures ineffective. JIRCAS's study, therefore, focused on understanding how farmers exacerbated salinization and what countermeasures can be applied. Relevant researches and experiments have been implemented to improve the technical aspects and to verify the effects of the measures on farmers' fields in Syr-darya region, which has large areas of salinity.

Photo 1. Accumulation of salt on a wheat field in Uzbekistan (Dec. 2010)

As a result of the research, a guideline titled "On-farm mitigation measures against salinization under high groundwater level conditions" was published in February 2013. Following a discussion among MAWR, FC and JIRCAS, the guideline was translated into Russian and Uzbek languages, with a simplified popular version in addition to the original one. It explains intelligibly to farmers the following topics, namely: the mechanism and monitoring method of salinization, the results of monitoring in the field, simple water-saving irrigation and low-cost land leveling methods, drainage maintenance, and crop rotation to generate funds for the measures and improve soil fertility. The costs and benefits of introducing each measure stepwise are also explained. The guideline is available for download at the JIRCAS website (http://www.jircas.affrc.go.jp/english/manual/manual_index.html) and had already been disseminated by FC in relevant seminars in Uzbekistan.

Currently, high groundwater levels remain a problem and improved remediation measures are continually being sought. Therefore, JIRCAS is studying measures concerning methodologies for efficient groundwater control and developing a technology that reduces the amount of infiltration water contributing to groundwater recharge. This study is being implemented in cooperation with FC. JIRCAS will thereafter verify the effectiveness of the measures on actual fields and propose more efficient measures to control the rise of groundwater levels.

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Rural Development Division

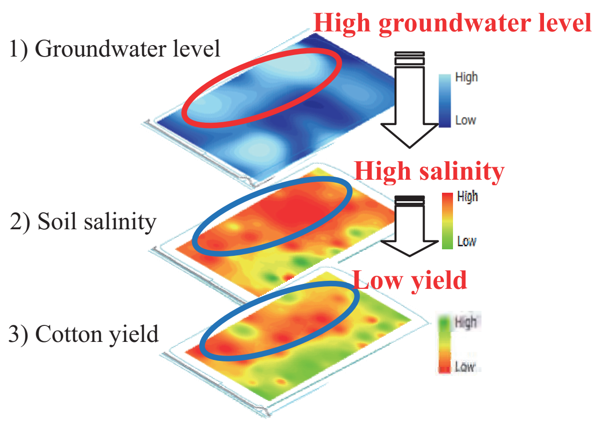

Figure 1. Visualized data explaining the mechanism of salinization based on monitoring results in a cotton field (From the guideline: popular version)

JIRCAS TODAY

2014 Japan International Award for Young Agricultural Researchers

The commendation ceremony of the 2014 Japan International Award for Young Agricultural Researchers was held at the Akihabara Convention Hall, Tokyo, Japan on November 27. The ceremony was attended by many participants including members of the selection committee.

Awardees, members of the selection committee, and other officials

This is the eighth time that the award was presented by the chairman of the Agriculture, Forestry and Fisheries Research Council to young foreign researchers with outstanding achievements to promote research and development of agricultural, forestry, fishery and other related industries in developing regions. This year's award recipients and their research achievements are as follows.

Dr. Giriraj AMARNATH
Nationality: Indian
Institute: International Water Management Institute (IWMI)
Research achievement: Enhancing Resilience to Agricultural Flood-Risks and Adaptation for Smallholder Farmers in Asia and Africa

Outline of Research Achievements

Dr. Amarnath's main research harnesses the potential use of satellite data to spatially and temporally characterize inundation patterns in order to formulate risk reduction and adaptation measures. For rapid emergency response, the Flood Mapping and Analysis Tool was developed to rapidly detect flood extent, and the tools were made freely-available to users. A global flood risk "hotspot" analysis was carried out to identify where the risks of natural disasters are particularly high to inform priorities for reducing disaster risk and making decisions on development investment. As a co-PI, he was involved in an innovative project that supports smallholders in Africa by providing climate, weather, and operational flood information to empower farmers to make informed decisions and better manage their land and water resources. The first of its kind in the region, the Smart-ICT system was implemented to allow sharing of operational flood information to farmers in advancing climate-smart agriculture. He is currently undertaking two major initiatives on the South Asia Drought Monitoring System in a holistic approach to address the implications of drought on agricultural production and advance the development of index-based flood insurance to support households that are severely affected by flooding in South Asia.

Dr. HO Le Thi
Nationality: Vietnamese
Institute: Cuu Long Delta Rice Research Institute (CLRRI)
Research achievement: Allelopathy and Allelochemicals in Vietnam Local Cucumber Variety and Vietnamese Rice Cultivars

Outline of Research Achievements

Allelochemicals produced by certain crop and rice cultivars have potential to biologically control barnyardgrass (*Echinochloa crus-galli* L.), a major rice yield-limiting factor. Three growth inhibitory compounds were isolated and identified from a Vietnam local cucumber variety (*Cucumis sativus* L. cv. Phung Tuong). 3-Oxo-α-ionol (3-OI) was first found as an allelochemical in cucumber plants, (S)-2-benzoyloxy-3-phenyl-1-propanol (SBPP) was first reported to have growth-inhibiting activity, and (6S,7E,9S)-6,9,10-trihydroxy-4,7-megastigmadien-3-one (TMO) was first identified to be an important potential allelochemical. The average ED50 (concentration required for 50% inhibition) of 3-OI, SBPP and TMO on test plant species (including barnyard grass) root and hypocotyl elongation were 99.3 and 38.4 µM, respectively. The endogenous contents of 3-oxo-α-ionol, (S)-2-benzoyloxy-3-phenyl-1-propanol, and (6S,7E,9S) -6,9,10-trihydroxy -4,7-megastigmadien-3-one in 1.0 kg fresh cucumber plants were 0.35, 2.5 and 5.1 mg, respectively. N-trans-cinnamoyltyramine (NTCT) was identified for the first time as an allelochemical produced by *Oryza sativa* L.cv. OM 5930 rice plants. The ED50 of NTCT on barnyard grass root and hypocotyl elongation were 1.35 and 1.85 µM, respectively. The endogenous content of NTCT in 1.0 kg fresh rice plants was 42 mg, this production of NTCT in intact rice plants can be considered high. These findings suggest that developing plants of cucumber variety Phung Tuong and rice cultivar OM 5930 release such allelochemicals and may be utilized to biologically control weeds in rice fields.

Dr. Asad JAN
Nationality: Pakistani
Institute: Institute of Biotechnology and Genetic Engineering, The University of Agriculture Peshawar, Pakistan
Research achievement: Analysis of Plant Growth Regulation under Abiotic Stress Conditions

Outline of Research Achievements

Plants are constantly challenged by a variety of biotic (pathogens, insect attacks, etc.) and abiotic (high and low temperature, drought and salinity) stresses. Progress has been made in understanding the molecular basis of the adaptive responses and identification of key pathways involved in different abiotic stresses. This has led to the utilization of more effective ways to improve plant abiotic stress tolerance/hardiness.

Dr. Jan actively pursued research on the mechanism and tailoring of abiotic stress tolerance in plants. His research was on the characterization of CCCH-Zinc Finger Protein genes and isolation of stress inducible promoters in rice. He characterized a gene designated as OsTZF1 which is involved in conferring multiple stress tolerance in rice (Jan et al., 2013). The transgenic plants over-expressing OsTZF1 gene exhibited delayed senescence and tolerance to multiple stresses, for example salt stress. The protein of OsTZF1 gene could bind the 3' untranslated regions of target RNAs. It was suggested that OsTZF1 gene confers abiotic stress tolerance in plants by regulating the turnover of the mRNA of target genes involved in abiotic stress. The expression of OsTZF1 with suitable stress inducible promoter will enhance its usefulness for abiotic stress tolerance to multiple stresses with minimal effects on plant growth (Nakashima et al., 2014). Dr. Jan also isolated and characterized another gene which confers abiotic stress tolerance and minimizes the penalty of abiotic stress on plants. Currently, the transgenic plants for unmentioned gene which is involved in an increase in panicle and seed number under drought conditions are under extensive investigation in the fields.

JIRCAS Newsletter
Japan International Research Center for Agricultural Sciences (JIRCAS)
March 2015 No.74
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