PROCEEDING
OF
THE INTERNATIONAL SEMINAR
ON
TECHNICAL TRANSFER OF RICE CULTIVATION TECHNOLOGY
AND
RECENT ACCOMPLISHMENTS IN RICE RESEARCH IN JAPAN

November 19, 1998

(Bangladesh)

November 27, 1998

(Thailand)

EX-PARTICIPANTS FOLLOW-UP TEAM

JAPAN INTERNATIONAL COOPERATION AGENCY

J I C A

PREFACE

It is a great pleasure for me to inform you that the Japan International Cooperation Agency (JICA) is makiing the utmost efforts to expand and improve its technical program year by year. JICA has accepted a total of 122,000 participants from developing countries to date since the program was launched in 1954.

In response to the request from developing countries, JICA will try to increase the number of participants as well as to improve the quality of training programs for the future training courses.

For this purpose,we would like to know how and what to extent the Ex-participants in our training course are utilizing the knowledg and technology obtained in Japan. We also would like to hear your suggestions and recommendations for betterment of our training course.

The JICA, therefore dispatches a technical follow-up team to participating countries. This year, JICA has decided to send the folllow-up team for Rice Research Techniques Course, and the team will conduct a seminar for providing information on the latest development in the field concerned.

I hope the seminar will be useful in up-grading your expertise in rice research technology.

November 1998

A. Hashimoto.

Akihiko HASHIMOTO

Managing Director,
Tsukuba International Centre,
Japan International Cooperation
Agency (JICA)

TECHNICAL TRANSFER OF RICE CULTIVATION TECHNOLOGY

Kimio MIURA *

Toshio FUJII **

INTRODUCTION

Japan began receiving technical participants when it became a member of the Colombo Plan in 1954. Since then 44 years passed. During those years, the areas covered by the technical cooperation of JICA expanded from Asia to Middle East, Africa, Latin America and Oceania, i.e., all regions on the earth.

In fiscal year 1996, 9081 participants were accepted by JICA from 148 countries, and the total number of participants to date since the training program was launched is 122,000.

In this report, the author explains the technical training program mainly for the achievements of training of rice cultivation technology.

TECHNICAL TRAINING PROGRAM IN GENERAL

The program entails a wide range of participation and cooperation, such as the relevant ministries and research institutes, hospitals and enterprises which directly instruct participants. The program covers a very wide number of fields as its theme from rice cultivation to atomic power.

Efforts are being made to deal with various new development issues, especially environmental probrems of global significance, support for the new field of aid represented by the transition to a market economy and democratization, social welfare and Women in Development (WID).

In terms of the proportions of technical participants per region in 1996, as mentioned in Figure 1,48 % of them were from Asia, followed by 19.8 % from Latin America, 13.7 % from Africa, 9.7 % from the Middle East, 5 % from Europe, and 3.8 % from Oceania.

The major increases in numbers per region in recent years have been from Africa, Europe and Oceania.

With its aims of training participants from various countries, JICA achieved the acceptance of participants as described below according to different scheme of training in FY 1996.

* Tsukuba International Centre (TBIC), Japan International Cooperation Agency (JICA)

** Instructor of Rice Research Techniques Course, Japan International Cooperation, Centre (JICE)

1 .Group Training

The training curriculum is set beforehand and participants are recruited from unspecified countries.

570 courses,5,129 participants

2 .Individual Training

Training arranged on individual request. 1,773 participants.

3 .Third Country Training

Support for technical cooperation among developing countries and training is implemented at training organization in Third Countries;1,692 participants

4 .In-country Training

Support for the dissemination and establishment of technology in developing countries. Training is implemented at the training organization in the targeted countries for cooperation ; 10 courses, 490 participants

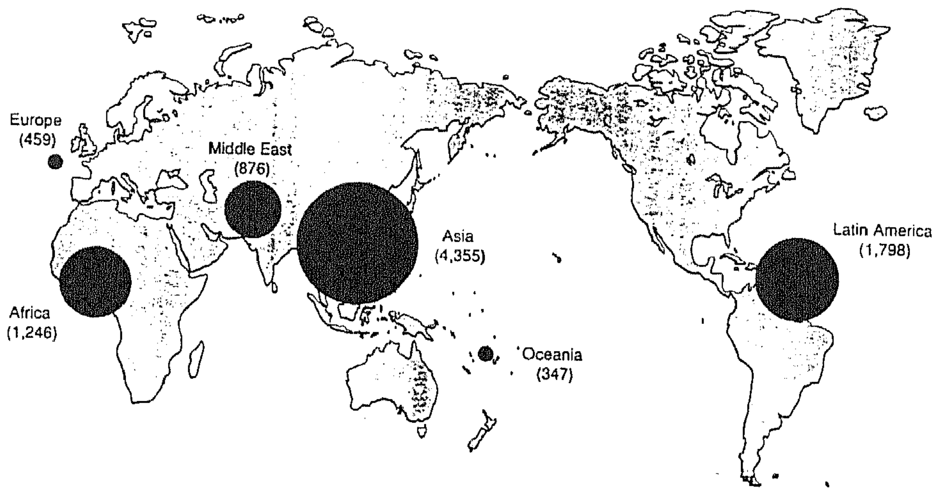


Figure 1 Technical Training Participants by Rigions

AGRICULTURE TRAINING IN JAPAN

Recently, agricultural training in Japan has been directed more to sustainable agricultural development. Typical subjects are biotechnology,alleviation of poverty, WID and environmental problems.

JICA has invited 14,558 participants for agricultural training sector since the training programs was started. The number accounts for 11.9 percent of the total. The yearly acceptances are around 900 to 1,000 participants.

This report introduced group training activities in agriculture which is important to the participants working for agriculture and rural development in their countries.

Table 1 Group training courses in the field of Agriculture (1998)

Training course	Number of Participants	Days	Institutios
1. Agricultural Cooperative II	16	62	The Institute for the Development of Agricultural Cooperation in Asia (IDACA)
2. Agricultural Extension Service for Leader II	12	67	Japan Agricultural Development and Extension Association
3. Vegetable Cultivation Technology for Extension	9	209	Tsukuba International Centre
4. Plant Genetic Resources	6	180	National Institute of Agricultural Resources ,Ministry of Agriculture, Forestry and Fisherries
5. Rice Research Techniques	6	279	Tsukuba International Centre
6. Vegetable Seed Production	9	286	Tsukuba International Centre
7. Effective Utilization of Tropical Agriculture and Forestry Resources	5	222	University of the Ryukyus
8. Women Leaders of Farm Household Development	12	75	Rural Women Empowerment and Life Improvement Association
9. Plant Quarantine (Disinfestation of Fruit Flies)	5	150	Naha Plant Protection Station, Ministry of Agriculture, Forestry and Fisheries
10.Soil Analysis and improvement	7	97	City of Obihiro
11.Agricultural & Rural Development with Environmental Consevation	15	79	Japanese Institute of Irrigation and Drainage
12.Distribution of Fresh Fruits and Vegetables	7	73	The Osaka Municipal central Wholesale Market
13.Integrated Pest Management for Plant Protection	7	105	Faculty of Agriculture, Kobe University
14.Statistical Information System for Agriculture	8	73	Statistics and Information Department, Ministry of Agriculture Forestry and Fisheries
15.Introductory Gene Manipulation for Agriculture	8	126	College of Agriculture, Osaka University Prefecture
16.OISCA Farmers Development	24	334	The Organization for Industrial
17.Farming Technology in Sloping Areas for Environmental Conservation	5	55	Hiroshima Prefectural Agriculture Research Center

Training course	Number of Participants	Days	Institutios
18.Horticulture in Protected Environment	5	91	College of Agriculture, Osaka University Prefecture
19.Rice Cultivation (Middle Eastern & African Countries)	9	244	Tsukuba International Centre
20.Integrated Agricultural and Rural Development Through the Participation of Local Farmers	10	41	Japan Agricultural Land Development Agency
21.Agriculture related Information Processing	8	89	Fujitsu Higashi-Hokkaido Systems Engineering Limited
22.Seed Production of Upland Crops	7	106	Tokachi Station National Center for Seeds and Seedings
23.Upland Farming Management and Research	10	61	City of Obihiro
24.Crops Cultivation is Sub-Tropical Area	5	158	Okinawa Prefectural Agricultural Experiment Station
25.NGO-JICA partnership Training Course for Rural Development	10	31	Kansai NGO Council
26.Agricultural and Rural Development (Revitalization of Rural Areas)	5	81	City of Obihiro
27.Food processing Preservation Technology	7	75	Hiroshima Prefectural Food Technology Research Centre

TRAINING OF RICE CULTIVATION TECHNOLOGY

Japan has a 2000-year history of rice production, and has achived a stable high yield over 6.5 tons per hectors through the efforts made by both public and private sectors in the development of cultural techniques such as varietal improvement, crop management, plant protection and so forth as well as improvement of the production environments such as land consolidation, irrigation and drainage, facilities, mechanization, agricultural cooperative and extension service.

Learning this kind of experiences of Japan in rice cultivation technology, JICA has been assisting the development and modification of its own techniques of rice cultivation technology and of extension system which are suitable to the socio-economic and natural conditions of the participating countries. And JICA contributes with three technical training courses of rice cultivation,which are conducted by Tsukuba International Centre (TBIC), they are "Rice Research Techniques" , "Rice Cultivation" and "Rice Production in French" .

Rice Research Techniques course is prepared for those young researchers while the Rice Cultivation and Rice Production(French) are prepared for those agricultural extension leaders . The objectives of each course are as described in figure.2.

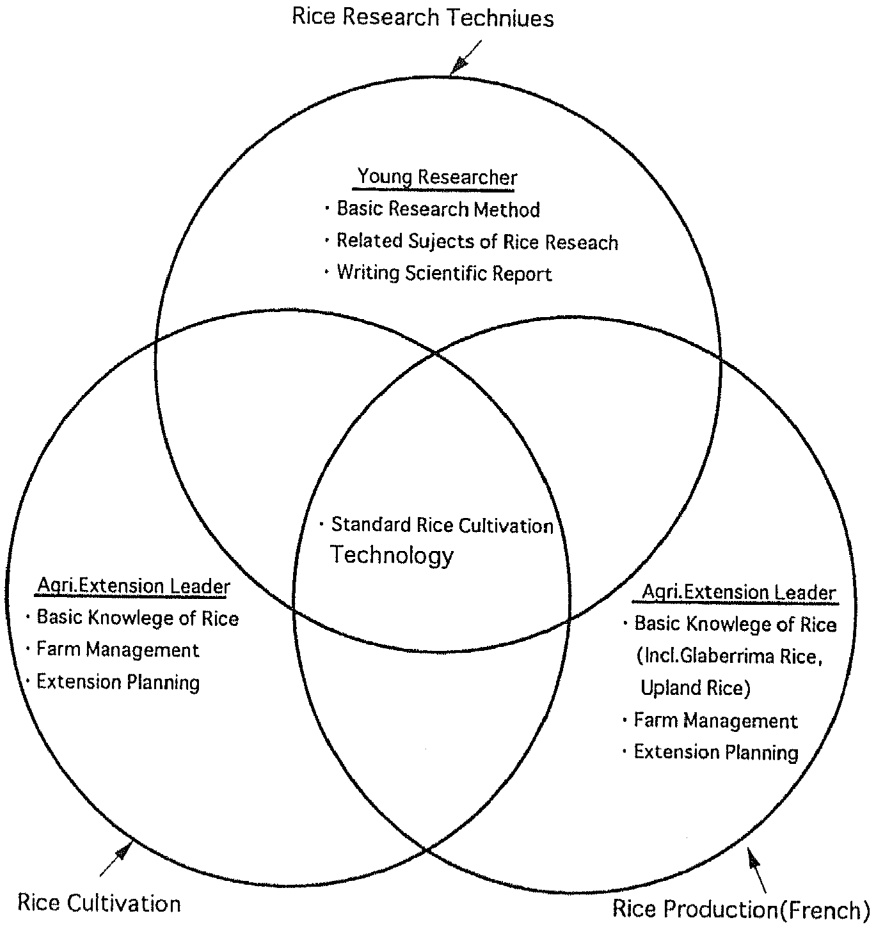


Figure 2 Main Objective of Three Rice Courses

The transition of the above-mentioned three courses are as follows.

1961; Uchihara International Agriculture Training Centre (UIATC) started "Agriculture Training Course" .

1964; The Course was renamed "Rice Cultivation and its Extension Course" .

1979; It was renamed "Rice Cultivation Course" .

1981; The training centre was shifted from Uchihara to Tsukuba. Uchihara International Agriculture Training Centre was renamed Tsukuba International Agriculture Training Centre

(TIATC).

1984; The course was divided into two; "Rice Cultivation(Advanced)Course" and "Rice Cultivation (General) Course" .Rice Cultivation (Advanced) Course aims at researchers and those who are related to education. Rice Cultivation (General) Course is purposed for those working in the field of agriculture extension.

1988; The "Rice Cultivation (Advanced) Course" was renamed "Rice Cultivation Technology Course" and "Rice Production Course" .Besides these two courses, "Rice Production in French " started this year, aiming at the participants from West Africa.

1996; "Rice Cultivation Technology Course" was renamed "Rice Research Techniques Course" and "Rice Production Course" was renamed, "Rice Cultivation Course" .

1996; Tsukuba International Agriculture Training Centre and Tsukuba International Centre have amalgamated and renamed, "Tsukuba International Centre" .

Since the establishment of agriculture course at UIATC in 1961, a total of 655 participants were accepted. Out of the total number, "Rice Research Techniques Course" so far accepted 125 participants from 28 countries, "Rice Cultivation Course" , 456 participants from 52 countries and " Rice Production Course in French" , 74 participants from 18 countries.

The Centre has undergone reformation in these years. It usually accepted around 100 participants yearly, including those courses. However, the number of participants became more than six times, around 600, since acceptance of individual participants in the field of agriculture was transferred from JICA Head Office to the Centre from April, 1994.

After the transition of the training centre from Uchihara to Tsukuba in 1981, the training courses have been conducted in cooperation with the national research institutes of MAFF such as Agricultural Research Centre, Tsukuba University, Regional Extension Centers, Agricultural Cooperative Associations, Rice Producing Farmers and others.

Tsukuba is the centre of agriculture research institutes, which makes it easy for us to do some arrangements of lectures and observations of related organizations. Therefore, we are much benefited in obtaining good outcome compared to the previous years.

At UIATC, JICA staff made the training schedule, managed the training courses and did technical training for the participants. After coming to Tsukuba, JICA staff, technical advisors, instructors, and coordinators are all together involved in training. At present three JICA staff, three technical advisors, five instructors and a French-speaking coordinator manage the courses and work for technical transfer.

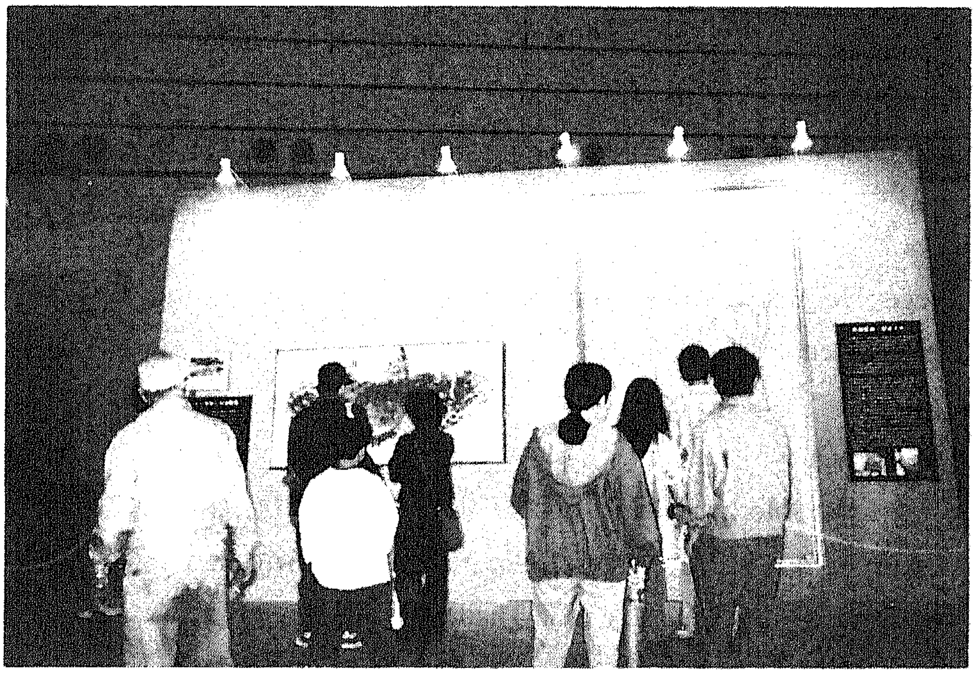
At present, instructors conduct training, which was done by JICA staff before.JICA staff do administrative work including training budget, while technical advisors, following to the plan, give guidance and advice as well as lecture and experiments.

The Centre publishes the outcome of training in scientific journals, since it is important to give information on technical training to the related staff and organizations. One example is a Chinese participants in 1991, who participated in Rice Cultivation Technology Course. The results of this experiments were published in Japan Breeding Journal under the title of " Response of Genetic Variability of Quantitative Characters of Nitrogen Levels in Rice" . Two participants from Bangladesh and Indonesia, who participated in the same course in 1995, published their experiments in Annals of the Phytopathological Society in Japan under the title of "Nonrandom Association of Avirulence Loci in Four Disease Resistance Gene System" .

There are some other activities of participants. The Rice Production Course participants took part in International Exhibition held at SENBOKU Town, AKITA Prefecture In October, 1992. They contributed to International Cultural Exchange with the town peoples. They exhibited "FLOATING RICE " originated in Bangladesh grown at TIATC by themselves and also exhibited the same floating rice at JAPAN EXPO IN MIYAGI '97 which was held in Sendai City ,Miyagi prefecture and intoroduced its ecology,quite new to the people.

They have also participated in the Intarnatiol Symposium organaized by Japan International Research Center and the Crop Science Society of Japan on Food Production Technology ,World Food Security and other Topics almost every year,in order to exchange achievements of research activities in different countries .

The participants experience home-stay in NIIGATA , AKITA and YAMAGATA prefectures every year, which is helpful for both participants and the town people to have cultural exchange.



Picture 1 At "JAPAN EXPO IN MINAGI' 97

Above are the activities of three rice courses. Though, the rice production (French) course has terminated successfully this year by eleven years cooperation with seventy four (74) technical participants accepted from West Africa. I would expect all the ex-participants for their active in respective countries and also greatly appreciate those who concerned of Agriculture Research Institutes in Tsukuba, Tsukuba University and other organizations all over Japan.

WORLD RICE PRODUCTION AND ACCEPTANCE OF PARTICIPANTS FROM BANGLADESH AND THAILAND

Figure 3, shows the regional distribution of the total Ex-participants of 665 for three courses of rice cultivation. According to this Figure, Asia account for 56% of all Ex-participants, Africa 25%, and Latin America 8.2%. The major increases in numbers per rigion in recent years from Africa.

The Ex-participants were mainly from Experimental Station,Extension Office,JICA's Project Type Technical Cooperation and Counterparts of Individual Experts.

Figure 4,shows the comparison between rice production in Developing Countries,based on FAO data by 1994,and accepted participants for the three courses of rice cultivation by JICA from 1961 to 1997. World rice production renged from 510 million to 530 million tons. Among this production, China contributed 34% (180 m.t.) of total World production, while India 23% (120 m.t.), Indonesia 9% (46 m.t.), Bangladesh 5% (27 m.t.) and Thailand 3% (18 m.t.) respectively. About the region on rice production, Asia as a whole contributes 92% of the World's rice harvest.

Figure 5,shows the achievements of accepted participants from Bangladesh in the field of agriculture under the jurisdiction of TBIC. This indicates that 18 participants for Vegetable Production, 12 for Vegetable Seed Production and 10 for Irrigation & Drainage. Therefore, it recognized that Vegetable Production, Irrigation & Drainage are more important than the other fields for agricultural development in Bangladesh.

Figure 6,shows the achievements of accepted participants from Thailand. 32 participants for Rice Cultivation, 29 for Farm Mechanization, 22 for Farm Machinery Design, 21 for Irrigation & Drainage. According to this achievements, Rice cultivation, Irrigation & Drainage and Farm Mechanization are the most important subjects in Thailand.

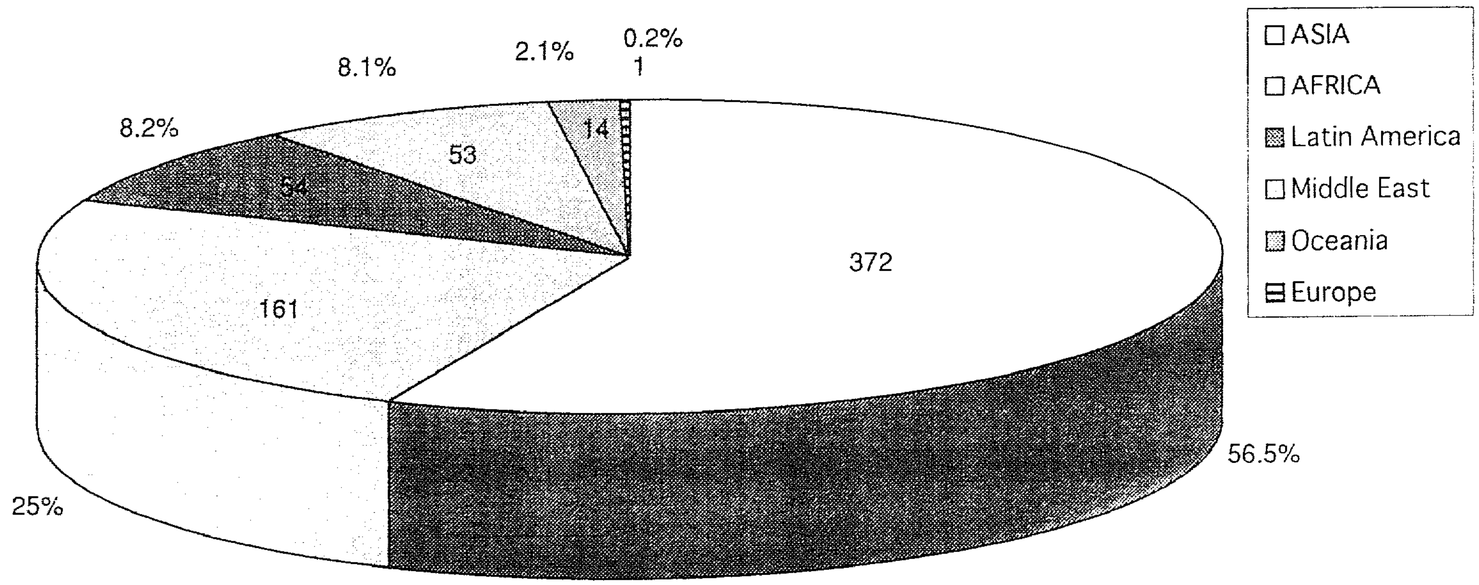


Figure3 Regional Distribution of the Ex-participants for Three RIce Courses

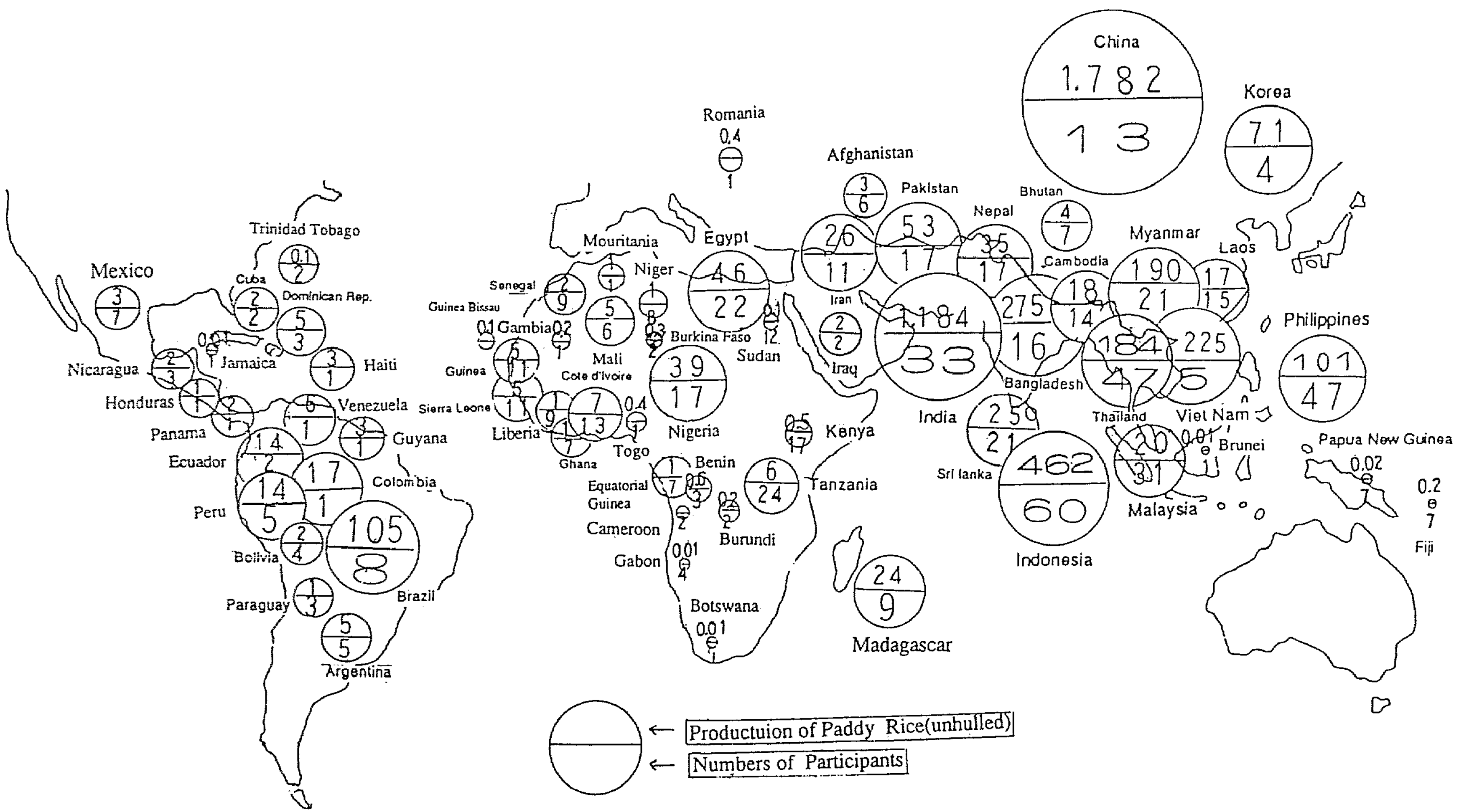


Figure4 Production of Paddy Rice and Acceted Participants in Japan from 1961-1997

Figure 5 Participants Accepted from Bangladesh

—1961～1997—

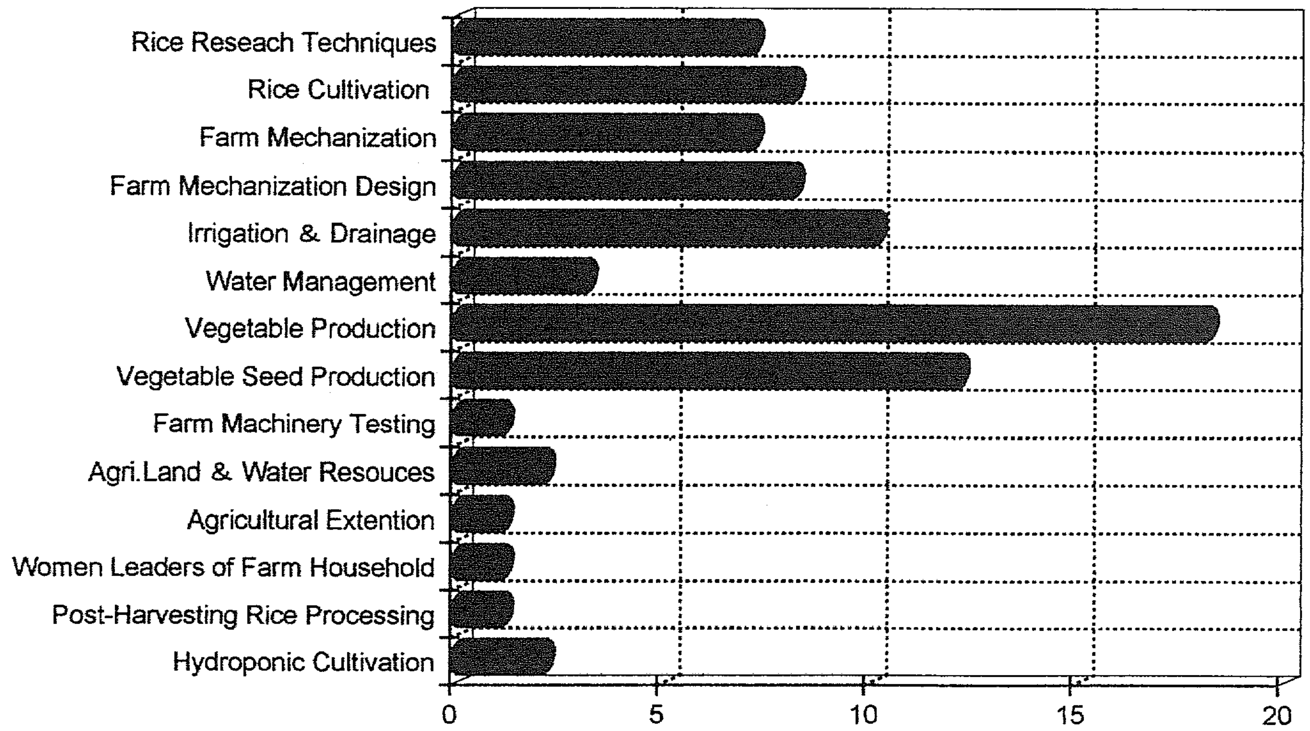
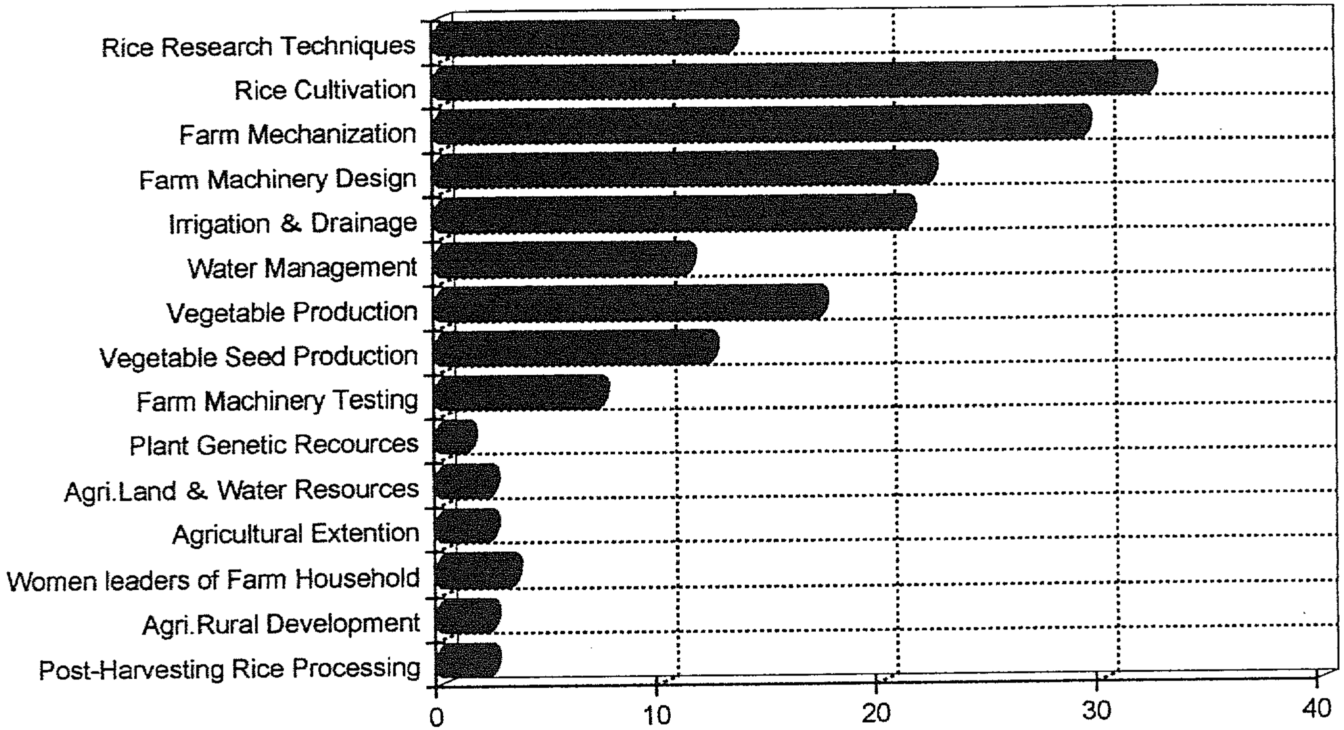


Figure 6 Participants Accepted from Thailand

—1961—1997—



Recent Accomplishments in Rice Research in Japan

Masao YOKOO
Institute of Agriculture and Forestry
University of Tsukuba
Tennodai 1-1-1, Tsukuba, Ibaraki 305-8572 JAPAN

I. Introduction

1. Japan celebrated its centennial year of organized scientific research on modern agricultural technology in 1993, and was proud of doubled increase of rice yield per unit area during these 100 years. By the second half of the 1960s, rice production exceeded its domestic consumption and the complete self-sufficiency of rice was achieved for the first time in the country's long history of rice production. Since then, the country's per caput rice consumption has decreased, and about one fourth of paddy fields have had to be used for non-rice crops or left uncultivated (Fig. 1).

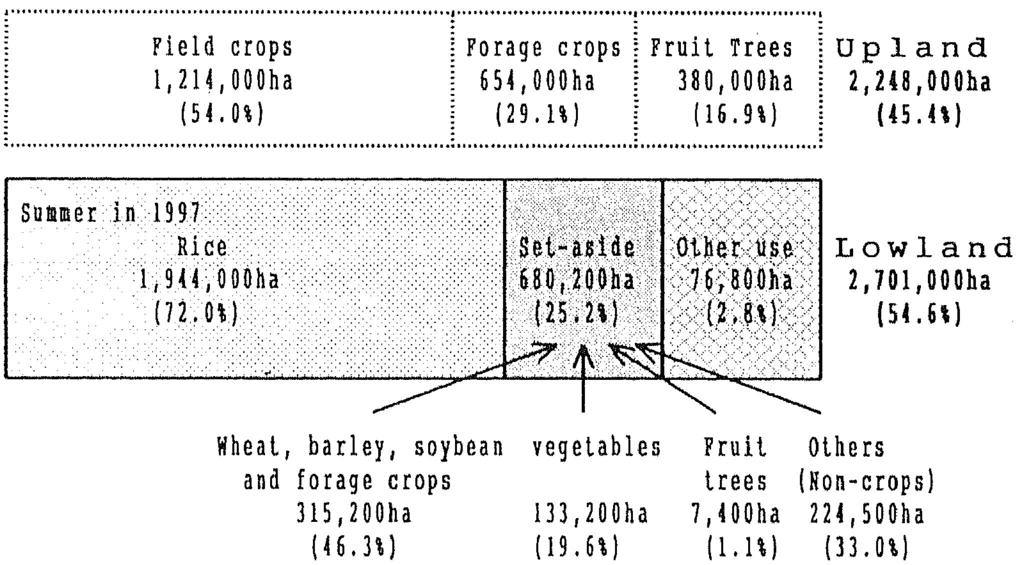


Fig. 1. The arable land in Japan

2. Rice production in 1993 suffered from severe damages due to the extraordinarily low temperature which prevailed during the whole rice-growing season and the incidence of blast disease. Consequently, Japan imported 2.55 million tonnes of rice from Australia, China, Thailand and the United States of America. Rice crops since 1994 have become better than in 1993 and rice growers faced the set-aside plan in one third of 2,700,000ha lowland fields. Moreover, they met also the minimum market access of importing 379,000 tonnes of milled rice in 1995 increasing to 758,000 tonnes by the year 2000 as a result of the General Agreement of Tariffs and Trade (GATT) Uruguay Round Agreement on Agriculture. Under these circumstances, research and development on rice production are searching for maintaining 2700,000ha lowland fields from the standpoint of sustainable rice production and environmental conservation for both rice growers and consumers.

3. During these three decades, breeders have focused their research efforts on developing new cultivars with various qualities of crops while raising yielding ability of cultivars. The following recent achievements of breeding for quality rice will meet the demands from consumers and growers in the near future.

II. Rice Genome Research and Genetic Transformation

1. More recently, DNA markers such as RFLP (Restriction Fragment Length Polymorphism) and RAPD (Random Amplified Polymorphic DNAs) have been used to detect DNA polymorphism.

2. The DNA markers densely mapped on the linkage maps are powerful tools for precise analysis of genotypes of rice plants. A DNA linkage map was developed consisting of about 1,400 DNA markers along about 1,500cM over 12 rice chromosomes from an intraspecific cross of *Oryza sativa* in 1994. Since then, the Rice Genome Research Program in Japan has added markers along 12 chromosomes, totaling nearly 2300 DNA markers covering 1500cM of genetic distance on the RFLP linkage

map in 1998 (Fig. 2).

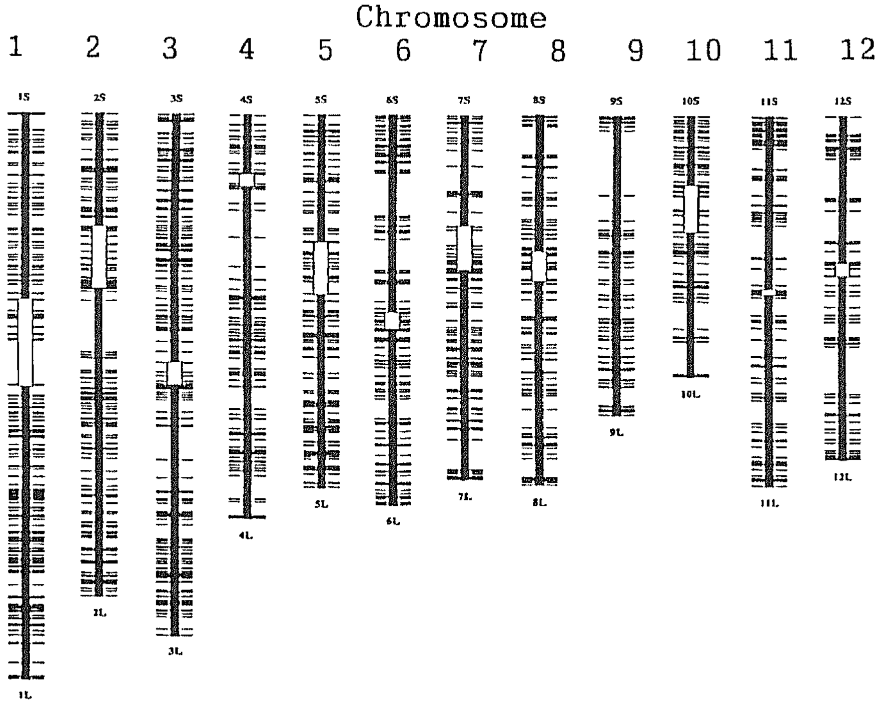


Fig. 2. A high-density rice genetic linkage map with 2275 markers.

3. Genome researches support the precise analysis of qualitative and quantitative trait loci on chromosomes and the marker-aided selection of desirable traits in breeding. The RFLP linkage map also helps to locate the genes definitely on the particular chromosomes, which were so far identified from the classical genetics. Some genes controlling morphological and physiological traits have been located on the RFLP linkage map.

4. The map is promising especially for locating and selecting quantitatively inherited traits that are controlled by multiple genes with smaller effects each. In the practical rice breeding, desirable recombinants for these quantitative traits are selected in later generations, but the possibility for obtaining favorable lines is low because the materials on hand become few in later generations after hybridization. The quantitative trait loci analysis on the RFLP linkage map will help rice breeding for identifying better recombinants in earlier generations of hybrid populations by RFLP types indirectly. The analyses and indirect selection for agronomically important quantitative traits have started in breeding

stations.

5. Currently, the following three methods of gene introduction in rice are reported to have been used among researchers. The first is the electroporation method which directly introduces foreign genes into protoplasts. The second is the biolistic (particle gun bombardment) method which directly introduces foreign genes into regenerable plant cells such as scutellum cells. The third is the improved Agrobacterium-mediated method which has been initiated a few years ago.

6. Selection markers constitute genes for resistance to antibiotics. Kanamycin was used in early stages, but most of the recent successful results of rice transformation have been using hygromycin and geneticin.

7. The target genes of agronomically or industrially important traits recently transformed include disease and insect resistance, herbicide tolerance, specific grain quality and a factor for photosynthesis (Table 1).

Table 1. Transformed rices under cultivation trials

Gene	Line	Test year in Greenhouse		Field	
		Closed	Open	Isolated	Open
Coat protein gene of rice stripe virus	A	1990	1992	1993	1994
	B	1990	1992	1996	1997
	C	1990	1992	1996	1997
Gene for bialaphos resistance	A	1997	1997	1998	
Antisense of allergen gene	A	1992	1993	1994	1995
Antisense of glutelin gene	A	1991	1993	1994	
	B	1994	1995	1997	1998
	C	1994	1995	1997	1998

III. Multiline Cultivars of Rice for Blast Disease Control

1. A first multiline cultivar of rice was released in 1995 to rice growers in Miyaghi Prefecture to control blast disease, which causes severe damages through whole growing stages of rice plants. The planting area of the multiline cultivar is limited to that prefecture and estimated to be 6,000ha in 1998.

2. A multiline cultivar is composed of several isogenic lines which have different resistance genes but resemble each other for main agronomic characteristics. The concept of multiline cultivar for disease control has been well studied in oats and oat crown rust in Iowa State University, U. S. A. in the 1960s and 70s (Fig. 3).

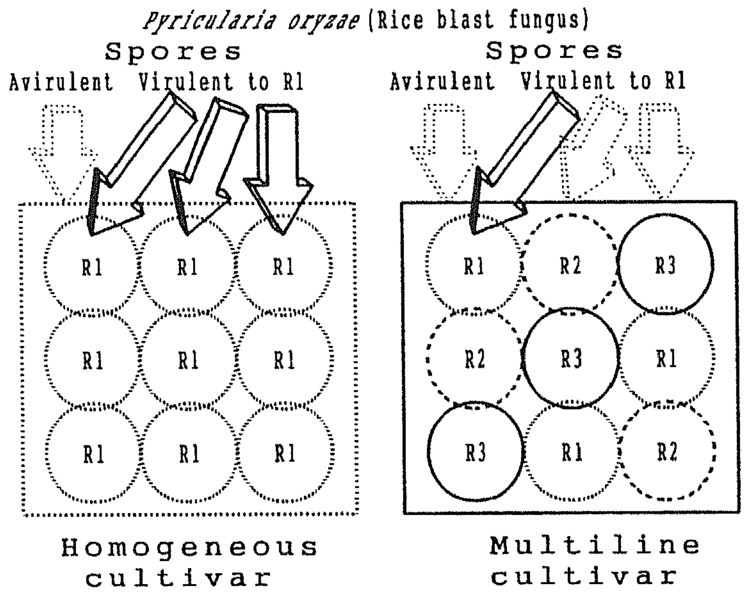


Fig. 3. Concept of a multiline cultivar

3. The multiline cultivar Sasanishiki BL for the 1997 production is composed of four isogenic lines which were developed by five to eight backcrossings with a well adapted leading cultivar Sasanishiki as the recurrent parent (Table 2). Four effective resistance genes involved in Sasanishiki BL are Pi-k, Pi-k^m, Pi-z and Pi-z^t, although Sasanishiki and its isogenic lines commonly have a Pi-a gene which is not effective to prevailing fungus races of *Pyricularia oryzae* in the country. The multiline cultivar does not involve seeds of Sasanishiki. Sasanishiki, a very susceptible cultivar, has attracted

rice growers and consumers for a long time, because of its high yield and better grain quality. Sasanishiki was grown for the first time in 1960 and its planted area was 207,438ha in 1990, but since then the area was decreased and is 30,000ha at present.

Table 2. Isogenic lines for blast disease resistance with the genetic background of Sasanishiki, developed in Miyaghi-Furukawa Agricultural Experiment Station

Isogenic line	Resistance gene	Number of backcrosses
Tohoku IL 1	+	6
Tohoku IL 2	Pi-i	5
Tohoku IL 3	Pi-k	6
Tohoku IL 4	Pi-k^{m}	5
Tohoku IL 5	Pi-z	6
Tohoku IL 6	Pi-ta	8
Tohoku IL 7	Pi-ta^{2}	6
Tohoku IL 8	Pi-z^{t}	5
Tohoku IL 9	Pi-b	6

All the lines have a Pi-a gene for resistance.

4. Races of *Pyricularia oryzae* on Sasanishiki BL plants are monitored by plant pathologists each year. Some virulent races were isolated from lesions of leaf blast and neck blast in the 1996 field.

Based on the of race survey, the composition of isogenic lines in Sasanishiki BL will be changed. Sasanishiki BL for the 1996 production had seeds of 30% for Pi-k, 30% for Pi-k^{m} and 40% for Pi-z, but for the 1997 and 1998 production a Pi-z^{t} gene was added and the seed composition was 10% for Pi-k, 10% for Pi-k^{m}, 40% for Pi-z and 40% for Pi-z^{t} (Table 3). Other isogenic lines with Pi-ta, Pi-ta^{2}, or Pi-b gene will be incorporated into Sasanishiki BL to raise the level of resistance to blast disease.

Table 3. Composition of isogenic lines in a multiline cultivar Sasanishiki BL

Year	Proportion of genes			
	Pi-k	Pi-k^{m}	Pi-z	Pi-z^{t}
1996	30%	30%	40%	–
1997	10%	10%	40%	40%
1998	10%	10%	40%	40%

5. Seeds of isogenic lines are mixed and multiplied for two generations by seed producers prior to the use of certified seed for rice growers. Rice growers are urged to renew their planting seeds every year for maintaining the favorable resistance level that is suggested by the Prefectural Rice Production Board.

6. The Board suggests rice growers not to apply any fungicides for leaf blast but to apply it for neck blast only once if necessary. Usually growers spray fungicides several times to the original cultivar Sasanishiki to prevent blast disease even when the occurrence of blast is less. With minimum fungicide use, rice growers can sell the Sasanishiki BL rice as for less-fungicide-applied rice to special consumers more advantageously than the Sasanishiki rice with more fungicide sprays.

7. Rice breeders in other experiment stations are developing isogenic lines to introduce different blast resistance genes into the genetic backgrounds of such leading cultivars as Hitomebore, Koshihikari, Hinohikari and others by backcross breeding.

8. Resistance genes in a multiline cultivar react for reducing the first-inoculum density of virulent races coming from the outside of the cultivar, depressing the second infection due to virulent races within a cultivar, and inducing internal resistance after infected with avirulent races.

9. However, there are several problems in rice multiline cultivars for blast disease control. Firstly, the genetic resources for blast resistance are narrow and only 13 resistance genes are effective to prevailing races, and all of them have once lost their effectiveness for resistance due to the natural occurrence of virulent races in farmers' and experimental fields. Secondly, leading cultivars have a relatively short span after released. Breeders should select appropriate recurrent parents for developing isogenic lines for a possibly short period by foreseeing the trend of needs from growers and consumers.

IV. Very Low Amylose Rice

1. Temperate Japonica rice is widely distributed in higher latitudes of the world. This ecological group of rice has two types of grain starch composition, waxy or glutinous and non-waxy or non-glutinous, and most non-glutinous Japonica rice cultivars are of low amylose, when amylose contents of rice grains classified into waxy (0-5%), very low (5-12%), low (12-20%), medium (20-25%) and high (over 25%) (Fig. 4). People of temperate regions like low amylose rice and cleverly utilize the stickiness and softness of cooked rice for various foods. Very low amylose rices were found to have the intermediate physico-chemical characteristics between waxy and low amylose rices. The distribution of very low amylose cultivars was limited to Laos, Myanmar and adjacent areas.

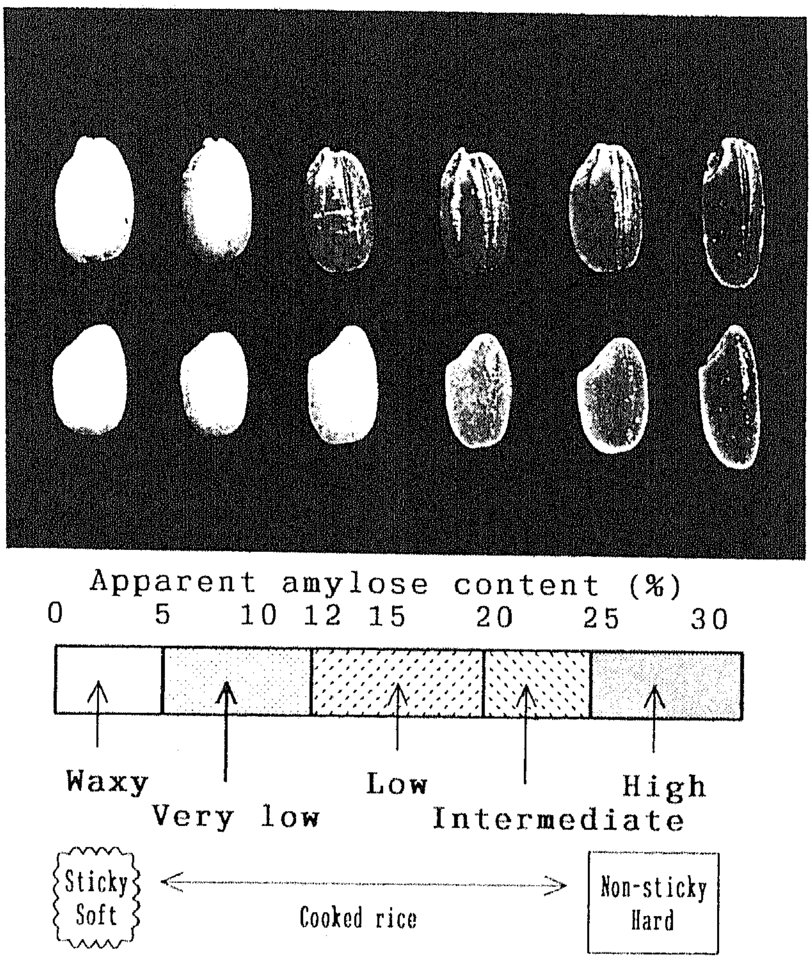


Fig. 4. Classification of milled rice according to the amylose content

2. Breeders have made their efforts to develop cultivars of very low amylose with an emphasis on the stickiness and softness of cooked rice after the 1980's.

3. The first cultivar "Aya" of very low amylose was developed in 1987 in Hokkaido. In the northernmost Japan the low temperature during the rice ripening period tends to make the amylose content in rice grains higher than in the mainland Japan. The amylose content of Aya's grains is 15%, being 7% lower than that of leading cultivars. Aya's very low amylose was originated from a mutation by gamma-irradiation.

4. Waxy or non-waxy character of rice grains is decided by the genotypes for a wx locus in Chromosome 6. Homozygous wx/wx plants produce waxy grains, while Wx^a and Wx^b genes control low and high amylose contents, respectively. Recent researches on rice endosperm starch revealed there are several dull genes controlling very low amylose content. Plants with homozygous dull genes produce dull or opaque grains in appearance, while ordinary low- to high-amylose plants have translucent grains. Aya's very low amylose is controlled by one of these dull genes.

5. A new cultivar "Hanabusa", which inherited the very low amylose type from Aya but is higher cold-tolerant and more yielding than Aya, was developed in 1998, and will be grown to replace Aya within a few years.

Table 4. Texturometer hardness and adhesiveness of cooked rice of the two very-low-amylose cultivars

Cultivar	Amylose (%)	Texturometer property Hardness (H)	Adhesiveness (-H)	H/(-H)
Aya	12.4	3.47	2.29	1.52
Kirara 397	20.8	3.84	1.55	2.48
Milky Queen	11.3	3.08	2.44	1.26
Koshihikari	18.4	3.86	1.95	1.98

6. Koshihikari is a leading cultivar widely planted to about 30% of the total two million hectares of paddy fields in Japan. Soft and sticky cooked rice of Koshihikari attracts almost all the consumers and then growers. A new and very low amylose cultivar "Milky Queen" was developed in 1995, that was a mutation from Koshihikari whose spikelet flowers were treated with MNU (methyl-nitroso-urea). The amylose content of Milky Queen grains is 12%, being 6% lower than that of Koshihikari. The very low amylose of Milky Queen is possibly controlled by a dull gene, but the gene was not identified yet. Since most agronomic characteristics of Milky Queen are similar to those of Koshihikari except for dull grains, rice growers acquainted with Koshihikari growing can easily grow Milky Queen also.

7. Cooked rice of very low amylose cultivars such as Milky Queen is much more sticky and softer than ordinary low amylose rices (Table 4), and keeps this characteristics for a longer time even when cooled or refrigerated. It attracts not only general consumers but also rice- based industries for foods such as rice box lunch, retort-sterilized rice, asceptic-cooked and packed rice, alpha-starch dried rice flakes, etc. Very low amylose rice will be also blended with much less sticky and hard cooked rice for improving the taste of other cultivars.