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Tofu and deep-fried tofu seller in Malang, Java, Indonesia (Photo by S. Nikkuni)

NEWSLETTER

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For International Collaboration

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Contents

Role of New Division — Food Science and Technology Division

Establishment of new Division

The Food Science and Technology Division was established on April 1, 2001, when JIRCAS was reorganized from a governmental institution into an Independent Administrative Institution (IAI, semi-autonomous agency), under the supervision of the Ministry of Agriculture, Forestry and Fisheries of Japan. The Division is to be engaged in research activities in the field of postharvest technology to contribute to food security, poverty alleviation and sustainable development on a global scale through research collaboration with scientists in developing countries, while another IAI, National Food Research Institute, is mainly engaged in research for and development of food science and technology relevant to the interests of the Japanese consumers and the Japanese food industry. Postharvest research covers a wide range of fields in the harvest-consumption chain: harvesting, handling, drying, storage, grading, packaging, processing, transport, disease and insect control, quality/safety evaluation and inspection, and marketing.

Food security

Food security is one of the major global problems facing humans today. The world population reached about 6 billion in 2000 and it is anticipated that the population will exceed 7.5 billion in 2020, according to United Nations' World Population Prospects. Because agriculture is influenced by the environmental conditions and global arable land is limited, global food production may not increase sufficiently to meet the demand of the rapidly increasing population. On the other hand, postharvest losses of grains have been estimated at 20-30%, caused mainly by insect infestations and microbial infection in developing countries. Therefore, the products once harvested should be consumed with minimum loss during handling, transportation and storage. Developing techniques to reduce postharvest losses of agricultural products and to maintain their quality will contribute to global food security.

Poverty alleviation

Agriculture is still the largest sector of rural economies, and a majority of the rural population is engaged in agriculture, in developing countries. The income of urban people is much higher than that of the rural ones, and population has moved from the rural to the urban areas, seeking higher income and more convenient living conditions. Against this background, we must make utmost efforts to give rural people the means to increase their income, so that they may stay in the rural areas and continue to cultivate their land and rear their livestock.

The prices of agricultural commodities are declining and their percentage in the final consumer price is decreasing, which indicates the necessity of value addition to the commodities. Consumers are concerned about the quality and safety of what they eat. Changes in the urban life-style associated with increased income and women's work have resulted in increased consumers' demand for a more diversified diet, for processed and convenience foods and for animal products.

It is important for rural farmers to market products that meet the demand of urban consumers. Therefore, studies to ensure high quality/safety of agricultural commodities and to enhance their value will contribute to the improvement of rural income.

Sustainable development

Postharvest technologies to be developed should be environment-friendly in order to promote environmental sustainability. Since technologies less dependent upon chemicals are preferable from the viewpoint of not only food safety but also environmental preservation, the development of alternative methods to chemical treatment is highly required. For example, the world's most widely used fumigant, methyl bromide, is to be phased out by 2015 due to its ozone-depleting potential, and worldwide scientists have been making efforts to develop alternative methods for disinfesting agricultural products such as grains and fruits and vegetables.

Research activities

We are currently conducting a research project titled: "Development of low-input technology for reducing postharvest losses of staples in Southeast Asia" in collaboration with Thai organizations, to develop low-input drying technology using natural energy sources such as sunlight, husks and straw and to develop insect-controlling technology employing natural enemies and bioactive botanicals. The technologies will result in

Rice noodles in China

Fingerroot *(Boesenbergia pandurata)*, produced in Nakhon Pathom, Thailand

Koji-making process of kecap, an Indonesian soy sauce effective and lower-cost systems that are also environment-friendly to reduce postharvest losses of rice. We investigate the bioactivity of indigenous plants in Southeast Asia such as ginger as well as the characteristics of Thai aromatic rice in order to promote value-adding utilization of these commodities.

We are also involved in other research projects, including the improvement of the process for the production of Chinese traditional foods such as soybean milk curd (tofu) and rice noodles (miefun) in China and the development of technology for the utilization of soybeans for non-feed purposes in Brazil. In Indonesia, we have successfully isolated white-spored mutants from the koji molds for the production of Kecap, an Indonesian soy sauce, to discriminate the koji molds from mycotoxin producers.

All these research activities are expected to contribute to global food security, rural poverty alleviation and environment sustainability.

Toru Hayashi
Director, Food Science & Technology Division, JIRCAS

Collaborative Research Project

Contribution of JIRCAS to the Development of New Rice Varieties for Africa

In the middle of the 1990s, West Africa Rice Development Association (WARDA, based in Bouaké, Côte d'Ivoire) had succeeded in producing fertile progeny lines from the interspecific cross of *Oryza sativa* (Asian rice) and *O. glaberrima* (African indigenous rice). These hybrid lines have attracted considerable attention because they are expected to be better adapted to crop management with limited resource input, compared with Asian varieties that cover almost 100% of the rice area in this region. WARDA has been the major organization involved in the Africa/Asia Joint Research Project (Interspecific Hybridization between African and Asian Rice Species), a South-South Cooperation Project funded by UNDP/TCDC since 1997. In early 1998, JIRCAS joined the project with an independent budget and started a 5-year collaborative research program with WARDA to analyze the genetic and eco-physiological characteristics of the interspecific hybrids. For the project, JIRCAS had been assigned to conduct research on drought and soil acidity, which are the major constraints on rice production in the resource-limited rainfed ecosystems in West Africa.

During the first half of the project (1998-2000), JIRCAS dispatched a crop physiologist to WARDA. He was assigned to the Molecular Biology Laboratory of the Breeding Unit, headed by Dr. Monty Jones, who had successfully conducted studies on interspecific hybridization. The laboratory aims at tagging genes responsible for important traits of the interspecific progenies through QTL analysis, on the basis of which superior marker-aided selection systems could be developed. With substantial assistance from Dr. Cadalen, a molecular biologist, and the technical assistance extended by Cornell University, a molecular analysis scheme for polymorphism among rice varieties/lines was effectively developed in the laboratory. The main activity of the crop physiologist sent by JIRCAS was centered on the development of screening methods and quantitative criteria applicable to QTL analysis of drought and soil acidity tolerance.

For drought tolerance, field experiments were conducted during a dry spell at Mbé, in an upland field near Bouaké, using several African and Asian lowland and upland rice varieties. Growth analysis showed that upland rice varieties displayed a much higher tolerance to drought than lowland varieties. It was interesting to note that the growth of the African rice varieties was significantly reduced by drought stress at the early vegetative stage. Another finding on the physiological response of *glaberrima* rice to drought was that CG20, an African rice variety originating from Casamance (Senegal), showed a much higher reduction rate in transpiration than in photosynthesis. Though it is not necessarily true for all African rice, the drought-tolerance mechanism of CG20 was associated with a rapid closure of the stomata leading to a reduction in the amount of transpired water. This was confirmed by the larger increase in the $\delta^{13}C$ value (carbon isotope discrimination rate) in CG20, compared with other *glaberrima* varieties. Therefore, it was assumed that there would be a wide range of variation among African rice varieties in the response to drought stress.

First observation of the drought trial at Mbé by the team of WARDA's Molecular Biology Laboratory, Mr. Gabriel Aluko, Mme Hortense Séhi, Dr. Monty Jones, Mr. Dobo Macaire, Dr. Thierry Cadalen and Mr. Pierre-Louis Amoussou (from left).

The ability of water uptake by roots is another determinant for drought tolerance at the vegetative growth stage of rice plants. With the technical assistance of Dr. Ookawa, Associate Professor, Tokyo University of Agriculture and Technology, during a short-term visit to WARDA, several parameters of water relations were examined. Among them, the rate of xylem exudation from the cut section of stem was well correlated with drought tolerance. Due to the simplicity of this measurement, the xylem exudation rate could be adopted as a quantitative criterion for QTL analysis of drought tolerance at the vegetative growth stage.

Emphasis was also placed on the genotypic variation in soil acidity tolerance among *O. glaberrima* varieties. We conducted an experiment in an upland field at Man, an acidity-prone area in the western part of Côte d'Ivoire, using several Asian and African rice varieties. As phosphorus deficiency is the main limiting factor in acidic soils in this area, the studies were focused on the response to P-application. The responsiveness to P-application in *glaberrima* rice was as high as that of *sativa* rice. IG10, an African rice variety from Côte d'Ivoire gave the highest yield under P-deficiency. After confirmation of the reproducibility of the results, it was suggested that new interspecific crosses could be made for breeding a variety with outstanding tolerance to soil acidity and P-deficiency.

Satoshi Tobita
Crop Production & Environment Division, JIRCAS

JIRCAS Research Highlight

Forest Conversion and Road Construction

– A Case Study in a Rubber Village in Sumatra, Indonesia –

Indonesia has the third largest area of tropical forests in the world. According to FAO, about one million ha of forests are being lost each year in this country. Historically, shifting cultivation had been considered to be the primary cause of deforestation. However, subsequent studies have paid more attention to profitable tree crops and found that smallholder tree crop production, rubber in particular, contributes to the deforestation rather than shifting cultivation. Rubber earns the highest agricultural income in Indonesia. Rubber is the dominant smallholder crop in much of Sumatra and Kalimantan.

The construction of roads is well known to accelerate forest conversion to agricultural land. Previous studies on road and deforestation revealed that closer distance from roads and higher density of roads likely lead to a higher rate of deforestation. However, little is known about how road construction affects farmers' behavior in forest clearing.

Collaboration work between JIRCAS and International Centre for Research in Agroforestry (ICRAF) focused on the impact of road construction on forest conversion to agricultural land in a village of rubber smallholders in Sumatra. The village named Talang Sungai Bungo was chosen for the farmer survey. Swidden-based rubber cultivation is the dominant economic activity in the village. The farming system is a combination of shifting cultivation and traditional rubber planting. Our fieldwork was conducted in 1999-2000. A survey was conducted for 40 randomly selected households in the study village through two interviews. The first interview was made in May-June 1999, to obtain information about land acquisition and land tenure and the second was performed in February-March 2000, to analyze the household economy.

The economic development policy of President Suharto (period: 1967-1998) had accelerated the improvement of the infrastructure in Indonesia. The road related to the transport of rubber from the village to the market had been substantially improved and paved by the government in 1974 and 1978. The road construction enabled to lower the cost and shorten the time of transport of rubber remarkably. As the market price of rubber remained constant, the villagers were able to sell rubber at a higher price and the profitability of rubber increased.

To identify changes in farmers' behavior in terms of forest clearing after road construction, the following data were analyzed: data-1) Land ownership of the households, data-2) Acquisition methods of the land owned by the households, data-3) Forest clearing implemented by the households, (1) distance from the village center to the plots of forest clearing, (2) year when the plots were cleared, (3) size (ha) of the plots, data-4) Number of total households in the village, based on statistical data of the district.

Results of analysis of data-1) showed that a household owned an average of 16 ha of land, including rubber gardens (9.7 ha) and bush fallows (5.8 ha). Analysis of data-2) indicated that the main method of land acquisition involved the clearing of primary forests (73% of the plots of land). According to the custom law, the person who clears a primary forest can acquire the land. Other methods of land acquisition included inheritance and purchase. Results of data-3) analysis showed that forest conversion to agricultural land in the village had been sharply accelerated in the late 1970s and has been stable since then. Analysis of data-4) showed that population growth had been stable and ranged between 1 and 3% during the period of 1970-2000. Analysis of data-3) (2)-(3) indicated that the area of forest cleared per household had doubled in the late 1970s and has been stable since 1980. As a result of the analyses of data-3) and -4), it was found that the expansion of agricultural land in the 1970s was mainly associated with the increase in

Forest cleared for planting rubber in the study village in Sumatra

Mature rubber garden in the study village forest clearing per household and that the contribution of population growth was not significant.

Based on this study, we observed that expansion of agricultural land occurred not because of local population growth, but because smallholders cleared a larger forest area, reflecting farmers' behavior in response to road construction. Road construction, which had improved the transport of rubber and raised the profitability of rubber in the village, enhanced farmers' incentive to expand the farm size.

This study indicates that road construction is effective for local people to improve their living standard in the short term. However, excessive clearing of forests may result in inequality of the land area among local people in addition to all the adverse effects associated with deforestation, including the loss of biodiversity. It is thus important to strike a balance between forest conservation and the welfare of the local people in this area.

Motoe Miyamoto
Forestry Division, JIRCAS

Complete Nucleotide Sequence and Genetic Organization of Papaya Leaf Distortion Mosaic Virus* RNA

Papaya (*Carica papaya* L.) is one of the most important fruit trees in tropical and subtropical areas. Papaya leaf distortion mosaic virus (PLDMV) and *Papaya ringspot virus* type P (PRSV-P) have been reported to cause papaya diseases in Japan. Out of them, PLDMV is the most destructive factor in papaya production in Japan (Fig. 1). The viruses belong to the genus *Potyvirus*. They are similar to each other in several properties including characteristic symptoms that appear on papaya plants, host range, transmission mode of aphid and physical properties.

Information on the nucleotide sequence of PLDMV-RNA is necessary to identify similar viruses, as mentioned above, and to develop methods for their control. The complete nucleotide sequence of the RNA genome of the PRSV-P Hawaii isolate was reported in 1992. On the other hand, only the 3' terminus of that of PLDMV was reported in 1996.

In this study, the complete nucleotide sequence of the RNA genome of PLDMV was analyzed to determine the genomic organization of PLDMV and to classify PLDMV based on molecular taxonomy.

The sequence was determined from 6 overlapping cDNA clones and by primer extension. The genomic RNA was 10 153 nucleotides (nt) in length, excluding the poly(A) tract, and contained one large open reading frame that started at nucleotide positions 135 to 137 and ended at positions 9942 to 9944, encoding a polyprotein of 3269 amino acids. The 5' untranslated region (5'UTR) of PLDMV preceding the ORF was 134 nt and contained box a-like (ACAAAACTT) and box b-like (TCAATACA) sequences which were highly conserved sequences in the other reported potyviruses. The 209 nt of the 3' untranslated region (3'UTR) was present downstream of the ORF.

The polyprotein was cleaved by viral proteinases into smaller proteins. Cleavage sites were predicted by analogy with the other potyviruses. The genetic organization of PLDMV RNA was defined as follows: P1, the first proteinase, a protein with a proteolytic activity; Hc-Pro, helper component proteinase, a protein with aphid transmission helper component activity and proteolytic activity; P3, the third protein, function unknown; 6K1, 6kDa protein 1, function unknown; CI, cytoplasmic inclusion protein, a protein with RNA helicase activity; 6K2, 6kDa protein 2, function unknown; NIa, nuclear inclusion protein "a" including the VPg (NIa-Vpg), genome-linked viral protein covalently attached to the 5' terminal nucleotide and NIa proteinase (NIa-Pro); NIb, nuclear inclusion protein "b", the RNA polymerase and CP, coat protein (Fig. 2). The proteins were not assembled into virus particles, but they were nonstructural virus-encoded host-alien proteins except for CP.

Fig. 1. Ringspot and distortion symptoms on a papaya fruit caused by PLDMV.

The genetic organization of PLDMV was similar to that of the other potyviruses. Predicted amino acid sequences of PLDMV proteins were compared with those of PRSV-P and other 23 distinct potyviruses. The overall percentages of amino acid sequence identity ranged from 46.4% with *Potato virus V* (PVV) to 50.5% with *Plum pox virus* (PPV). PLDMV exhibited the highest percentage of amino acid identity (65.6%) in its NIb with PPV. The region with the lowest identity among the potyviruses was the P1 protein, with identity ranging from 18.4% with *Bean yellow mosaic virus* (BYMV) to 29.2% with *Bean common mosaic virus* (BCMV). CP amino acid sequence identities, which are the criteria used for the taxonomy of potyviruses, ranged from 61.9% with *Potato virus Y* (PVY) to 52.1% with *Tobacco vein mottling virus* (TVMV). These molecular characterizations confirmed that PLDMV is a distinct member of the genus *Potyvirus*.

The PLDMV and PRSV-P also shared the highest sequence identity value (63.0%) in their NIb, and the lowest (22.8%) in their P1 protein. Since the P1 protein of the potyviruses is the most variable, it is considered to be a very important protein for the identification of individual potyviruses. It might be useful for the distinction between PLDMV and PRSV-P by RT-PCR. The information on the complete sequence will be used for the development of technology for the transformation of PLDMV-resistant papaya in the near future.

**Since Papaya leaf distortion mosaic virus has not yet been officially recognized by the International Committee of Taxonomy of Viruses, italics were not used.*

Tetsuo Maoka
Okinawa Subtropical Station, JIRCAS
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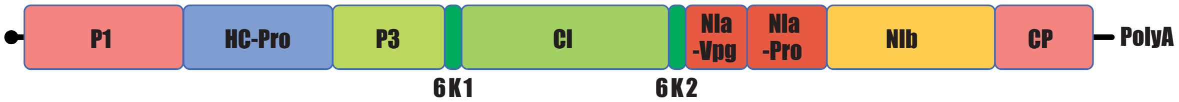

Fig. 2. Proposed genomic map for PLDMV RNA.

P1, the first proteinase; Hc-Pro, helper component proteinase; P3, the third protein; 6K1, 6kDa protein 1; CI, cytoplasmic inclusion protein; 6K2, 6kDa protein 2; NIa, nuclear inclusion protein "a" including the VPg (NIa-Vpg), genome-linked viral protein and NIa proteinase (NIa-Pro); NIb, nuclear inclusion protein "b"; CP, coat protein.

APEC/JIRCAS Joint Symposium and Workshop on Agricultural Biotechnology

The Asia-Pacific Economic Cooperation (APEC) Agricultural Technical Cooperation Working Group and JIRCAS joined hands to organize the "Joint Symposium and Workshop on Agricultural Biotechnology" in Bangkok during September 3-7, 2001. The first day was open to the public, attracting more than 300 participants. Discussion was focused on "The Future of Biotechnology in World Agriculture." Several internationally known experts gave keynote speeches followed by a panel discussion. It became clear that agricultural biotechnology would have a significant impact on future agriculture and world trade, especially through the safe and prudent application of transgenics (genetically modified organisms, GMOs) in both developing and developed countries. Public acceptance of biotechnology applications was considered to be the key for current and future society to benefit from biotechnology applications.

Subsequently, APEC organized a workshop focused on "Policy and Regulations on Biotechnology Applications." Special attention was directed towards food safety and environmental safety in relation to GMOs. APEC member economies are sharing information and experience in this very sensitive area in order to achieve a more regionally coherent approach. Many developing economies requested further support for their capacity building in policy, regulatory and technical areas for the active and safe implementation of biotechnology to address their agricultural production and use problems.

JIRCAS' workshop, which was organized from 5 to 7 September, was titled: "Genetic Engineering of Crop Plants for Abiotic Stress" The reasons why abiotic stress was chosen as theme are threefold. First of all, poor farmers in marginal areas are more vulnerable to the impact of abiotic constraints (e.g. drought) on the production of food crops. Second, most of the transgenics that are already present in farmers' fields or in the pipeline for future release are related to herbicide resistance, disease/pest resistance, postharvest or nutritional quality. These are important traits for high-income countries and high-input agriculture. Unfortunately, no transgenics with abiotic stress tolerance are anticipated for commercial use. This is probably because poor farmers in marginal areas are not the prime targets of biotechnology research by the private sector. Poor farmers of developing countries are deprived of the benefits from transgenics adapted to their growing conditions. Thirdly, JIRCAS believes that recent developments in basic biological science (genomics in particular) can lead to a much better understanding of the biological mechanisms of abiotic stress response and tolerance. Moreover, knowledge and DNA obtained through research in one crop can be used for other crops since the biological mechanisms for abiotic stress response are considered to have common features (functional synteny) among higher plants.

More than 10 prominent scientists gave lectures on the basic biological mechanisms for tolerance to drought, high temperatures, low temperatures and high salinity, as well as on recent progress in the development of transgenics in cereals, legumes, tropical fruits and root and tuber crops. Dr. J. M. Ribaut of CIMMYT and Prof. K. Watanabe of Tsukuba University reported on successful transformation with abiotic stress tolerance in wheat and potatoes, respectively, presenting the promise of future production of crops with abiotic stress (such as drought, low temperature) for use by poor farmers in marginal areas. They used DREB (drought responsive element binding protein) genes provided by Dr. Shinozaki of JIRCAS, demonstrating that the genetic mechanisms controlling the biological response to drought, low temperature and high salinity that were originally found in *Arabidopsis* can also be used for those important economic plants.

Participants benefited from the joint symposium and workshop organized by APEC and JIRCAS since they could attend sessions dealing with policy aspects (APEC's main interest) as well as scientific progress (JIRCAS' main interest). Policy and science should go hand-in-hand, but there had not previously been any opportunity for policy authorities and science experts to get together. Proceedings of the JIRCAS workshop will be published as a JIRCAS Working Report in early 2002.

Masa Iwanaga
Director, Biological Resources Division, JIRCAS

Seminar on "Multifunctionality of Agriculture"

On October 17-19, 2001, an international seminar on the multifunctionality of agriculture was held at JIRCAS. The seminar was organized by the Food and Fertilizer Technology Center for the Asian and Pacific Region, a Taiwan-based international organization, and co-sponsored by four Japanese research institutes, including JIRCAS.

The purpose of the seminar was to gain a better understanding of the multiple functions of agriculture through the exchange of information and to determine whether information gaps exist and how these can be filled, for the benefit of those involved in agricultural research and policy formulation. The participants came from eight Asian countries, and 17 papers were presented. The keynote speech on “Agriculture and the Environment” was delivered by Dr. K. Minami, President of the National Institute for Agro-Environmental Sciences, Japan, followed by four sessions: Food security, Environmental protection, Other externalities, Evaluation of multifunctionality.

During the discussion, the multifunctionality of agriculture, one of the key topics being currently debated at forums, especially in developed countries, was found to be an important issue for developing countries’ agriculture, of which roles need to be recognized from a broader viewpoint in order to obtain stronger support. There was a wide consensus among the participants that paddy rice production, which is a common agricultural activity in the region, has positive externalities in several aspects. However it was also concluded that the definition of multifunctionality needed additional clarification, and that the methodologies used for evaluating externalities, in general, should be improved by further promoting the research network and research collaboration among the Asian countries.

On the third day of the seminar, the participants made a field trip to “Kasama Kleingarten” located north of Tsukuba, a small community where city dwellers are able to rent simple cabins with vegetable and flower gardens.

Participants in the FFTC International Seminar on Multifunctionality of Agriculture

Osamu Koyama
Research Planning & Coordination Division, JIRCAS

8th JIRCAS International Symposium

Water for Sustainable Agriculture in Developing Regions
– More crop for every scarce drop –

For its 8th International Symposium, JIRCAS chose the theme, “Water for Sustainable Agriculture in Developing Regions - *More crop for every scarce drop* -.” This theme was chosen because of impending conflicts among agriculture, human livelihood, and the environment for scarce water, and the real danger of future food shortages and famine.Over 200 participants exchanged research results and ideas on ways to address this pressing problem during the two days of the Symposium, November 27-28, 2001.

The symposium presented current knowledge and state-of-the-art research in three sessions, moving from the global to the user-based level. In the opening session, three keynote speakers presented key elements of the problem and directions towards solution. Prof. A. Musiake, University of Tokyo, presented results of global modeling of water supply and demand until 2050, using a $0.5° \times 0.5°$ grid and specific river basins, showing projected water scarcities driven by population increase. Dr. D. Molden, International Water Management Institute, explained that to meet environmental water needs, reduction in irrigation use will require productivity increases of 60% in irrigated agriculture and 35% in rainfed agriculture. Prof. Y. Kaida, Kyoto University, presented a framework for solution and numerous real-world examples based on individualized, communalized, and regionalized ecotechnologies. This framework proposed moving from engineering approaches that characterized the Green Revolution era to environmentally formative and adaptive approaches, with the goal of “more welfare for every drop.”

Opening address by Dr. T. Inoue, President of JIRCAS

The following three sessions examined concrete ways to achieve the goals of productivity increase and environmentally formative water management. *Session 1* presented new genetic and ecological approaches to increasing drought resistance and water stress tolerance. Prof. S. Inanaga, Tottori University, presented examples of crop ecological adaptation using mechanisms of escape, avoidance, tolerance, and recovery, and approaches to enable crops to better use these mechanisms, including conservation tillage, deep tillage, fallow, mulching, and intercropping. Dr. R. Ortiz, International Institute of Tropical Agriculture, presented a model for decentralized plant breeding based on expansion of the phenotype concept adding management, farmers, institutions, and policy to genotype-environment interaction. He supported this with concrete examples of maize, cowpea, groundnut, and soybean breeding, including recent advances using genetic markers. Finally, Dr. K.

Yamaguchi-Shinozaki, JIRCAS, described recent progress in transferring drought stress genes and promoter proteins in model plants, and explained plans being developed with other public institutions and the private sector to extend these new methods to economic crops.

Session 2 presented new agronomic approaches for improved crop water use. In terms of Dr. Ortiz' model, this moved from the genotype side to the environment side of the phenotype model. Prof. R. Wallach, Hebrew University of Jerusalem, explained results of detailed studies of water movement demonstrating how water flux from the soil to the plant, measured by unsaturated hydraulic conductivity, is the real determinant of soil water depletion, rather than tension or water content alone. Dr. S. Hasegawa, Hokkaido University, showed the importance of macropores for crop deep water exploitation, and presented techniques for reducing soil impedance of root penetration developed in Northeast Thailand, including hardpan fracture and organic amendments in trenches. Finally, Dr. P. Thornburn, CSIRO, explained how soil wetting patterns using trickle irrigation depend on structure and hydraulic properties of specific soils, and not simply on soil structure, and illustrated this with a new decision-support tool.

Session 3 examined concrete examples of approaches to transforming agricultural production in water-stressed areas, through two series of presentations and comments. In the first series, Dr. O. Ito, JIRCAS, presented two models of comprehensive research in rainfed agriculture in Northeast Thailand, the first focused on crop-livestock integration, and second which will develop small-scale watersheds through toposequence management and small-scale irrigation, starting in 2002. Three commentators provided additional perspectives relevant to the new project. Dr.W.Pichai, Department of Land Development, Thailand, explained the national policy background which the new project will support. Dr. Y. Shinogi, NIRE, presented an example of small-scale watershed management, the cascade system of Sri Lanka. Dr. J. Caldwell, JIRCAS, through comparisons between small-scale watershed research in Northeast Thailand and Mali, West Africa, showed the potential for cross-regional research interaction. These included participatory methods, future adaptation of small-scale ponds for long *bas-fonds* in West Africa, and strategic weather prediction for crop management decision-making being developed in Mali.

In the second series, Mr. R. Nishimaki, JICA, using an example from Kenya, explained how JICA has integrated participatory approaches into its development programs, combining water management with support to other needs of users. Paralleling the concept of "more welfare for every scarce drop," evaluation of its programs examines relevance, sustainability, and impact, as well as efficiency and effectiveness. Two commentators provided additional perspectives. Dr. A. Al-Jaloud, King Abdulaziz City for Science and Technology, Saudi Arabia, showed how well-integrated management practices have enabled that country to achieve remarkable increases in food production in an arid environment. Mr. Y. Kano, JICA, presented a case study of how community forestry in Senegal, led by beneficiaries themselves, has increased sustainable reforestation.

The Symposium concluded in *Session 4* with an introduction to the World Water Forum, a summary of JIRCAS' achievements in water-focused research over the past 10 years, and general discussion of research needs, contributions, and potential partnerships for achieving more crop and more welfare from every scarce drop.

Poster session

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