1983 RICE GERMPLASM CONSERVATION WORKSHOP

THE INTERNATIONAL RICE RESEARCH INSTITUTE
and
THE INTERNATIONAL BOARD FOR PLANT GENETIC RESOURCES

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1983
INTERNATIONAL RICE RESEARCH INSTITUTE
LOS BAÑOS, LAGUNA, PHILIPPINES
P.O. BOX 933, MANILA, PHILIPPINES

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of 13 nonprofit international research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 50 donor countries, International and regional organizations, and private foundations.

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ISBN 971-104-115-4

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FOREWORD

Crop genetic resources constitute an important human heritage. As such, they should be conserved and made available without restriction to crop scientists of all nations. Every crop researcher should be conscious of his professional as well as social responsibility to contribute to the mission of assembling and preserving the global genetic resources of crops and their wild relatives.

Rice workers of many nations have played an active role in collecting and conserving their indigenous rice germplasm since the 1930s or even earlier. The exchange and cooperative use of rice germplasm are unique examples of the power and value of cooperative endeavor.

The extensive collection activities on a worldwide basis since 1971 were assisted by planning sessions during the 1971 Rice Breeding Symposium and the 1977 Rice Germplasm Conservation Workshop. A total of 36,000 seed samples collected in Asian countries and about 3,700 in Africa were added to the national, regional, and international collections. The coverage is far from complete, however, and a concerted effort to save the remaining resources from the threats of replacement or extinction is urgently required.

Both the International Rice Research Institute (IRRI) and the International Board for Plant Genetic Resources (IBPGR) are concerned with revitalizing the collection activities toward completion of the conservation of diverse rice germplasm. This second Workshop, held at IRRI 25-26 April 1983, represents another joint venture of IRRI and IBPGR. It is hoped that the discussions and planning session of this Workshop will lead to our achieving the goal of preserving for posterity the fruits of evolution in rice since the Gondwana period.

The Workshop was organized by Dr. T. T. Chang, head of the International Rice Germplasm Center (IRGC) at IRRI, in consultation with officers of the IBPGR Secretariat. Sixty participants came from 19 national programs and universities, 7 international centers, one regional center, and the Food and Agriculture Organization (FAO). Assistance from the IRGC staff enabled the programs of the Workshop to be completed despite the tight schedule. Mr. Roy Denton and Dr. Chang performed the technical editing of the proceedings. Mrs. Gloria S. Argosino did the final editing.

M. S. Swaminathan
Director-General

OPENING REMARKS

M. S. SWAMINATHAN

I welcome all participants on behalf of my colleagues at IRRI. The fact that all those invited are here is a good index of your strong commitment to the exceptional cause of rice germplasm genetic conservation.

I extend a special welcome to Dr. L. Kåhre, chairman of the International Board for Plant Genetic Resources (IBPGR), both for his presence at the workshop and on his first visit to IRRI. Dr. Kåhre is successor to the first chairman of IBPGR, Mr. R. H. Demuth.

Within the past 8 years, IBPGR has evolved into an internationally important organization. The Board's chairman and its members deserve our gratitude for devoting so much of their valuable time to IBPGR activities, particularly because, apart from the Executive Secretary and his Assistant, the members work in an honorary capacity.

It is also a pleasure to welcome the members of the IBPGR-IRRI Rice Advisory Committee, all of whom are present in recognition of this important occasion. The members are Professor E. H. Roberts and Drs. A. O. Abifarin, T. T. Chang, Yu-Shen Dong, T. H. Johnston, J. Kawakami, S. D. Sharma, and B. H Siwi.

You may recall that the last meeting of this kind was the workshop on the genetic conservation of rice held at IRRI in December 1977.

The 1977 workshop was organized to synchronize with the inauguration of the Rice Genetic Resources Laboratory at IRRI. That facility, now known as the N. C. Brady Laboratory, has been named after the former IRRI Director-General, Dr. Nyle C. Brady, in recognition of his contributions to bringing the Laboratory into existence. The heart of the ground floor of the Laboratory is the International Rice Germplasm Center, which houses the cold storage facilities and seed laboratories.

During the first workshop, a detailed strategy for the organized collection and conservation of rice germplasm was formulated and the first 5-year plan (1978-82) was developed. The workshop proceedings were published in 1978.

In the implementation of the first 5-year plan, 14 countries in Asia collected 13,400 distinct seed samples during 1978-82. IRRI itself received over 16,500 rice accessions during the same period.

The keen interest in depositing valuable rice germplasm for long-term storage at IRRI is so great that even today Dr. Yu-Shen Dong arrived at the workshop with 500 seed samples from China for safe deposition in the IRRI germplasm bank. Such interest in ensuring the security of collected material is greatly appreciated.

IRRI's direct participation in collecting germplasm from 1978 to early 1981 led to an assemblage of over 3,000 seed samples collected with the collaboration of scientists in Bangladesh, Indonesia, Sri Lanka, and the Philippines. IRRI has also enjoyed cooperation in collection not only with rice scientists, but with a wide range of interested personnel including missionaries, visiting professors, and anthropologists. In the Philippines, Dr. Hal Conklin, the noted anthropologist,

supplied IRRI with invaluable rice germplasm from Ifugao Province in northern Luzon.

In recent years, the IBPGR has also become involved in germplasm conservation. Since 1980, it has actively supported and stimulated national research programs in field collection and the establishment of medium- and long-term storage facilities. Certain governments have also collaborated in improving conservation facilities. The Government of Japan has assisted Thailand and other countries in establishing cold storage units. Thus, IBPGR and national governments have acted as catalysts in the conservation movement.

In early 1983, IBPGR sanctioned the position of a trained germplasm collector, Roy Denton, at IRRI to assist national governments in their conservation activities. We hope that participating countries will involve Mr. Denton in their national programs either to help in direct collection work or to assist in the holding of national training courses.

Now, of course, the collections themselves have no value unless they are properly grown, multiplied, classified, and finally, preserved for use today and in the future. One of the many advantages of multidisciplinary institutes such as IRRI and many national research programs is that, through the use of the Genetic Evaluation and Utilization (GEU) concept, the vast collection is subjected to screening for a large number of traits. The 38 traits analyzed under the GEU program at IRRI include pest and disease resistance, quality characters, tolerance for drought, salinity, alkalinity, and other soil problems. Through the GEU network, these collections are classified and documented and the data and seed material made freely available to international scientists.

As the first 5-year plan, and, hence, phase one, has been completed, it is time that we took stock of the existing situation before planning phase two. In this conference, we need to review and update the status of previously designated priority areas, and to work toward widening the genetic base of rice collections. The United Nations Environment Programme's report, "Ten years after Stockholm," published in 1982, assessed the world environmental situation since the Stockholm Conference on Human Environment in 1972. The section in the report that relates to genetic resources portrays a very alarming situation. In developing countries in particular, the destruction of natural habitats, such as the tropical rain forest ecosystems of Southeast Asia, is continuing at a rapid pace. Some of those tropical rain forest habitats have been important sources of resistance factors for rice. For example, the "Silent Valley" forest reserve area in the Kerala State of India has been an important source of resistance genes now incorporated into many Pattambi lines. The Assam hills in the northeastern Himalayas of India are another invaluable source of rice germplasm in the form of the well-known Assam Rice Collection (ARC).

The endangered natural habitats should therefore be a priority area for immediate collection, while at the same time public awareness of the need for preserving these areas in their pristine purity for the sake of posterity should be emphasized.

The modern rice cultivars have replaced innumerable traditional varieties in many areas; for example, more than 11 million hectares are now planted to IR36.

Collection and conservation of the threatened primitive varieties must continue to receive urgent attention if they are not to be irretrievably lost.

There is a growing interest in and pressure on developing new high-yield technologies for the more unfavorable rice-growing environments. So far, rice improvement has concentrated on the irrigated areas or assured-rainfall areas. However, members of the recent International Rice Research Conferences have tentatively accepted as a working formula the classification of rice-growing environments into 18 categories. The categories were identified by a special committee and are described in the paper "Terminologies for rice growing environments." The environments are classified into 5 major categories: irrigated, rainfed-lowland, deepwater, upland, and tidal wetlands. Each category is subclassified in more detail.

Consequently, we must now actively search for new genetic material to provide the genes required to breed varieties more suited to these ecologically handicapped environments.

I urge the members of the different working groups to provide guidance during the identification of the priority collection areas and the formulation of the second 5-year plan (1983-87). Three main points should receive emphasis:

1. Attempts should be made to collect more germplasm representing genetic diversity remaining in the genus *Oryza.* The challenge for us is: "Can we say at the end of the second 5-year plan, or even before that, that we have with us a reasonably good sampling of the variability in rice which is still existing in the world today?"

The mechanism through which such an objective would be achieved consists of three cooperating groups:

a. The professional scientists with expert knowledge of rice.
b. The important network of farmers and the general public. Generating cooperation within this large group is essential to a thorough collection. Many countries have developed their own methods. In China, for example, each provincial academy mobilizes local farmers of the production brigades to send in seeds of traditional varieties. Although some samples will be duplicated, the structure of such a system somewhat simplifies the professional's work and allows him to concentrate on classifying the material, identifying duplicates and distinct types, and so on.
c. The defense services. Some of the high priority collection areas or endangered habitats are also in either sensitive border zones or inaccessible regions. Therefore, the assistance of the defense services, who travel frequently to such areas, would be of great benefit in securing additional valuable germplasm. Special training programs for personnel of defense services may have to be organized for this purpose. I am prepared to contact various governments to seek such collaboration.

2. There is a need for a more organized network for seed rejuvenation and seed exchange. The constraints to seed rejuvenation at IRRI include ravages by diseases and insects, and the unsuitability of the environment for sufficient sped yield of many genotypes. The development of an international cooperative network would help resolve this problem. Furthermore, the mechanism of seed

exchange should be standardized by adopting the use of aluminum foil seed envelopes whenever possible.

3. The long-term storage and security of collections would benefit from certain modifications. The process of selecting and preparing seeds for canning for long-term storage is tedious and time-consuming and, even at IRRI, constitutes a holdup in the workflow of the gene bank. The canning process should therefore be examined and attempts made to accelerate it.

Whenever large centers of seed storage exist, it is always advisable, for purposes of long-term security, to have at least two, or preferably three, dual or multiple storage sites. The IRRI collection is duplicated at Fort Collins, Colorado, USA; seed is also exchanged between IRRI and the Tsukuba Center in Japan. We should remember that we are attempting to ensure the security of seed collections into the 21st and 22nd centuries, and beyond.

Let me share with you some recent developments in the IRRI germplasm center.

IRRI's commitment to the cause of rice genetic resources conservation is already obvious from its achievements so far. In support of this, the IRRI Board of Trustees at their recent meeting in March decided to specifically recognize the work of the Rice Genetic Resources Program by designating the IRRI germplasm center as the International Rice Germplasm Center (IRGC). The IRGC was declared a global research service with Dr. T. T. Chang as its head.

It was also decided to set up an IRGC Advisory Committee to provide guidance to the Center, particularly on priorities in collection and conservation, to advise on policy issues, and to monitor its progress. The IRGC will be responsible for producing its own annual report in which it will review progress and constraints and provide information on future activities in the field of rice germplasm conservation.

It is hoped that the establishment of the IRGC will encourage greater involvement of all groups working in rice genetic resources. I invite you to offer your advice on how to enhance the value of the IRGC to all cooperating countries.

I wish to reiterate IRRI's appreciation of the wholehearted support extended to us by the IBPGR, who cosponsored this workshop and sanctioned funds for the field collection activities. During 1983, the IRGC received additional funds: $75,000 from the Netherlands Government and $100,000 from The Rockefeller Foundation. Such assistance accentuates the general concern and involvement felt in this important cause.

A major objective of this workshop, therefore, should be to decide how to most effectively use existing funds for development of the collection, maintenance, and, in particular, utilization of rice genetic resources.

At a recent meeting of the FAO Council, of which I am at present the independent chairman, considerable concern was expressed about the future of plant germplasm collections. A resolution introduced by Mexico in 1981 proposed that the importance of large germplasm collections was such that they warranted a form of intergovernmental control. The resolution further advised that there should be a signed memorandum of understanding between governments for the free exchange of genetic materials.

The example illustrates two important points: first, that governments are concerned and recognize the importance of germplasm collections, and second, that governments are particularly concerned with the security of existing collections and their availability to member nations on an unrestricted basis.

As working scientists at this workshop, we should all be aware of the concern of governments in these matters as reflected by the United Nations and other bodies.

The essential message therefore is that, through the formulation of the second 5-year plan, we should strive to collect and conserve the material, ensure its long-term security in storage, and ensure freedom of exchange.

My good wishes again for the success of the workshop. I hope that it will prove to be a milestone, just as the first workshop in December 1977 was a landmark from which the excellent rice germplasm facility at IRRI was created and a more organized cooperative endeavor in rice germplasm collection and conservation was generated.

KEYNOTE ADDRESS

L. KÅHRE

I am extremely pleased to present a keynote address on behalf of the International Board for Plant Genetic Resources (IBPGR) at this Workshop on the Conservation of Rice Germplasm. This workshop is the second of a series; the first one was held in December 1977 here at IRRI.

At this point, I would like to express my personal gratitude and also that of my Board to Dr. Swaminathan and recognize his long-standing interest in genetic resources.

I am also taking this opportunity to offer my congratulations to IRRI for its recent awards — the first King Baudouin International Agricultural Research Award and the Third World Agricultural Prize, for outstanding work in IRRl's rice breeding program as illustrated by the development of IR36, a rice variety which is the most widely grown rice in Asia. The IBPGR is delighted to note in the citations of the awards that specific reference was made to IRRI's role in the collection and conservation of rice germplasm. The IBPGR has been closely linked with IRRI's genetic resources program and jointly, IBPGR and IRR1 established the Advisory Committee on Rice Germplasm. The Committee has held three meetings — 1976, 1978, and 1982 — and most members, past and present, are attending this workshop. It gives me pleasure to offer our sincere thanks to the dynamic chairman of the Committee, Dr. T. T. Chang, under whose leadership there have been significant achievements in collection, conservation, evaluation, and utilization of rice germplasm.

The Advisory Committee at its first meeting in April 1976 determined gaps in the existing collections and assigned priorities for collection. At the IRRI-IBPGR Workshop in December 1977, a 5-year plan was formulated under the leadership of IRRI and in close collaboration with a number of national programs, and regional, and international organizations. The plan of action included collection, multiplication and conservation aspects. The IBPGR at its fifth meeting in February 1978 was delighted that a carefully considered plan of action had been formulated and considered this to be a model for other crops.

After the workshop in 1977, IRRI accelerated its field collection activity in Asia and the IBPGR readily provided some financial support for this work in South and Southeast Asia. In Africa, IITA was active in collecting rice germplasm from 1976 to 1980; other organizations (IRAT, ORSTOM, and WARDA) have been collecting African rice during the past decade. From the outset, the IBPGR has coordinated this work and provided funds to IRAT, ORSTOM, and IITA for their collection activities.

Since 1980, the IBPGR Secretariat staff have been directly involved in collection in many African countries, south of the Sahara.

The IBPGR has been in existence for 9 years. In accordance with its mandate, a worldwide network of genetic resources centers is being developed. Currently, this program embraces institutions in nearly 100 countries. Practical field work

has been carried out in 70 countries. To date, we have organized and/or supported about 250 collecting missions in all parts of the world. The work was carried out in close cooperation with participating national, regional, and international programs. These expeditions have collected about 100,000 new seed samples of the major food crops, and safe storage in gene banks has been arranged. In the IBPGR global network, 38 centers in 29 countries have already been designated for long-term storage of so-called base collections of 30 crops or groups of crops. Of these centers, 23 are in 18 developing countries. IRRI is an important center in this network.

During 1981, the Board refined its previously set priorities among crops and there is now a long list of species requiring action to safeguard germplasm for future use. The Board's priority crops, numbering about 50, cover all major food crops, vegetables, fruits, some cash crops important to rural development, and fuel wood species. A recent development includes work on clonally propagated species. In this area there is a need for further research and development on the technology of long-term conservation and the IBPGR in 1983 established a standing committee to advise on *in vitro* techniques.

The IBPGR program has grown from a modest beginning in 1974 to a worldwide effort during the recent past. The highlights of the progress made over the past year in various activities follow:

- The Board financed and executed 64 missions in 48 countries during 1982 and the total number of samples collected was about 9,500.
- In 1982, IBPGR employed 295 local scientists and 41 expatriate scientists to work in the field and to collect germplasm of 41 first-priority crops in 31 countries in 7 regions of the world, 28 second-priority crops in 35 countries in 6 regions, and 12 third-priority crops in 21 countries in 6 regions.
- To date, most of the 160 participants who have received postgraduate training at the University of Birmingham are from developing countries and received IBPGR-UNEP fellowships. In addition, 450 scientists from developing countries have been trained on short technical courses. In 1982 alone the IBPGR supported 12 short technical training courses.
- The Board has published 130 technical publications; 29 of which were issued in 1982. They include several reports of Working Groups, directories of crop germplasm, and descriptor lists.
- The Board has provided basic equipment for national gene banks of developing countries, and financial support to four countries for the establishment of collections of crops propagated by vegetative means.
- Technical assistance and the provision of hardware for documentation and information work have continued.
- Financial support has been provided toward the multiplication, characterization, and evaluation of plant collections in 26 countries.

At its meeting in February 1983, the Board agreed to expand its work on characterization and evaluation of existing germplasm collections.

Even though much progress on collection and conservation of rice germplasm has been reported during the last decade, especially through the efforts of IRRI in Asia, and IITA, IRAT, ORSTOPA, WARDA, and also IBPGR in Africa, some of

the gaps identified by the IRRI-IBPGR Rice Advisory Committee in 1976 seem to be unfilled. I urge the participants at this workshop to take stock of the present situation and suggest a clear action program. I wonder if we have enough ecogeographic information from the areas of diversity and if we have collected sufficient diversity from such localities? Most of the existing collections seem to be made from accessible areas and, therefore, remote areas should be given more attention.

The Advisory Committee at its third meeting placed emphasis on the collection of wild relatives of the cultivated species of *Oryza.* The IBPGR agrees that much greater emphasis on wild species is needed and I urge the workshop participants to consider this aspect.

There are about 200,000 accessions of rice in various gene banks or seed stores around the world. Many are duplicates. IRRI's gene bank currently holds about 63,000 accessions, but still lacks collections from some national programs, which need to be duplicated for safety.

We know that genetic erosion goes on in some gene banks. Before it is too late, appropriate measures should be taken.

We are immensely pleased to learn that in March 1983 the IRRI Board of Trustees established an International Rice Germplasm Center (IRGC) in place of the former Rice Genetic Resources Program, and that Dr. Chang has been appointed head of the Center. I would like to assure the Director General and the management of IRRI that the IBPGR will collaborate in this new program. Many of you know that the IBPGR has funded a post of rice collector here at IRRI. The international work on preservation and use of genetic resources will clearly continue to be a joint IRRI-IBPGR responsibility.

Furthermore, I wish to bring to your attention some other important matters: *First,* the size of collections. Accessions need to be fully characterized and, when possible, identified to gene symbols. Without characterization and evaluation, the total number of samples does not realy mean much.

Second, the larger a collection, the more the problems in handling it. Clearly, breeders are interested in pools of samples representing known patterns of variation including ecologies, breeding systems, and other attributes. This is something to aim for to ensure maximum utilization.

In conclusion, I would like to emphasize the philosophy of the IBPGR. We believe in and practice free and full availability of the germplasm and related information. In this endeavor, the IBPGR is collaborating with numerous centers within its global network. The principle of all this work is equal partnership.

Dr. Murthi Anishetty, assistant executive secretary of IBPGR, and I look forward to participating in this workshop.

We wish you all a successful meeting.

RICE GERMPLASM GENETIC CONSERVATION WORKSHOP • 25-26 APRIL 1983

IRRI, Los Baños, Laguna, Philippines

CONSERVATION OF HETEROGENEOUS RICE POPULATIONS

H. I. OKA

The populations of wild plants as well as of crop land races are genetically heterogeneous or polymorphic in varying degrees. On the strategy of seed sampling from such populations, excellent reviews have been presented by Marshall and Brown (1975) and Brown (1978). But the seed multiplication of population samples already collected seems to need some more consideration. This is the major object of discussion in this paper.

COLLECTOR'S SEED

Collectors take seeds from field populations by different methods according to their objectives. A collector usually selects the mother plants at random, but he may be interested in plants exhibiting a particular phenotype in some cases. His sample is a bulk in which seeds from a number of plants are put together, but when he is interested in within-population variation, his sample is a set of seed lots taken on a single-plant basis. The number of plants sampled from a population is 10 to 50 in many cases. In a germplasm bank, the collector's seeds are registered with data on field conditions and are maintained in cold storage.

The distribution of genes in an area is often localized and within-population diversity varies widely among populations (Brown 1978). When populations at different sites seem to be differentiated, sampling from as many populations in different environments as possible is recommended even if the sample size per population is thereby reduced (Marshall and Brown 1975). When populations are apparently polymorphic, larger samples from fewer populations are recommended for capturing rare genes. The sample size *(N)* necessary for restoring genes distributed in a population with a certain frequency *(p)* was discussed by Oka (1969, 1975). It is given by the probability of at least one success (*P;* Snedecor and Cochran 1980, p. 115). For instance, when $p = 0.05$, $P = 1 - (1 - 0.05)^N \geq 0.95$, then, $N = 59$.

REGENERATION OF POPULATION SEEDS OF RICE

The original seeds collected must be multiplied for regeneration and evaluation. When the populations are polymorphic, this operation is labor-consuming and is restricted by the availability of human labor and of space in the experimental field.

There are two seed multiplication methods: *pedigree* and *bulk.* When the original seed is in bulk, a bulk population is raised in the first generation of multiplication, and the seeds produced are harvested either in bulk or on a single plant basis (pedigree method). When the original seed consists of a number of samples each from a single plant, their progeny lines are raised separately (ear-to-row method)

and the seeds produced are harvested either on a single plant basis (pedigree method) or in bulk. Both methods can be applied to the same population simultaneously. Their possible profit and loss are compared in Table 1.

Which method is better would depend on the objective of the operation and characteristics of target populations. By the bulk method, the size of population for regeneration is assumed to be 60 plants. By the pedigree method, it depends on the number of mother plants sampled; tentatively, it is 20-60 lines.

EXPERIENCES WITH WILD RICE SPECIES

At the National Institute of Genetics, Misima, Japan, collection and maintenance of rice germplasm have been practiced since 1957. Emphasis is on wild relatives of cultivated rice species. Dr. Y. Sano is in charge of this operation. The seeds collected from mother populations in the fields, quite small in amount per population, are registered with collector's records, and are kept at –10°C with desiccating material. Some seeds are germinated in the season following collection, and the plants are grown for regeneration and research purposes. As the plants are grown in concrete beds with automatic short-day control, the space available for this work is quite limited (20 to 30 m^2/season).

Because of limited space, the bulk method has not been adopted. When within-population variation is ignored, a population is regarded as a strain and

Table 1. Comparison of *pedigree* and *bulk* methods of seed multiplication.

Criterion	Pedigree	Bulk
Objective envisaged	To establish a set of inbred lines representing the mother population	To establish a population genetically similar to the mother population
Major object of conservation	Within-population diversity	Between-population diversity
No. of populations manageable with limited human labor	Few	More
No. of plants per mother population included in regenerated population	Limited (by available labor)	More or less according to sampling
Size of regenerated population envisaged	20-60 lines, each with 5 plants	60 plants (or more)
Probability of detecting a particular gene/population	High	Lower
Rate of change of population genotype due to random drift	High	Lower
Rate of change of population genotype due to natural selection	Low	Higher[a]
Control of pollination for isolation	To be selfed by bagging	Isolation from neighboring plots
Suitability for populations	Highly polymorphic	Less polymorphic
Applicability of the system established for fixed cultivars	Applicable to some extent	A new system required

[a]When a population of wild rice contains genes of cultivated rice as the result of introgression, those genes rapidly increase in frequency if propagated in bulk (cf. Oka and Morishima 1971).

Table 2. Number and size of populations of wild rice species maintained at the National Institute of Genetics, Japan.

No. of populations collected (Acc. no.) K_o	No. of plants from which seed was collected in the field N_o	So. of plants raised per population, from which seed was obtained $N_1 \times \bar{n}_1$	Total no. of plants whose seeds are preserved $K_1 \times N_1 \times \bar{n}_1$
	Pedigree ($K_1 \leq K_o, N_1 \leq N_o, \bar{n}_1 < \bar{n}_o; \bar{n}_1 = 4$)		
30	> 30	about 120	about 3,600
17	20-29	100	1,700
55	10-19	50	2,800
	Bulk (or strain, ignoring within-population diversity; $N_1 < N_o$)[a]		
500	> 10	4	2,000
180	2-9	4	800
782			10,900

[a] Space for growing plants is limited, 20-30 m^2/year in concrete beds with automatic short-day control

represented by only 4 to 5 plants. From each plant, selfed seeds (by bagging) are harvested 10 produce inbred lines. When a study of within-population variation is necessary, a number of lines each represented by 4 to 5 plants are raised from a population, and selfed seeds are harvested from each plant. The number and size of populations of wild species so far regenerated and maintained in storage are summarized in Table 2.

A part of the inbred lines are raised repeatedly for research purposes, and the lines are represented by a number of seed lots from plants of different selfing generations. If not used for experiments, the first-generation seeds are kept in storage (about 0°C, moisture 7-8%) for 10 years or longer. The number of plants raised for regeneration per year is about 500. More than 10,000 seed lots of wild species are kept in the storage room.

The numbering system is as follows:

For collection on a single plant basis,

- Collector's seed — W123-1 (1 ~ n),
- First-generation multiplied seed — W123-1-1, etc.,
- Second-generation multiplied seed— W123-1-1-1, etc.

For collection in bulk,

- Collector's seed — W123-0 (0 is sometimes omitted),
- First-generation multiplied seed — W 123-0-1 (1 ~ n),
- Second-generation multiplied seed — W123-0-1-1, etc.

Although there are no precise data on the longevity of seed of wild *Oryza* species in storage, there is no evidence that their life is shorter than that of seeds of cultivars, if fully mature seed is put in storage. Fresh seeds are highly dormant; if they are kept in cold storage, dormancy is not overcome for years.

Major technical problems are encountered in this work. The first is bagging. Bagging is necessary for self-pollination (before flowering) and for collecting seeds which are shed at maturity. Bagging is made either on a single panicle basis (paper bag) or on a plant basis (nylon bag), and each bag is tied to a bamboo stick. Bagging of single panicles is laborious. Bagging of single plants is easier, but it is not

possible to put all panicles of a plant in a bag as the flowering period often exceeds two weeks in wild rice and the internodes elongate much around heading time. Bagging for self-pollination is much more tedious than that for collecting seeds. Many bags are necessary, but nylon bags can be used repeatedly.

Second, low seed productivity, particularly in highly perennial plants (1-2 g/plant, sometimes a few seeds only), is a problem. In this case, maintenance of living plants is useful. In general, shortage of human labor and space is an important problem in the operation.

REGENERATION OF VARIETAL POPULATIONS OF CROSS-POLLINATED CROPS

The varietal populations of cross-pollinated crops are highly heterogeneous genetically. Experiences have accumulated on the methods of stock-seed production in maize and other crops more or less cross-pollinated, but the present author is not aware of a published comprehensive review on the methods.

In maize, seed production aims at maintenance of heterozygosity and genes for superior performance. Pollination is either controlled or open. In the former, a population is divided into two parts: one part is detasseled and pollinated by the other, or a number of plants are selfed to produce inbred lines. In the latter case, a population is isolated from others by distance (300-500 m), and an equal number of seeds are taken from each ear (plant) to prepare a lot of bulked seed. In the field, plants showing deleterious characters are eliminated (mass selection), or the ear-to-row test is carried out to increase the frequency of superior genotypes. In the maintenance of land races and wild relatives of rice, however, maintenance of heterozygosity is not necessary and selection must be avoided.

The size of the population raised for stock-seed production in maize ranges from 20 to 400, with a mean of about 120 in Japan (Namai 1983), and 50 to 400 in the USA. For controlled pollination, the population is less than 100 plants. When inbred lines are raised, a population is usually represented by 30 lines. When plants are open-pollinated in an isolated field, the population size is greater than 200 plants.

In sorghum where the outcrossing rate is 4-5%, the population size ranges from 20 to 100 with a mean of about 50 (Namai 1983). Hybrid populations are produced by the use of genetic male sterility *(ms_3)* for gene maintenance and population improvement. In finger millet *(Eleusine coracana),* which is predominantly self-pollinated but the populations are heterogeneous, the population size is 10 to 100 plants (Namai 1983).

In cross-pollinated crops, isolation is an important requisite in seed production. It can be done by spatial distance, temporal separation (different flowering times), and by bagging. The necessary distance between neighboring populations is 300 to 500 m in maize as well as in ryegrass *(Lolium multiflorum)* grown in an open field (AOSCA 1973, p. 9-13), but it can be reduced if two plots are separated by forest or houses. It can also be reduced when a large population is raised and seed is taken from the central part only. In maize, a border row is considered equivalent to a 16-m distance (Matsuo 1974, p. 349-403). In rape and other insect-pollinated crops, 3 km is necessary if isolation depends on spatial distance only.

In cultivated rice and wheat, the required distance is 2.5 m; in soybean it is 20 m. The outcrossing rate of rice cultivars ranges from 0.1 to 6.8%, while that of the common wild rice *Oryza perennis* (= *O. rufipogon*) is about 10% for the annual type and 50% for the Asian perennial type (Oka and Morishima 1967). The distance necessary for isolation of wild rice populations, however, remains unknown but may be assumed to be 20 to 30 m. Whichever is better, bagging or spatial isolation, would depend on the conditions of field management.

GENETIC STRUCTURE OF RICE POPULATIONS

The degree of polymorphism or gene diversity is measured by the polymorphic index,

$$\mathrm{PI} = \frac{1}{m}\sum_j\sum_i x_{ij}(1-x_{ij})$$

(Allard et a1 1978), or by average gene diversity,

$$\mathrm{AGD} = \frac{1}{m}\sum_j(1 - \sum_i x_{ij}^2)$$

(Nei 1975), where x_{ij} is the frequency of allele *i* at locus *j* and *m* is the number of loci observed. These two statistics are equivalent since $S_{xi} = 1$, and both represent the variance of allele frequencies or potential heterozygosity. The fixation index,

$$\hat{F} = \frac{1}{m}\sum_j\left[1 - h_j/\sum_i x_{ij}(1 - x_{ij})\right]$$

where h_j is the observed frequency of heterozygotes at locus *j*, is a useful measure of homozygosity (Wright 1965).

Evaluation of gene diversity usually depends on data for isoenzymes, which are considered neutral in natural selection. The genetic variance of quantitative traits which are relatively nonplastic, like seed size, may also be used for evaluating genetic variation. Although genetic variance is not a direct measure of gene diversity (Marshall and Brown 1975), the isoenzymic and morphological variabilities are expected to be significantly correlated when different populations are compared (Marshall and Allard 1970).

From the frequencies of alleles for isozymes of peroxidase (PX), acid phosphatase (ACP), and phosphoglucose isomerase (PGI), polymorphic indices and fixation indices were estimated in various *O. perennis* populations (Dr. H. Morishima, in preparation). The mean estimates of these population parameters for the perennial, intermediate perennial-annual, and annual populations obtained from sites in Asia are given in Table 3. The perennial populations had much higher polymorphic index and heterozygote frequency, and much lower fixation index than annual populations. This is in close agreement with the higher heterogeneity in morphological traits of perennial than annual populations as reported by Morishima et a1 (1961) and Morishima and Oka (1970). The intermediate perennial-annual populations (classified on the basis of morphological pheno-

types) show an intermediate situation between the perennial and annual ones. Most probably, these differences are due to differences in breeding systems (Oka and Morishima 1967).

The relative magnitude of genetic variances within and between populations estimated on four quantitative traits are given in Table 4. As pointed out earlier by Morishima et al (1961), the data show that between-population diversity is much greater for populations of annual wild rice than for perennial populations. The G_{ST}, values in Table 3 indicate the same trend. The annual types of wild rice would have more specialized niches than perennial types and would be differentiated to a greater extent in adaptation to environmental diversity. The populations of the annual *O. breviliguluta* (=*O. barthii*) in Africa are differentiated to a similar extent (Table 4).

The populations of land races in the hilly areas of tropical Asia are quite diverse within as well as between populations. They showed the largest value of total genetic variance in quantitative traits although only four populations were studied (Table 4). The relative amounts of within- and between-population genetic variance (19% and 81%) were of the same order as those of annual wild rice populations. The populations also varied widely in the magnitude of within-population variability (Morishima and Oka 1970). Some of them were mixtures of indica and japonica types and others appeared to be intermediate indica-japonica types (Morishima et al 1980).

Table 3. Polymorphic index (PI) and other parameter values estimated for wild and cultivated rice populations (H. Morishima, unpubl. data).
a. Eight loci for PX, ACP, and PGI.

Taxon	Populations tested (no.)	Proportion of polymorphic loci per population	Av no. of alleles per locus	PI
O. perennis				
Asian				
perennial	6	.625	1.59	.256
intermediate	3	.458	1.54	.125
annual	4	.104	1.12	.035
O. sativa				
land races	8	.329	1.30	.092

b. *Px*-1 and *Acp*-1 loci *(O. perennis)*.[a]

Taxon	Populations tested (no.)	PI	Hetero-zygote frequency	Fixation index (F)	H_T	H_S	D_{ST}	G_{ST}
Asian								
perennial	24	.292 ± .215	.230 ± .236	.083	.620	.290	.330	.532
intermediate	12	.129 ± .175	.091 ± .161	.427	.375	.117	.258	.688
annual	14	.114 ± .165	.014 ± .035	.914	.279	.092	.187	.670
African								
(O. longistaminata)	13	.143 ± .180	.080 ± .172	.441	.202	.111	.091	.450
various plants[b]	15	.227 ± .123[c]	.071 ± .071					

[a] H_T — Total genic diversity = average gene diversity: $\frac{1}{n}\sum_j(1-\sum_i x_{ij}^2)$. H_S — Genic diversity within population. D_{ST} — Genic diversity between populations. G_{ST} — Relative magnitude of differentiation of populations (= D_{ST}/H_T). [b] Frankel and Soulé (1981, p. 43, for various isoenzymic loci). [c] Computed from Brown (1978, Table 1).

Table 4. Total genetic variance of populations (mean for spikelet length, spikelet width, anther length, and panicle length, each in 100 *ln* X), and percentages of within- and between-population genetic variances (computed from Morishima and Oka 1970, Tables 2 & 5).

Taxon	Populations observed (no.)	Total genetic variance	Genetic variance (%)	
			Within-population	Between-population
O. perennis				
Asian race				
perennial	9	155.5	67	33
intermediate	7	154.1	37	63
annual	10	186.7	19	81
American race	5	269.5	25	75
African race[a]	4	105.4	72	28
O. sativa, land race	4	374.1	19	81
O. breviligulata[b]	6	269.6	27	73
O. glaberrima	6	184.8	22	78
Environmental variance:		15.3		

[a]*O. longistaminata* Chev. et Roehr. [b]*O. barthii* A. Chev.

In the evolutionary process of domestication, gene diversity for morphological-physiological traits would be greatly increased, particularly in relation to the indica-japonica differentiation (Oka and Morishima 1982). However, isoenzymic diversity is much reduced with domestication (Pai et al 1973, 1975).

SOME THEORETICAL CONSIDERATIONS

The number of potential allelic variants per species would be innumerable, but one plant can represent a considerable portion of them. In a relatively small population, most alleles are expected to be either very common or very rare, showing a U-shaped curve of distribution (Kimura and Crow 1964; Marshall and Brown 1975, Fig. 4.1). Rare genes ($p < 0.05$) cannot be the object of conservation, if not isolated (Marshall and Brown 1975). When the frequency of the most frequent allele is less than 0.95, operationally the locus can be considered polymorphic (Frankel and Soule 1981, p. 42).

The gene diversity, or PI, seems to vary among populations of the same species in a wide range, e.g., 0 to 17% in *Hordeum spontaneum* and 0 to 27.5% in *Lycopersicon pimpinellifolium* (Brown 1978). The percentage of polymorphic loci is a problematic statistic as nonpolymorphic loci cannot be subjected to genic analysis. However, this has been estimated from isoenzymic data on certain assumptions. Among 14 plant species, the percentage ranged from 5 to 100 (Brown 1978, Table 1) with a mean of 0.259 ± 0.166 (Frankel and Soulé 1981, Table 3.5). In *O. perennis*, it ranged from 0.625 (Asian perennial type) to 0.104 (annual type, Table 3). In general, it is highly correlated with observed heterozygosity although this correlation depends on the manner of sampling (Frankel and Soulé 1981, p. 43). Most of the variable loci are expected to have two or three alleles (Marshall and Brown 1975, Table 4.1 & p. 61), and overdominance increases the number of alleles. It was found in *Lycopersicon* populations that heterozygote excess (over the frequency expected from outcrossing rate; fixation index < coefficient of

inbreeding) was inversely correlated with outcrossing rate (Rick et al 1977). An excess of heterozygotes was also found in *O. perennis* (Sano et al 1980, Table 6; negative values of fixation index). Heterozygotes are adgantageous in selection, and probably, the higher the selfing rate, the higher would be the heterozygote advantage.

The size of the collected and regenerated population is much smaller than that of the mother population in the field. This may be compared with the bottleneck effect in evolutionary theory. The loss of genes due to a finite effective population size (N) is: $(1 - 1/2\,N)^t$, where t stands for generation number. The number of alleles remaining after a bottleneck is: $E(n) = m - S\,(1 - p_j)^{2N}$, where m is the number of alleles prior to the bottleneck and p_j is the frequency of j-th allele (Frankeland Soule 1981, p. 35). When $m = 2$, $p = 0.05$, and $N = 20$, $E(n) = 1.87$. It is expected that the loss of genes due to a bottleneck is not very serious although rare genes are lost, if the population is increased to a larger size in the next generation.

When the target of conservation is to maintain 95% of genes (gametes) distributed randomly in a population with a 5% frequency, there should be 59 plants per population. However, this target may be lowered to maintain 95% of genes with 5% or higher frequencies. The probability formula employed was:

$$P = 1 - (1 - p)^N \geq 0.95.$$

Letting $(1 - p) = q$, this is rewritten as:

$$1 - P = q^N = 0.05, \text{ or, } N\,ln\,q = ln(0.05) = -2.996$$

Then,

$$ln\,q = -2.996/N$$

Although the mode of distribution of gene frequencies cannot be specified, if it is assumed to be logarithmic (similar to Marshall and Brown 1975, Fig. 4.1), it follows that:

$$\int ln\,q\,dq = q\,ln\,q - q + C,$$

while the range of q projected is 0.95 to 0.5 as $p = 0.05 \sim 0.5$. Then,

$$-\ 2.996/N = \int_{0.5}^{0.95} ln\,q\,dq = -\ 0.9987 - (-\ 0.8466) = -\ 0.1521.$$

From this, $N = 19.695$; the number of plants required is about 20.

Furthermore, a heterozygous locus has two alleles, each with a 0.5 frequency. Then, $1 - 0.5^{2N} \geq 0.95$, and $N = 2.16$. Taking this into account, $N = 20(1 - h) + 2h$, h being the observed frequency of heterozygous loci. When $h = 0.2$, $N = 17$, and when $h = 0.4$, $N = 13$.

Operationally, it may be assumed that the higher the polymorphic index, the more important would be the within-population diversity in conservation. When PI = 0.05, the average frequency ($\bar{p}$) of less frequent alleles will be 0.026 if it is assumed that there are two alleles and $\bar{p} = \frac{1}{2}(1 - \sqrt{1 - 2PI})$; then, the population may be regarded as homogeneous practically. Actually, PI varies between 0.05 to

0.3 (Table 3). According to Dr. Major M. Goodman (Department of Statistics, North Carolina State University, Raleigh, N. C.; pers. comm.), to preserve a certain level (R) of gene diversity ($H_e = 1 - \sum_i p_i^2$) in the regenerated population, it is expected approximately that:

$R = 1 - 4\sqrt{(\Sigma p_i^3 - \Sigma p_i^4)/2N} / (1 - \Sigma p_i^2)$. When $p_i = 0.5$, $R = 1 - 2\sqrt{1/N}$, and for R = 0.8, N = 100. This is much greater than the above expectations.

These theoretical considerations indicate that a practicable number of plants per regenerated population, say, N = 20 ~ 100, can maintain a considerable fraction of gene diversity.

CONCLUSION AND RECOMMENDATION

Regeneration of population samples of wild *Oryza* species by the bulk method has not been practiced at the National Institute of Genetics, Misima, because of lack of space. Yet, where enough space is available in the field under a tropical climate and where within-population variation is considered unimportant, the use of the bulk method may be recommended for populations of wild species not containing many genes of cultivars (cf. Table 1). It is practiced in many other crops whose populations are heterogeneous, and is relatively labor-saving. For screening of particular genes, evaluation of characters, and genetic experiments, however, a number of inbred lines must be raised from each population.

Traditionally, in a field for seed multiplication, a line is represented by a row or a few rows. This is not wise for reducing natural hybridization. It is recommended that a population of 100 single plants to raise in a square (10 × 10) plot and seeds be collected from the inner 64 plants (8 × 8) after discarding the border rows. Neighboring plots must be spaced by distance (e.g., 2 m in cultivated species and 20 m in wild species) if bagging for self-pollination is not made or is incomplete, but the field space can be saved if neighboring plots are planted with materials differing in heading time. A number of populations may be planted in a field following a checkerboard arrangement.

The wild species shed seeds, and bagging is necessary to collect seed even if hybridization could be minimized by spatial isolation. The use of large nylon nets, each enclosing one plant and supported with a bamboo stick, may be recommended to save labor.

The populations of wild species with high perenniality can be maintained as living specimens. For this, a number of small concrete beds, separated from neighbors by proper distance and equipped with an automatic watering apparatus, will be needed. As nylon bags are used for collecting seed, wire-net caging will not be necessary. As wild rice plants are photoperiod sensitive, if not established permanently, they can be grown only in the wet season in the Philippines.

In a germplasm conservation program, the wild species belonging to the so-called primary gene pool are as important as, or more important than, cultivated land races. Some of them are expected to carry various genes of economic importance, like those for pest or disease resistances, and are now threatened with extinction in many parts of the world.

CONSERVATION OF WILD SPECIES OF *ORYZA*

S. D. SHARMA

The genus *Oryza* consists of about 24 species, out of which *sativa* and *glaberrima* are cultivated. The species of the genus *Oryza* are grouped into three sections, namely, Sect. *Oryza,* Sect. *Angustifolia,* and Sect. *Padia.* The two cultivated species and their close relatives belong to Sect. *Oryza,* which has a pantropic distribution. The species of Sect. *Angustifolia* and Sect. *Padia* are distantly related to the cultivated rices. Sect. *Angustifolia* is confined to Africa, and Sect. *Padia* is confined to Southeast Asia (Appendix 1).

About 20 years ago, Tateoka (1962a, b) made a thorough study of the *Oryza* specimens available in the important herbaria of the world. Subsequently, Sharma and Shastry(1965a,b), Clayton(1968), Chang(1976a), Brucher(1977), and Ng et a1 (1981a, b) added new information on the identification, delimitation, and nomenclature of species.

WORK ALREADY DONE

Collections already made

The collection programs of wild species made before 1963 were not based on any systematic exploration. The earliest systematic collections of wild rices were made by K. Furusato in 1959 and 1960 and by H. I. Oka in 1963 and 1964 in Africa. Those were followed by explorations by S. V. S. Shastry in Assam and Tripura (India), S. D. Sharma in Dangs district of Gujarat (India), Tuguo Tateoka in eastern Africa and the Philippines in 1964, and T. C. Katayama and his party in India and Sri Lanka (Katayama et a1 1972a, b).

These explorations greatly added to the wealth of genetic material available to biosystematists of *Oryza.* The collections of Tateoka were the most valuable in that they made available for the first time some of the species (*eichingeri, punctata-2n, perrieri*) that were not available to rice workers earlier. The collections of Shastry and Sharma, Tateoka, and T. C. Katayama brought out the variation available in *O. officinalis.*

Location of collections

Up to 1965, a number of laboratories in Japan, Taiwan, and India were active in the study of wild species. But in 1983, hardly two or three laboratories were working on wild rices. Not all the laboratories that have closed since 1963 have transferred their material to the IRRI for conservation. At present, collections of wild rices are maintained mainly at IRRI, IRAT, IITA, and NIG.

Evaluation

The evaluation of wild rices has so far been mostly for taxonomic traits, i.e. the material has been studied: a) to identify or delimit the species, b) to classify the

species in their appropriate taxonomic group, c) to analyze their genome, or d) to study their cytology. Studies on use of the material for the improvement of the cultivated species are few. However, such studies have helped us get a better understanding of the genetic makeup of species.

PLANS FOR THE FUTURE

Exploration and collection

Keeping in view the area of distribution, ecology, genetic makeup, and financial limitations, the wild rices could be divided into the following groups for the purpose of exploration and collection:

Group 1: *rufipogon - nivara - meridionalis*

This group of species is the most closely related to the widely cultivated rices *O. sativa.* The number of chromosomes (2n = 24) and genomic constitution (AA) of these species are the same as those of *O. sativa.* This group also represents the progenitors of the cultivated rices. The importance and significance of the genetic resources of these species cannot, therefore, be underestimated.

The disappearance of this group in the genus *Oryza* is the fastest for several reasons: a) these species occur in one of the densely populated areas of the world and hence are highly exposed to disturbance by men; b) the population in such areas increases at a very high rate and so the habitat of these species is being fast reclaimed for cultivation of crops, construction of roads, buildings, etc.; c) the cultivation of sativa rices is becoming more and more proximal to the population of these wild species; therefore, these species are losing their genetic identity because they are being "swamped" by the genes of *O. sativa.* The urgency of collecting these species was highlighted by the IBPGR-IRRI Rice Advisory Committee meeting held at Cuttack in October 1981 (IBPGR-IRRI Rice Advisory Committee 1982).

Collections of these species were made earlier by Kihara and Katayana from India, Nepal, and Sri Lanka. A better understanding of this group has, however, emerged only recently (Sharma and Shastry 1965a, b; Chang 1976a, b; Ng et al 1980a). It is, therefore, necessary that these species be collected extensively and intensively on a priority basis.

A time-bound collection program is needed for the exploration and collection of species from South and Southeast Asia and tropical Australia.

Group 2: *longistaminata - breviligulata - glaberrima*

This is an African group of species related to the African cultivated rice *O. glaberrima.* Of the three species, the distribution of *O. longistaminata* is the widest and that of *O. breviligulata* wider than that of *O. glaberrima.* Thanks to the excellent efforts of IRAT, ORSTOM, IITA, and Japanese workers, these species have been fairly well-collected and conserved.

Group 3: *glumaepatula* (= *cubensis*)

This material has frequently been treated as a mere variant of the Asian species *O. rufipogon* (Roschevicz 1931, Chevalier 1932, Tateoka 1962b, Second 1982). If so, collection of this species from tropical America is all the more desirable.

Group 4: *collina - officinalis - australiensis - minuta - malampuzhaensis*

This is an Asian group of species occurring in forests in partial shade, by the side of running streams or swamps, etc. With deforestation, this group is also endangered. The present collection of *O. collina* (= *eichingeri*) from Sri Lanka and *O. officinalis* from the whole of South and Southeast Asia is not representative of their natural distribution. It is desirable that the collection be done before these species disappear.

Group 5: *punctata - eichingeri - schweinfurthiana*

This is an African group of species of Ser. *Latifoliae.* The species occur in forest shades, near sources of water. Thanks to the efforts of Tuguo Tateoka and other Japanese workers, this group has been fairly well-collected and conserved in recent years.

Group 6: *brucheri - latifolia - alta - grandiglumis*

The collection and conservation of the diploid *Oryza* species described by Brucher (1977) is highly desirable as this species is suspected to be the diploid DD species. Except for this material, there is no immediate urgency in collecting this group of species.

Group 7: *brachyantha - angustifolia - perrieri - tisseranti*

This is an African group of species that are distantly related to the cultivated rices. They do not deserve any high priority in any collection program of wild rice .

Group 8: *meyeriana - ridleyi - schlechteri*

This a South and Southeast Asian group of species distantly related to the cultivated rices. They too deserve a low priority in any immediate collection program.

Conservation

One of the major changes that have taken place since 1963 is that the burden of conserving *Oryza* species has shifted from the national institutes to international institutes such as IRRI, IITA, WARDA, IRAT, and ORSTOM. IRRI has taken the key role in this matter. But for IRRI, a large number of accessions of *Oryza* species would have been lost forever. The following aspects need greater attention at present:

A central repository. IRRI has the necessary facilities for the conservation of the wild as well as cultivated species of *Oryza.* It would, therefore, be desirable that duplicates of all accessions of *Oryza* species be deposited at IRRI to ensure conservation. This will also ensure against the loss of material at any one institute.

Inventory of collections. For the information of rice workers, inventory (or inventories) should be made of the *Oryza* species accessions now maintained at various national and international institutes. IRRI may take a lead in this matter.

Rejuvenation. Different species of wild rices require different types of handling for seed rejuvenation. For example, *O. longistaminata* is a self-incompatible species in which the seed can be rejuvenated only for populations and not for individual plants. Some of the species prefer open sunshine, and some other species prefer not only shade but also well-drained soils. Cross-pollination may lead to genetic mix-up of species (particularly of isogenomic species such as *latifolia - alta - grandiglumis - minuta - malampuzhaensis - schweinfurthiana -*

rufipogon - *nivara* - *meridionalis*, etc.). Shattering of spikelets may cause germination of seeds in neighboring plots or pots of another species, leading to a mix-up of species.

IRRI, NIG, and other centers now maintain about 3,000 collections of *Oryza* species. The cited difficulties highlight the efforts of these centers in maintaining such a large number of accessions.

Evaluation

The evaluation of wild *Oryza* species has various aspects.

Morphological variation. At present there is only the taxonomic description of the species as given by Roschevicz (1931) or Tateoka (1962a), based on their studies on herbarium species. Very few papers give the full range of variation available in natural populations or institutional collections (Tateoka 1965, Tateoka and Pancho 1963, Bardenas and Chang 1966, Chang 1976b, Chang et al 1977). Similar description of the variation for all *Oryza* species is required for proper use of the species.

Genome analysis. A good deal of work has been done on the genome analysis of *Oryza* species. The work done up to 1963 has been summarized by Morinaga (1964), Li (1964), and Chang (1964). Later, the genomes of *O. eichingeri* were determined by Hu (1968) and those of *O. punctata* by Katayama and Ogawa (1974).

Despite these studies, the diploid *Oryza* species with the DD genome still evades identification. A diploid *Oryza* species of *O. latifolia* complex has been described by Brucher from South America. This species of *O. officinalis* might have the solution to this unsolved problem (Gopalakrishnan and Sampath 1966; S. D. Sharma, unpubl. data). Work on this line needs the attention of rice cytogeneticists.

Genetic recombinability. The diploid species of *Oryza* having AA genome are the closest relatives of *O. sativa* and hence offer a greater scope for use than the other species of *Oryza.* They could be used only by incorporating any of their desirable traits into *O. sativa* background. This could best be achieved by way of producing an F_1 hybrid with *O. sativa* and then by repeatedly backcrossing with *O. sativa.*

It is, therefore, desirable that genetic recombination of characters should be studied in F_1 hybrids of *O. sativa* and wild species repeatedly backcrossed with *O. sativa.* A theoretical understanding of this kind will help in the immediate use of the traits of those wild species, if and when required.

Screening of Oryza species for resistance to biotic and abiotic stresses. The major use of wild rice species could be the incorporation of their desirable traits, such as resistance to insect pests and diseases, into *O. satiza.*

IRRI has successfully screened and identified a strain of *O. nivara* (collected from eastern Uttar Pradesh in 1963) and used its resistance to grassy stunt virus (Chang et a1 1975). This has saved the rice crop in about 11 million ha in Southeast Asia. The CRRI has identified a strain of *O. longistaminata* as immune to bacterial leaf blight (Devadath 1983).

A thorough screening of *Oryza* species for resistance to various pests, diseases, and environmental stresses is, therefore, highly desirable.

Appendix 1. Species of *Oryza*. [a]

I. Sect. *Oryza*

(A) *Ser. Satizae:*

In Asia	: *sativa* (AA), *nivara* (AA), *rufipogon* (AA), *meridionalis* (AA).
In Africa	: *glaberrima* (AA), *barthii (breviligulata)* (AA), *longistaminata* (AA).
In America	: *glumaepatula,* i.e. *cubensis* (AA).
In Australia	: *meridionalis* (AA).

(B) *Ser. Latifoliae*

In Asia	: *officinalis* (CC), *collina* (CC), *malampuzhaensis* (BBCC), *minuta* (BBCC)
In Africa	: *punctata* (BB), *eichingeri* (CC), *schweinfurthiana* (BBCC)
In America	: *brucheri* (??), *latifolia* (CCDD), *alta* (CCDD), *grandiglumis* (CCDD)
In Australia	: *australiensis* (EE)

II. *Sect. Angustifolia*

In Africa : *brachyantha* (FF), *angustifolia* (??), *perrieri* (??), *tisseranti* (??)

III. *Sect. Padia*

In Asia : *granulata* (??), *meyeriana* (??), *abromeitiana* (??), *ridleyi* (????), *longiglumis* (????), *schlechteri*

[a] Based largely on Sharma and Shastry (1965b). *Oryza brucheri* is a provisional name for the diploid *Oryza* species of *O. latifolia* complex, reported by Brucher.

SURVEY OF CONSERVATION ACTIVITIES IN ASIAN COUNTRIES AND PROPOSALS FOR FUTURE ACTION

BANGLADESH

MD. NASIRUDDIN and N. M. MIAH

The wide environmental diversity in Bangladesh, attributed mainly to the considerable variation in topographic and seasonal components, is reflected in the range of rice groups cultivated, viz. *aus, transplanted* (t.) *aman, broadcast* (b.) *aman,* and *boro,* as well as in the distribution of wild and weed races.

Before the first IRRI-IBPGR Workshop in 1977, the Bangladesh rice collection held at IRRI had more than 4,000 samples, representing all rice groups from all parts of the country. From 1978 to 1982, further collecting work increased the total to 5,285 accessions. However, the more recent collections included many obvious duplicates of varieties collected during earlier expeditions. To overcome the problem of duplicates in the existing collection of additional land races, a national survey of varietal names, their location, and seasonal distribution was recently completed. The survey used questionnaires which were distributed to the lowest administrative farm units and the resulting information was collated and documented in the form of a book entitled *Local rice varieties.* This book provides a sound basis for cross-referencing existing named varieties in the collection and identifying new additions.

A total of 12,479 names, including duplicates, are listed, and the bulk of data is too impractical to process manually. To date, only accessions of the boro group have been analyzed. Of 1,200 accessions, only 250 (about 20%) had no duplicate sample names. The collections belonging to the aus, b. aman, and t. aman groups each contain 3,500-4,000 accessions and require the use of computer facilities for effective analysis.

Traditional rice varieties in Bangladesh have been relatively well-collected. Since 1972 IRRI has directly participated in nine collecting missions. During the next 5 years, emphasis will be given to land races in the more remote inaccessible parts of the country, tribal rices, and wild and weed races. Further collecting will be done in the Chittagong hill tracts, Sylhet, Noakhali, Mymensingh, Faridpur, Jessore, Khulna, Tangail, Pabna, Rajshahi, Bogra, Rangpur, Dinajpur, and Kishoreganj for aus, b. aman, and t. aman seasons, and from Rajshahi and Sylhet for the boro season.

Very little is known about the rice culture of the numerous tribal groups in Bangladesh, but indications are that their varieties may represent minor, primitive, or obscure types. Collectors will encounter difficulties with language and travel because many of the tribes are located in remote hilly areas in the southeast and along the borders with India.

Wild and weed races are mostly endemic with the deepwater rice areas in the central region and generally mature 2 weeks earlier than the cultivars. Two types of wild rice are recognized: the first is morphologically close to *O. rufipogon* and the second is similar to the cultivated floating rice varieties except for its shattering habit.

The proposed collecting activities require continuing support from IRRI. Training assistance in germplasm processing and maintenance technology is needed for scientists associated with the medium-term seed storage unit at IRRI.

BHUTAN

A. N. PRADHAN

Bhutan is a landlocked, mountainous country with a diverse range of topographic and climatic environments representing sharp intraregional variation in rainfall, temperature, humidity, and solar radiation.

Three major climatic zones are recognized: the subtropical Southern Zone with altitudes up to 1,000 m and annual rainfall of more than 5,000 mm, the temperate Central Zone with valleys up to 3,000 m and annual rainfall of 750-1,500 mm, and a cold-temperate-to-arctic Northern Zone with snowcapped ranges of the Himalayas with elevations exceeding 3,000 m.

Rice farming is concentrated on irrigated terraces in the Central Zone valleys, from the foothills to an altitude of about 2,500 m. A rich diversity exists in traditional rice varieties and the higher altitudes are known as an important source of cold-tolerant germplasm.

Since the early 1960s, high-yielding rice varieties have been introduced. Improved semidwarf varieties such as Pusa 33 are gradually replacing the traditional cultivars in the more accessible areas, but as yet their distribution is relatively limited. Introduction programs are underway through the agricultural extension services.

Little progress has been made in field-collecting activities to date. Following an initial collecting expedition in 1975, IBPGR sponsored in the Central Zone in late 1981 a multicrop exploration covering most of the more accessible regions between 700 and 2,500 m in elevation.

At present the Bhutanese collection maintained at IRRI is represented by only 107 accessions.

External funding and manpower assistance are prerequisites for the collecting programs planned for the next 5 years. Priority areas for exploration are the Southern Region and parts of the Western Region for lowland and flood-tolerant varieties and the Western, Eastern, and Southeastern Regions for upland cold-tolerant types.

The Department of Agriculture faces an acute shortage of technical personnel as well as facilities for training and evaluating genetic stocks. Financial support for all aspects of germplasm conservation is required from international organizations.

BURMA

U OHN KYAW

More than 60% of the about 5 million hectares planted to rice in Burma is found in the south, particularly in the lower valleys and the Irrawaddy and Sittang River deltas. Rice cultivation extends to the plateau and hill regions to the west, north, and east of the central basin and to the higher altitude hill tracts.

An estimated 2,000 traditional varieties are cultivated but the increasing adoption of high yielding varieties, at present mainly in the rainfed lowland and irrigated areas, is gradually replacing the indigenous germplasm in the more accessible regions.

Several rice germplasm collecting expeditions have been organized since the early 1970s in Lower and Middle Burma. Attempts have been made to structure field collecting on a national basis, extending to the village level through the various agencies of the Agricultural Corporation, including the Agricultural Research Institute (ARI) at Yezin, and the People's Peasant Council. In 1980, the Burma-IRRI Project organized a short training course on rice germplasm collection and conservation at ARI. The course was attended by 43 participants from ARI, the regional research farms, and village units. It was intended to stimulate nationwide collecting activities and to facilitate more intensive exploration in the remote areas where traditional land races still predominate. However, progress in collecting work has been slow because travel in these remote regions is both difficult and risky.

By 1982 wet season, the national collection comprised about 2,080 entries, including representatives of the wild species *O. rufipogon, O. nivara,* and *O. officinalis.* In 1981, IRRI received 561 samples representing collections between 1976 and 1980, and now maintains a total of 1,724 accessions from Burma.

Preliminary evaluation of traditional varieties has identified promising sources of genes for seedling vigor, for tolerance for salinity, drought, abrupt flooding; for good eating quality, aroma, fine grain appearance, and resistance to nematodes, brown planthoppers, bacterial leaf blight, and blast.

Most of the regions still to be canvassed are expected to contain valuable germplasm. In Lower Burma, traditional floating varieties are cultivated along the Irrawaddy and Pegu Rivers. Middle Burma may contain potentially drought-tolerant types in the rainfed lowland plains, and hill rices may provide genes for cold tolerance both at the seedling stage in the dry season and at the flowering stage. Sources of cold tolerance at flowering may be found in the hill states such as parts of Shan, Chin, Kayah, Kachin, and Karen.

In the proposed 5-year plan, to be coordinated by the Rice Division at ARI and the Agricultural Extension Division, a wide area will be canvassed for both upland and lowland types, deepwater and salinity-tolerant varieties, and wild species. Priority is high for collection in the western part of Magwe division in late 1983 and in Tenasserim division in the extreme south and Kayah division in the east in

late 1984. Later collecting expeditions will canvass Kachin State and the division of Mandalay and Sagaing, then in the states of Arakan, Mon, and Chin. These activities require outside funding assistance for the training of local field collectors and the collection of wild rice species.

The seed collection is stored in screw-top plastic containers and maintained in a small medium-term refrigerated seed store at ARI. However, financial support is required to expand the presently limited storage capacity at least at the medium-term level.

There is a need to train research scientists in germplasm bank management and documentation to catalog the existing collection and thereby make available to breeders new sources of local germplasm. A closer working relationship with IRRI will be developed to facilitate the accomplishment of these objectives.

CHINA

YU-SHEN DONG

China, probably the world's oldest rice-growing nation, presently produces about 35% of the world's rice. Cultivation covers a wide range of environments: from the subtropical Hainan Isiand of Guangdong Province in the south to the cold regions of Heilongjang Province in the north, in the humid coastlands in the east, and in the arid parts of Xinjiang in the west.

Rice germplasm collecting expeditions were initiated in the 1930s in South China. However, the resulting collections were not completely maintained.

During the mid-l950s, a massive nationwide crop germplasm collecting effort that involved workers at all levels resulted in the collection of an estimated 200,000 accessions, of which 40,000 were rice, including some duplicates. The material was maintained at the Chinese Academy of Agricultural Sciences (CAAS) and agricultural academies in various provinces. Unfortunately, some accessions were lost in the 1960s.

To supplement the national collection, an additional countrywide collecting program was organized between 1979 and 1982. Technicians at the county level received training in germplasm collecting techniques from scientists of the provincial agricultural academies; the latter also actively collected in some remote areas rich in traditional varieties. Through a reward system, farmers themselves were encouraged to collect rice germplasm. Of about 90,000 accessions of different crops collected, 10,000 were rice.

The more recent exploration teams sampled wild rice germplasm in the southern provinces of China and collected numerous valuable accessions from the climatically variable and germplasm-rich Yunnan Province in the southwest. Those indica *(hsien)* varieties predominated below 1,400-m elevation and sinica (*keng*) above 1,800 m. Rice cultivation extends to an altitude of 2,650 m in this area.

Of the three species of wild rice in China, *O. sativa* f. *spontanea* has the widest range of distribution, being found in much of the southern half of the country. *O. officinalis* is distributed mainly in Guangdong, Guangxi, and Yunnan Provinces and *O. meyeriana* is limited to Guangdong and Yunnan Provinces in the extreme south.

The project of collecting rice germplasm on a large scale has been completed. National germplasm activities are coordinated through the Crop Germplasm Resources Institute at Beijing. Both medium-term and long-term storage facilities are being developed at Beijing and a Chinese National Rice Research Institute is being planned near Hangzhou, Zhejiang Province, in eastern China.

In the next 5 years, emphasis will be on evaluating the collection for such characters as blast and bacterial wilt resistance, cold tolerance, and saline-alkaline tolerance. In addition, research will start on the origin and taxonomy of rice to aid selection of breeding materials.

Cooperative relationships between China and IRRI are expressed in the exchange of scientists, study and training scholarships, rice genetic material, and research information. Rice germplasm from China is regularly deposited for duplicate storage at IRRI; a total in excess of 3,800 accessions has been received by the IRGC to date. Plans for closer collaboration with IRRI will be further developed.

INDIA

J. K. ROY, S. BISWAS, S. D. SHARMA, and K. L. MEHRA[1]

As one of the primary centers of origin of *O. sativa,* India contains a rich and diverse genetic wealth of rice. It has provided numerous donors against biotic and abiotic stresses and for quality characters.

A national survey estimated that about 50,000 rice varieties are still in cultivation but accelerating genetic erosion, particularly in the irrigated tracts, poses a major threat to the indigenous germplasm.

Considerable progress has been made in genetic conservation. A total of nearly 15,200 rice accessions are maintained at the national gene bank at the Central Rice Research Institute (CRRI), Cuttack, and an estimated 35,000 local cultivars are held as working collections at 40 rice research stations. Thus, there is a total collection of 50,000 cultivars and, assuming 50% of the collection to be duplicates, the national collection is now estimated at 25,000 with scope for further collection of another 25,000 accessions from India. More than 14,000 accessions have been sent to the IRRI germplasm bank.

During the national workshop on rice held at CRRI in February 1978, a coordinated national rice germplasm collection program was formulated. Twenty-four collecting agencies under the Indian Council for Agricultural Research (ICAR), State Departments of Agriculture, and agricultural universities were nominated to collect rice germplasm from the areas allocated to each agency. The CRRI was designated as the coordinating agency for the collection and conservation program, while the National Bureau of Plant Genetic Resources (NBPGR) in New Delhi was made responsible for coordinating seed exchange, collection in other countries, and training. The program drew up a 3-year (1978-80) national plan for germplasm collection, which was funded through ICAR.

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[1] Dr. K. L. Mehra, director of NBPGR, was unable to attend the workshop but provided, by letter, information on the activities of the NBPGR.

To implement this national program, the NBPGR organized three training courses, one in 1978 and two in 1979, covering all aspects of rice germplasm collecting methodology. The Bureau also developed a standardized format for the site-collection data sheets (passport data) to be used by each collecting agency.

A total of 5,224 samples were collected during 1978-80 by the executing agencies, comprising collaborating teams from diverse regions. Each accession was divided into three subsamples: one was retained by the respective states for local evaluation, the second was sent to the CRRI gene bank, and the third went to IRRI for long-term storage.

The cooperating State Units, priority areas for collection, and target material have been identified. In the next 5 years, CRRI will continue the national collecting effort and add support in the form of finance or direct participation where necessary. The NBPGR has also mobilized 10 base centers in the country to serve the different regions in the collection of germplasm of a wide range of crops, including rice. The centers are located at Simla, Almora, Jodhpur, Ranchi, Shillong, Cuttack, Hyderabad, Akola, Trichur, and at the Bureau headquarters in New Delhi. Each center has been allocated a state or region in which it will actively collect and has been provided with vehicles and other facilities. Emphasis will be on the collection of wild rice species and local varieties of upland rainfed rice, lowland flood-tolerant types, and varieties displaying saline-alkaline tolerance, cold tolerance, pest and disease resistance, and aromatic and quality characters.

The next phase of collecting, coordinated by the CRRI, will include the states of Andhra Pradesh, Bihar, Orissa, Tamil Nadu, Uttar Pradesh, Jammu, and Kashmir and later expand to cover other regions throughout the country.

A medium-term cold storage facility is nearing completion at CRRI where the national collection will consolidate duplicates of all genetic stocks currently held at different State Units.

Future emphasis will be given to documentation, evaluation, and international seed exchange. Training in germplasm conservation will continue through the NBPGR and will require partial financial support from international agencies.

INDONESIA

B. H. SIWI and K. SUTJIPTO

About 70% of the total rice area in Indonesia is under improved high yielding varieties. The areas are mainly in the provinces of West Java, Central Java, Yogyakarta, East Java, Bali, South Sulawesi, West Sumatra, and North Sumatra. Genetic erosion in these areas is becoming increasingly critical.

Indigenous rice cultivars are grown in hilly regions, swampy areas, and in remote places on various islands throughout the extensive archipelago.

By the end of 1977, the national collection at the Bogor Research Institute for Food Crops (BORIF) was represented by 4,388 accessions, a considerable number of additional samples having been lost due to improper storage.

During the last 5 years (1977-82), further explorations collected 4,398 cultivars, consisting of 912 bulu (javanica) and 3,486 cere (indica) types. Field collection was effected by local staff in numerous regions (981 cultivars) and in collaboration with

IRRI (587 cultivars) in Kalimantan, Sulawesi, and islands of the Nusa Tenggara group. Most samples (2,830 cultivars) were collected by field extension workers.

Presently, 7,500 samples are being preserved at BORIF and 1,346 duplicate samples are at Sukamandi Research Institute for Food Crops (SURIF). Duplicate samples were sent to IRRI where 7,840 accessions are now stored.

For the next 5 years, field collecting will be directed toward replacement of nonviable accessions and collection in the more remote areas on different islands. In 1983, emphasis will be on upland types in the hilly areas of West Java and Southwest Sumatra and on lowland types on Bangka Island off Southeast Sumatra. Collection during 1984-86 will be organized through BORIF and the Central Research Institute for Food Crops (CRIFC) in collaboration with IRRI, and will concentrate on North Sumatra, Kalimantan, and Nusa Tenggara for upland, lowland, and tidal swamp land races and wild rice species. In 1987, BORIF will coordinate the collection of upland types in Southeast Sulawesi. A special exploration team will also canvass the more inaccessible regions such as Maluku and Irian Jaya for wild species.

Since 1977, the seed storage capacity for the national collection has been expanded. Besides the walk-in refrigerated cabinet used for medium-term seed storage at BORIF, a larger unit, 6.8 × 2.6 × 2.2 m in size operating at 0-4°C and 60% relative humidity (RH), has been installed at SURIF and will be used to store duplicate samples of the Bogor collections. Air-conditioned rooms maintained at 22°C and 80% RH are available at BORIF and SURIF for storage of working collections.

Additional scientists should be trained in seed conservation technology to maximize the efficient use of existing seed storage facilities.

MALAYSIA

YOKE-HWA CHEN

About 60% of more than half a million hectares under rice cultivation in Malaysia is irrigated and double-cropped. The cultivars grown all belong to the indica group.

Systematic rice germplasm collection and evaluation began in 1970 with the formation of the Malaysian Agricultural Research and Development Institute (MARDI) and with the assistance of Japanese scientists from the Tropical Agriculture Research Center (TARC).

To date, the germplasm collection contains 4,550 accessions, 3,581 of which have been documented; the remainder are new collections. About 50% of the total accessions are indigenous varieties, and the rest originate from 28 countries.

For long-term storage, 120 g of each seed sample, dried to 11% moisture content, are stored in plastic containers at –10°C and 50-60% relative humidity (RH) in the Koitotron Seed Bank at the Rice Research Center, Bumbong Lima. One duplicate set of all samples (30 g each) is sealed in aluminum foil packets and stored in a freezer at –10°C, and a second set is forwarded to the IRRI germplasm bank. IRRI now maintains 2,395 accessions from Malaysia.

In recent years, the rapid increase in the size of the varietal collection has

resulted in the existing storage capacity (1.7 × 2.6 × 2.2 m) becoming severely limiting. Financial assistance from IBPGR has been requested to expand the facility.

Future rice collecting activities will be aimed at remote areas and areas that have not been previously covered, including Pahang, Terengganu, Kelantan, and Perak in West Malaysia, and Sabah and Sarawak, East Malaysia.

Screening the collection for resistance to pests and diseases will be emphasized.

Plans are underway to store all catalogued information on morpho-agronomic traits, grain quality, and reactions to pests and diseases in computerized format.

NEPAL

B. B. SHAHI and B. B. MATHEMA

The Nepalese Himalayas contain a widely diverse range of microenvironments caused by a combination of factors including an abrupt rise in altitude and correspondingly steep gradients of temperature and rainfall, and local variations in topography, soil type moisture regimes, and other influences.

The country can be divided into 4 categories based on variations in temperature and altitude: terai (50-200 m), inner terai (200-350 m), mid-hills (350-2,700 m), and high hills (2,700-9,000 m). The annual pattern of rainfall subdivides Nepal into three regions: western (100-800 mm), central (800-1, 600 mm), and eastern (1,600-2,500 mm).

This physical and climatic variation have resulted in a region of high floristic genetic diversity, with numerous isolated valleys and pockets where genetic differentiation has evolved and is maintained.

The ecological adaptation of rice in Nepal ranges from an elevation of about 40 m in the subtropical southern terai region to 2,800 m in Jumla Valley in the cold-temperate northwest hill region; the latter contains one of the world's highest rice fields. Almost all rice cultural types are encountered over this range, from upland cold-tolerant rainfed types in the mid-hills to the floating rices in the eastern terai. Wild rice species are concentrated mainly in the foothill areas.

Since an extensive collecting expedition in 1971, during which about 950 samples were collected with the support of USAID and IRRI, two further explorations have recently been funded. In 1981, canvassing in 45 districts in the terai, inner terai, and parts of the mid-hills resulted in the collection of 720 land races. This was followed by the collection of almost 300 samples in 1982 in eastern and far-western Nepal. A total of 1,243 accessions are held in long-term storage at IRRI.

Screening the national collection has identified a number of land races with useful agronomic traits such as cold tolerance, early maturity, high protein content, and resistance to bacterial leaf blight.

Although genetic erosion of traditional varieties has not attained critical levels in Nepal, the gradual adoption of modern improved varieties, particularly in lower altitude regions below 1,500 m, continues to threaten indigenous germplasm. In some of the hill valleys such as Kathmandu, Chitwan, and Trisuli, 80-90% of rice

cultivars are modem varieties. Other valleys such as Dang, Tumlingtar, and Chourghari in the mid-hills are similarly endangered by the influx of improved varieties.

A detailed 5-year (1983-87) collecting itinerary to be coordinated by the National Rice Improvement Program, and the Integrated Cereals Project and Regional Agricultural Development offices has been formulated. A wide range of cultural types will be collected, including irrigated, rainfed, cold-tolerant, midland bulu-like, and tropical types as well as wild rice species.

Collecting work is scheduled for 1983 in eastern Nepal in the Tamur Kosi River belt. This will be followed by annual explorations to systematically collect in far-western Nepal in the Mahakali and Seti River belts and valleys in the Jumla area, western Nepal in the Karnali and Bheri River belts, mideastern Nepal in the Sun Kosi River belt, and central Nepal in the Bagmati and Gandaki River belts. Collecting will extend into the high-altitude areas, isolated valleys, and pockets in each of the target regions.

Germplasm collecting in Nepal is faced with a number of hazards and constraints. Many of the target areas are situated in remote mountainous terrain and are often difficult to visit during collecting seasons. Difficulties in road travel often necessitate expensive flights by helicopter. Previous collecting teams have spent well in excess of 50 hours of helicopter flight time, part of which was frustrated by adverse weather conditions. Specialized collecting equipment during field trekking is also vital.

Consequently, Nepal requires substantial financial assistance from international agencies for the effective implementation of its proposed 5-year collecting program. Funding is also needed for the training of a small group of local scientists in field collecting methodology and for the development of seed storage facilities for the national collection, which at present is rejuvenated annually. A deep-freeze storage unit, at least of medium-term type, and associated seed processing equipment will be requested together with assistance in the training of staff in seed conservation technology.

PAKISTAN

M. S. BHATTI, M. AKBAR, and A. A. SOOMRO

Rice occupies a vital position in Pakistan's agriculture and is cultivated over an area of about 2 million hectares.

The introduction and spread of improved modern varieties during the last two decades resulted in a catastrophic loss of genetic diversity in traditional rice varieties in this important part of the central Asian gene center. High yielding varieties now occupy about 77% and 24% of the rice area in Sind and in Punjab, the main rice growing provinces. Although local varieties are still found in parts of Sind and, to a greater extent, in the North Western Frontier Province (NWFP) and Baluchistan Province (71% and 43%, respectively), genetic erosion of indigenous land races is expected to continue into the various ecological rice zones.

The national collection is represented by about 900 local accessions which were

collected mainly in Punjab and Sind Provinces between 1972 and 1977 by a coordinated project organized through the Pakistan Agricultural Research Council (PARC). In mid-1977, the PARC initiated a research project to collect, evaluate, and preserve the germplasm of the important crop plants of Pakistan. Under this project, seven multicrop-oriented collecting expeditions were organized, in collaboration with IBPGR and the Netherlands, with the aim of conserving threatened crop genetic resources and making new germplasm available to plant breeders. A small number of additional rice samples were collected from Baluchistan in 1981 and from had Kashmir in 1982.

More than 500 accessions of exotic origin are included in the national collection, which now totals 1,419 entries. To date, 936 varieties have been sent to IRRI for long-term storage.

The rice collection is being maintained in airtight screw-top metal cans in a medium-term cold store operating at 0 ± 1°C, which was established in 1981 at the National Agricultural Research Centre, Islamabad.

The national collection has been evaluated for the major local agronomic constraints such as tolerance for high ambient temperature, low water temperature, salinity, and zinc deficiency. During screening for resistance to pests and diseases, several traditional varieties manifested high levels of resistance to stem borer and blast. Screening for other useful traits continues.

Future collecting work will be mobilized in Baluchistan and NWFP, which previously received little attention. The two provinces share borders with other rice-growing countries such as China, the Soviet Union, Afghanistan, and Iran, and valuable rice germplasm resources are expected to exist. An IBPGR-sponsored multicrop collecting mission to Baluchistan in 1981 reported that traditional varieties were still widespread. Genetic erosion was high, however, in pockets where recently exploited sources of irrigation water had stimulated a change from subsistence to commercial farming.

The PARC is planning to collect hill rices in the NWFP from the districts of Mansehra and Kurram Agency in 1984 and Malakand, Swat, Dir, and Chitral in 1986. During 1987 the districts of Khuzdar, Turbat, Lasbella, and Sibi in Baluchistan will be explored for irrigated types. The Thatta district of Sind Province, which was earlier reported as a potential source of wild rice germplasm, has not been canvassed but will be included in future plans.

A prerequisite for such proposals is continued funding assistance from IBPGR or other international agencies. Appropriate vehicles are particularly urgent.

Progress has recently been made in the documentation of the national collection. The transfer from a manual to a computerized system of data management is planned for July 1983 when an Apple III computer, provided by IBPGR and housed in the Plant Genetic Resources Unit of PARC, will begin operation.

The PARC recently established an Institute of Plant Introduction and Genetic Resources with the assistance of the World Bank. The Institute will enhance the exploration, collection, evaluation, and documentation of plant genetic resources in Pakistan.

PHILIPPINES

RUSTICA S. BAUTISTA

The strategic location of the Philippines, as a natural bridge between the various regions of Southeast Asia, the wide climatic and ecogeographic variation among the thousands of islands, and the occurrence of different rice-based cropping systems have resulted in considerable diversity in the indigenous rice germplasm.

At the same time, the Philippines is one of the Asian nations which have experienced the most rapid spread of modem rice varieties. It has been estimated that, of a total rice area of 3.5 million ha, more than 2.6 million ha (about 75%) are now planted to improved varieties. In some areas, such as the lowland rice belt of Laguna Province in Luzon, traditional land races have almost completely disappeared. From 1955 to 1982 the Philippine Seed Board recommended 96 high yielding varieties for adoption by local rice farmers. In the past 10 years alone, 26 lowland and 6 upland varieties were approved and are now widely cultivated. Only the floodwater-prone and much of the upland rice growing regions, which constitute less than 15% of the total rice area, are relatively unaffected by the impact of modern varieties.

Rice germplasm collecting activities have a long history in the country, the earliest explorations having been undertaken at the turn of the century through the Bureau of Agriculture. Subsequently, numerous collecting efforts were made by the University of the Philippines at Los Baños (UPLB), the Bureau of Plant Industry (BPI), and the Bureau of Agricultural Extension (BAEx). In 1962, the national collection was transferred to the germplasm bank at IRRI and, by 1977, almost 1,200 accessions were registered. Since then and in recognition of the accelerating spread of modern varieties, the national collecting program involving field technicians of BPI and BAEx has continued to collect indigenous varieties throughout the country. From 1977 to 1981, the program submitted 1,786 entries to IRRI. Most of the entries originated from Northern Luzon, Mindoro, and Mindanao, with additional samples from Central Luzon and the Visayas. Field collecting has also been supported by IRRI scientists and various collaborators including missionaries, anthropologists, and other interested individuals throughout the country. To date, IRRI has registered 3,954 accessions from the Philippines.

The current need is to consolidate the existing data on the national collection and to collate information on regions not yet canvassed to firmly identify priority target areas in terms of the advance of genetic erosion and their potential as sources of germplasm of traditional varieties and wild species.

Wild species are relatively poorly represented in the collection and more attention will be given to the assembly of such indigenous species as *O. officinalis, O. rufipogon, O. meyeriana,* and *O. minuta* in the future.

The 5-year field collecting plan for 1983-87 will be jointly coordinated by BPI and IRRI and executed through the agencies of the Bureau of Agricultural Extension, the UPLB, the Agricultural Colleges Association of the Philippines, and the Bureau of Forest Development.

The remaining lowland sites where traditional land races are still cultivated, the more remote uplands which continue to display considerable varietal diversity, and the areas containing wild rice species have been designated as first priority for collection during 1983-85. These target areas encompass provinces in 10 of the 12 administrative regions of the country. First priority has been assigned to the regions of Ilocos and Cagayan Valley for upland types; to Bicol, Western Visayas, and Western Mindanao for lowland types; and to Southern Tagalog, Central and Eastern Visayas, and Northern and Southern Mindanao for both upland and lowland types. Other provinces within these regions and in Central Luzon and Central Mindanao will be canvassed during 1985-87.

Assistance has been requested from IRRI in terms of training for field collectors and, to some extent, direct participation in germplasm collecting activities. Evaluation of the existing collection will continue and attempts made to make the resulting information more widely available to local rice breeding programs.

SRI LANKA

I. GUNAWARDENA

In contrast to the relatively small size of the island, Sri Lanka contains a wide spectrum of eco-edaphic and agro-ecological zones which, together with a long history of rice cultivation and traditional farming practices, have contributed to the broad range of varietal diversity and adaptability displayed in the local rice germplasm.

Considerable variation in climatic, topographic, hydrologic, and, in particular, pedologic factors occurs within the country. Of the 10 recognized major soil orders, 9 are distributed in a mosaic pattern throughout the island. Considering rainfall, vegetation, soils, and present land use, the country can be divided into three main agroclimatic zones: wet, intermediate, and dry. During November-March the northeast monsoon causes islandwide rainfall (the maha season). This is followed in April-October by the southwest monsoon that brings precipitation to the southwest mountainous wet zone only (the yala season). The wet zone receives up to 5,000 mm rainfall annually and the dry zone about 1,250 mm.

Most of the rice lands are inland valleys of varying form and size. A small proportion is on coastal plains and minor floodplains. About 50% of the rice is cultivated in the dry zone, 20% in the intermediate zone, and 30% in the wet zone. Traditional rice varieties are typically tall with long, narrow, drooping leaves, and are generally lodging susceptible on grain filling. They are mainly of the indica type and are all nonglutinous. One group of varieties, locally known as samba, is characterized by short bold grain and is popular for its good cooking and eating qualities. The varieties cultivated in the maha cropping season are distributed over a wide range of environments — from the uplands where shifting cultivation or the chena system is practiced, to the rainfed and irrigated lowlands — and are mostly long-duration photoperiod-sensitive types. The yala season varieties are

photoperiod-insensitive and represent potential sources of earliness and drought tolerance.

The national rice collection has generated numerous outstanding sources of germplasm for such traits as broad-based resistance to the brown planthopper and resistance to leafroller. Sources for such traits were easily identified because farmers did not apply chemicals for insect control. Varieties from the cool humid mountainous regions have provided genes for blast resistance, and others have been used as donors for resistance to bacterial leaf blight. Traditional land races from the southwestern lowlands represent promising sources of tolerance for sudden-flood submergence. Varieties tolerant of salinity, drought, cold, iron toxicity, and low phosphorus have also been identified.

The introduction and dissemination of improved high-yielding varieties have progressed rapidly in Sri Lanka. Of the estimated 860,000 ha, more than 72% is planted to modern rice varieties.

Efforts to collect the indigenous rice germplasm on an islandwide basis started in 1967 when all District Agricultural Extension workers and government agents of the different administrative districts were mobilized in a national rice germplasm collection program. In subsequent years, this effort was continued with additional support from IRRI staff who have participated in six collecting missions to date. A total of 2,745 accessions have resulted from field collection from all 24 districts and an additional 408 samples, obtained from a farm survey in 1972, have been added to the collection. Most accessions are duplicated at IRRI where 2,069 entries are now in cold storage.

Of all the countries in Asia, the rice germplasm collection of Sri Lanka is probably the most complete. Moreover, some wet zone districts with diverse soils and climatic conditions, particularly the mountainous region and parts of the coastal plain, are known to be rich in rice germplasm.

The Central Agricultural Research Institute (CARI) at Peradeniya will coordinate collections in the wet zone districts of Ratnapura and Colombo during the 1984 maha. At the same time, the districts of Hambantota, Monaragala, Badulla, and Matale in the intermediate-dry zone will be explored. Collecting will continue in the remaining coastal districts of the dry zone in 1985 to complete large-scale collecting activities in the country. In the districts mentioned the new improved rice varieties have not spread extensively and farmers still continue to grow traditional types because of their better adaptation to local conditions.

The final phase will emphasize sampling of wild rice populations. Wild species are widely distributed, particularly in the dry zone and at low elevations on the coastal plains. They include *O. rufipogon, O. nivara, O. officinalis, O. granulata,* and hybrid swarms resulting from introgression with cultivated types.

There is a need for external funding to strengthen germplasm storage facilities in the country. A medium-term storage chamber at CARI is nonfunctional at present and the rice germplasm is in temporary storage in a borrowed facility of the INTSOY project. Assistance is also required in training scientists in seed storage technology and the associated operations in germplasm bank management.

THAILAND

SONGKRAN CHITRAKON, BORIBOON SOMRITH,
and CHANTABOON SUTTHI

The presence of a vast lowland area in the terminal basin of the Chao Phraya River Delta in the southern plain region and an extensive area of broad river terraces of the Mekong River and its tributaries in the northeast plateau region make Thailand one of the world's most important rice-growing countries.

Rice occupies more than half of the available cultivable land, being grown on about 11.7 million ha (or 63.1%). Each major rice cultural type is represented and a wide diversity is displayed within the indigenous floating, upland and hill rices, traditional rainfed forms, and glutinous and nonglutinous varieties as well as within the wild rice germplasm.

Extensive field collecting activities for local varieties began in 1950 to expand the somewhat limited earlier work initiated in 1937. During 1950-66 collected samples were maintained as genetic stocks at different experiment stations. In 1967, the collections were sent to Bangkhen Rice Station for storage in an air-conditioned room. However, due to lack of proper seed storage facilities, it was necessary to rejuvenate part of the collection every 1-3 years. This was both laborious and expensive and entailed the risk of seed loss or mechanical mixing.

Through a Japanese Government grant to the Thai Department of Agriculture in 1980, the sum of US$1.5 million was provided for the construction of a National Rice Seed Storage Laboratory for Genetic Resources. This facility was completed in late 1981 at Rangsit Rice Research Center, about 25 km northeast of Bangkok, and the national rice germplasm collection was transferred from Bangkhen shortly afterwards.

The seed storage unit includes rooms for short-(15° C), medium- (5° C), and long-term (—10°C)storage. From 30 to 50 panicles per sample are collected, the seed is dried to 7-8% moisture content, and 80 g are vacuum-sealed in metal cans for medium- and long-term storage. For short-term conditions, 300 g of seed are maintained in glass jars. Germination tests are performed on samples which have been stored longer than 3 years. At present, more than 6,000 rice accessions are in short-term storage, 500 in medium-, and 300 in long-term storage. The plan is to transfer about 500 accessions annually to medium- and long-term storage.

It is standard practice to send a representative portion of each new sample to IRRI. To date, 2,906 accessions from Thailand are registered in the IRRI germplasm bank.

The national program evaluates about 200 accessions a year for morphological and grain characteristics, using guidelines recommended by IBPGR; additional descriptors for drought tolerance and aromatic characters are also included because of their local importance.

Since 1977, local collectors have canvassed large tracts of the country and more than 2,900 samples have been collected. Most came from the Central Plain, but substantial collections were also made in the northern, northeastern, and southern regions. The local varieties included both glutinous and nonglutinous types from

lowland, upland, and deepwater sites. About 5% of the entries were wild rice species.

During 1979-80, the Tribal Research Center at Chiang Mai University collected about 300 upland varieties in the hill tribe areas of the northern region and in provinces extending along the borders of Burma-Thailand and Laos-Thailand. The Center and the Sanpatong Rice Research Station are collaborating to evaluate this hill rice collection with the objectives of improving hill rice varieties and cultural practices for hill tribe farmers and, on a broader scale, developing a nationwide upland rice improvement project. The tribal hill rices are in more than 135,000 km^2 of watershed area in 20 provinces. It is believed that more than 1,000 land races are grown by the hill farmers but, due to numerous difficulties such as the remoteness and relative inaccessibility of their settlements and the political sensitivity of the border areas, collecting can only progress slowly. Moreover, the work between the two cooperating organizations requires assistance in the form of facilities and funding to permit the growing, processing, and storage of the hill rice germplasm.

Following the development and rapid spread of new high yielding varieties such as the Rice Division (RD) series at the national level, many farmers are abandoning their own valuable traditional varieties. It is foreseen that RD varieties will dominate large rice growing areas within the next 5 years. This threat is recognized by the Thai Government, which has approved a 3-year rice collection program and budgeted US$54,150 for the period 1983-85. The program expects to collect about 4,000 new accessions, bringing the national rice germplasm collection to 10,000 by 1985. The program objectives are to collect all possible local rice varieties, weedy races and wild species; to conserve this germplasm at the new seed storage laboratory; and to evaluate the collection for important agronomic traits.

The collecting program will be coordinated by the Rice Research Institute at Bangkok and the Phrae Rice Research Center, and executed through the agencies of the Public Welfare Department by the Tribal Research Center and Provincial Hill Tribe Development Centers. Target areas during 1983-85 will be northern Thailand, parts of the southwest region, and the border areas with Burma and Laos. A survey by agricultural extension workers situated in these provinces has recently estimated the total number of existing traditional varieties to be more than 9,000.

Collecting will continue into 1987 with further canvassing of the upper north and southwest regions plus additional explorations along the extensive Burma-Thailand border.

A severe constraint to field collection in Thailand is the unfortunate coincidence of the slow release of government funds at the early part of the budget year starting in October with the beginning of the rice harvesting season. Hence, it was often impossible in the past to travel to the northern regions to collect the early-maturing varieties. To resolve this problem, the IBPGR has been requested to complement the Thai budget to give local collectors financial resources for travel expenditure in the early-season phase of the rice germplasm collection program.

VIETNAM

VO-TONG XUAN and NGUYEN VAN LUAT

Vietnam has considerable geographic diversity. Its principal features include the broad Mekong River Delta in the south; the Red River Delta in the northeast, fed by numerous tributaries from the mountains in the northeastern region; and a long central mountain range separating the two major deltas and itself containing a number of smaller river deltas along its narrow coastal plain.

The variation in climatic, hydrologic, and edaphic conditions has given rise to an equally variable pattern of rice cultural practices and associated traditional varieties.

Rice occupies about 80% (or 5.4 million ha) of the total cultivated area in Vietnam. Of the varieties planted, traditional ones make up between 45 and 50%. Because of insufficient irrigation and drainage, as much as 60% of the rice area in the Mekong Delta is still planted to traditional varieties. The adoption of modern varieties has been relatively slow in the past but their increasing distribution and acceptance by local farmers are recognized as a potential threat to the indigenous rice germplasm. The National Bureau of Census estimated that, in 1979, improved varieties occupied about 34% of the rice area in the winter-spring season and 11% in the summer-autumn season.

Early efforts to collect rice germplasm in Vietnam were carried out sporadically by various research organizations to provide basic material for local breeding programs.

In mid-1974, IRRI, in cooperation with the Ministry of Agriculture, assisted in the formulation of a 3-year rice collection program. This program was mobilized in early 1975 when members of the agricultural extension service and university students of agriculture were trained in field collection techniques by IRRI staff. Subsequently, IRRI supported collecting work in 14 provinces in the Mekong Delta, eastern Vietnam, the central highlands, and the central lowlands where the 108 samples collected included a few accessions of *O. spontanea* and *O. officinalis.* Agricultural extension workers supplied an additional 300 new samples, bringing the national collection to 695 entries by late 1975.

More recent exploration activities have concentrated in the northern part of the country, executed by the National Institute of Agricultural Sciences and the Institute of Food Crops. In the southern part, exploration has been done by the University of Cantho's Center for Rice Research and Development and the Cuu-long Delta Agricultural Techniques Institute. The University of Cantho has collaborated with provincial agricultural services in the Mekong Delta to collect local varieties before the improvement of water control facilities in the area allows the large-scale cultivation of high yielding varieties.

The northern collection is estimated at about 1,000 medium-growth-duration types (Lua Mua) and 500 spring varieties (Lua Chiem). These are being characterized at present.

In the Mekong Delta canvassing has continued since 1976 and most traditional varieties have now been collected. After identification of duplicates, the southern

collection contains 1,000 distinct land races. These have been characterized according to their site of collection and screened for a range of agronomic traits. Most of the varieties were found in Cuu-long, Hau-giang, Kim-giang, and Minh-hai Provinces and were generally single-transplanted, late-maturing types. A small proportion of double-transplanted and dry-seed-broadcast floating types were also collected. Some varieties were cultivated widely in several provinces; others were restricted to limited villages or districts such as the aromatic Nang-thom from Longan Province and the salinity-tolerant Nang-co-do from Tien giang Province. The Mekong Delta collection contains promising sources of genes for tolerance for salinity, acid-sulfate soils, drought, low temperature and shallow or deep flooding plus potential sources of resistance to the brown planthopper and green leafhopper. Several varieties were reported to be aromatic or to have good grain and eating qualities.

Characterization and registration of the existing collection and the regular transfer of subsamples to IRRI for long-term preservation will continue. A total of 1,634 accessions from Vietnam are now duplicated at IRRI.

The proposed field collecting plan for 1983-85 is to be coordinated by the National Institute of Agricultural Sciences in Hanoi, the University of Cantho's Center for Rice Research and Development, and the Mekong Delta Agricultural Techniques Institute at Hau Giang. High priority has been assigned to the collection of wild rice species and traditional varieties adapted to adverse or specialized conditions such as the 0.4 m ha of upland rice cultivated on unfavorable soils, saline- and acid-soil-tolerant types and floating varieties. Target areas for late 1983 and 1984 are the Central Highland provinces of Lam-dong, Dar-lat, and Gia-lai-Kontum, and nine provinces of the Mekong Delta. These areas as well as the mountainous northwest region will be further canvassed in 1985. Because of difficulties of access to the above areas in the past, they promise rich sources of new rice germplasm.

Characterization of the new accessions will be carried out in regional stations, but the total collection will be evaluated at two distinct ecological delta sites.

Due to the lack of both germplasm conservation facilities and the associated trained manpower, Vietnam requires considerable international support to maximize the use of its rich rice germplasm collection. At present, seed storage facilities are inadequate. The irregular and unreliable power supply to airconditioned storage rooms necessitates field rejuvenation of the collection every 2 years. International technical and financial assistance for the next 5 years has been requested to establish a National Rice Germplasm Center to serve local scientists and to promote collaboration with other international centers. Training of Vietnamese scientists in the standard practices of germplasm collection, evaluation, and preservation will be emphasized and international support will also be sought to attain this objective.

RICE GENETIC RESOURCES COLLECTION AND CONSERVATION ACTIVITIES IN AFRICA AND LATIN AMERICA

PROGRAMS OF IITA, WARDA, IDESSA, IRAT, AND ORSTOM

N. Q. NG, M. JACQUOT, A. ABIFARIN, K. GOLI, A. GHESQUIERE, and K. MIEZAN

Seven species of rice are indigenous to Africa (Table 1). Species with the genome A, namely, *Oryza longistaminata, O. barthii, O. stapfii,* and *O. glaberrima,* appear to be of immediate interest to plant breeders. They can cross freely with the Asian rice *O. sativa,* and gene transfer from one species to another is possible, although their F_1 hybrids are male sterile. The gene pools of these African species can be exploited to improve the quality and quantity of Asian rice. The gene pools of other rice species of African origin possessing genomes BB, BBCC, and FF and represented by *O. eichingeri, O. punctata,* and *O. brachyantha* can also be exploited if plant breeders and geneticists are willing to struggle with the strong crossing barriers between these species and cultivated rice.

The African land races of *O. sativa* represent another important genetic diversity of rice germplasm in Africa. This species reached East Africa about 2,000 years ago and West Africa about 450 years ago, possibly even earlier (Carpenter 1978, Nayar 1973, Porteres 1950). For hundreds of years, *O. sativa* evolved under African ecosystems that are different from its homelands in Asia. During this period, the occurrence of mutation and recombination due to occasional outcrossing followed by natural and artificial (by farmers) selections would have created considerable genetic diversity in the species. Furthermore, introgression of genes from *O. glaberrima* and other species with the genome AA to *O. sativa* or vice versa might have taken place. Natural hybrids between *O. sativa* and *O.*

Table 1. Rice species in Africa.

Species	2n	Genome	Origin
O. sativa (cultivated)	24	AA	Asia
O. glaberrima (cultivated)	24	A^gA^g	West Africa
O. stapfii (weed species)	24	A^gA^g	West Africa
O. barthii	24	A^gA^g	West Africa
O. longistaminata	24	A^1A^1	Tropical Africa
O. brachyantha	24	FF	West and Central Africa
O. eichingeri	24	CC	East and Central Africa
	48	BBCC	
O. punctata	24	BB	Tropical Africa
	48	BBCC	
O. schweinfurthiana[a]	48	BBCC	Tropical Africa

[a] Taxon of questionable status (see Tateoka 1963).

glaberrima have been observed in farmers' fields (Ng 1979) and in the multiplication plots of the International Institute of Tropical Agriculture (IITA). Second (1981) also speculated about this phenomenon. This outcrossing would certainly have enriched the genetic variability of rices in Africa.

The importance of collecting and preserving African rices had been stressed in several workshops and in literature (IRAT/ORSTOM 1977, International Rice Research Institute [IRRI] 1978, Ng 1982a, Williams 1978). Severalorganizations in West Africa, i.e., Office de la Recherche Scientifique et Technique d'Outre-Mer-Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (ORSTOM-IRAT). Institut des Savannes (IDESSA), International Board for Plant Genetic Resources (IBPGK), IITA, and West Africa Rice Development Association (WARDA) have been actively collecting rice germplasm in Africa during the past several years. In addition, staff of the National Institute of Genetics (Japan) also conducted a study tour to several West African countries from which rice germplasm was also collected. This paper summarizes the progress made on the collection and conservation of rice by ORSTOM-IRAT, IDESSA, IITA, and WARDA in Africa.

ROLE OF ORSTOM-IRAT, IDESSA, IITA, AND WARDA IS GERMPLASM COLLECTION AND CONSERVATION

IDESSA on the Ivory Coast is a national institute which works closely with ORSTOM and IRAT in the collection, multiplication, and evaluation of rice germplasm and the study of interspecific crosses among the group of *sativa* complex.

IRAT and ORSTOM are two regional research organizations in francophone African countries, which are financed by the government of France. These two organizations have regional offices in Ivory Coast. IRAT-ORSTOM initiated a genetic resource program on African rices in Africa in 1974. By 1977, they were coordinating and executing rice collecting missions sponsored by IBPGR, IITA, IRRI, WARDA, and ORSTOM-IRAT in West Africa.

IRAT was until now responsible for dispatching the multiplied seed samples to IITA, IRRI, and WARDA for preservation and utilization. ORSTOM, IRAT, and IDESSA store working collections for their own evaluation and studies.

ORSTOM's research activities focus on the studies of genetic variability and diversity, origin, and phylogenetic relationship of the species belonging to the sativa group. IRAT's evaluation activities focus on identification of plant breeding donors, especially of agronomic characters and characters favoring outcrossing.

In late 1975, IITA established a Genetic Resources Unit whose major responsibility is to conserve plant genetic resources in Sub-Saharan Africa. Its duties are to collect, conserve, evaluate, study, and document the genetic resources of crops within IITA's mandate, including rice.

IITA has a Rice Improvement Program collaborating with IRRI, WARDA, IRAT, and African national programs in the improvement of rice specific to the African region, IBPGR has designated IITA as a regional base center for preserving the African form of *O. sativa* (IBPGR 1979). In addition, at the 1977

Table 2. Rice germplasm collected by IRAT-ORSTOM's plant explorers during field explorations to 11 African countries during 1974-82, in collaboration with national institutes.[a]

Country	Years	Missions (no.)	Samples collected (no.)					
			sativa	*glaberrima*	*barthii*	*longistaminata*	Others	Total
			West Africa					
Cameroon	1977[b]	1	14	16	20	11	5	66
Chad	1977[b]	1	16	12	51	8	4	91
Guinea-Bissau	1978[b]	1	135	48	6	7	–	196
Guinea-Conakry	1978, 1982	2	577	165	17	9	6	774
Ivory Coast	1975, 1976, 1977,[b] 1980	4	544	47	1	2	9	603
Mali	1974, 1975, 1977[b]	3	9	142	132	51	7	341
Senegal	1974-75,[b] 1977,[b] 1978,[b] 1979[b,c]	3	472	309	82	57	–	920
Upper Volta	1976[b]	1	5	42	8	7	1	63
			East Africa					
Tanzania	1979	1	53	3	6	12	14	88
Zambia-Botswara	1978	1	19	–	4	11	–	34
Total		18	1844	784	327	175	46	3176

[a] Sources of information: see list of IRAT/ORSTOM Mission reports 1977-82. [b] Missions organized and/or supported by IBPGR. [c] In collaboration with Institut Senegalais de la Recherche Agronomique (ISRA), Senegal.

Workshop on Rice Genetic Conservation at IRRI, Los Baños, IITA was recommended to preserve, rejuvenate, and distribute cultivars of *O. glaberrima* and wild species of Africa (IRRI 1978). IITA accepted these responsibilities and worked in close collaboration with IRAT, ORSTOM, IBPGR, IRRI, WARDA, and the African National Institute to achieve those goals.

IITA's research on germplasm included the study of variability in grain characteristics and reaction to rice yellow mottle virus, blast, and other stresses.

WARDA's germplasm program is to extend needed logistic or administrative support to IITA, IRAT, IBPGR, and IRRI in germplasm collection. It also conserves, evaluates, distributes, and promotes the use of rice germplasm in collaboration with IITA and IRAT. Furthermore, WARDA collects in key areas where IITA and ORSTOM-IRAT have not collected or have not sufficiently collected.

Collaborations in rice germplasm exploration and collection between these organizations operating in Africa have been extremely good. The collected materials from Africa are shared among the organizations, including IRRI. IDESSA, IITA, ORSTOM, and IRAT recognize the role of IBPGR in coordinating, promoting, and supporting germplasm collection and conservation.

PROGRESS IN FIELD COLLECTION AND ASSEMBLAGE OF RICE GERMPLASM

A total of 58 missions conducted by ORSTOM-IRAT-IDESSA, WARDA, and IITA in 23 African nations during 1974-82 collected 7,789 samples. The collecting missions by institute are presented in Tables 2, 3, and 4.

ORSTOM-IRAT-IDESSA started the exploration activities in 1974. By 1982, they had completed 18 exploration missions to 11 African nations, from which a total of 3,176 rice samples were collected (Table 2).

WARDA conducted two explorations to Mali and Nigeria during 1979-80. During the trips, it gathered 666 rice samples representing different species (Table 3).

IITA began its plant exploration activities in 1976. By 1980 the Genetic Resources Unit had successfully accomplished 38 plant collecting missions to 18 African countries and collected a total of 3,942 samples (Table 4). Besides the field collections, IITA has received, through donations, 3,473 rice accessions (collected mostly in Africa) from ORSTOM-IRAT, IRRI, WARDA, IBPGR, and the African national programs. IITA now holds 7,633 accessions consisting of 1,941 *O. glaberrima*, 5,600 *O. sativa*, and 92 accessions of other species (Table 5). The growth of the rice germplasm bank at IITA is shown in Figure 1.

GERMPLASM PRESERVATION

At IITA, seeds after harvest were dried at 40°C for 3-4 days, then threshed, cleaned, and fumigated with phosphine gas before storage. Seeds for the working collection are at present stored in plastic jars in a short-term seed store (400 m^3) maintained at around 20°C and 40% relative humidity (RH). Parts of the working collection of rice and other germplasm at IITA will soon be transferred to another seed store (225 m^3), which is operated at 5° C and less than 65% RH. In the future IITA hopes to construct an additional 5°C cold store to keep all the available germplasm at IITA.

A seed store operated at –18°C for long-term seed conservation was commissioned during 1982. It is 7.3 m wide × 4.6 m long × 2.4 m high (=80 m^3) and has a capacity for 48,000 aluminum cans 99 mm high and 46 mm in diameter. Each can holds about 70 g of rice seeds. Two cans of seeds of every rice accession

Table 3. Rice germplasm collected by ORSTOM-IRAT's explorers to Nigeria and Mali during 1979 and 1980.

Species	Accessions (no.)		
	Nigeria[a]	Mali	
O. glaberrima	308		
O. sativa	237		
O. longistaminata	9	104	
O. barthii	6		
O. stapfii	2		
Total	562	104	
Grand total			666

[a] In collaboration with IITA.

Table 4. Rice germplasm collected by IITA during field explorations to 18 African countries from 1976 to 1980.

Country	Years	Missions (no.)	Samples collected (no.)			
			glaberrima	*sativa*	Others[a]	Total
		West Africa				
Benin	1978	2	23	45	14	82
Cameroon	1979	2	75	60	15	150
Gambia	1978	1	83	581	35	699
Ghana	1976[b], 1978	2	19	48	0	67
Ivory Coast	1977	1	0	0	17	17
Liberia	1977[b]	2	80	400	1	481
Mali	1977[b]	1	0	0	12	12
Nigeria	1976-79[b]	11	483	434	126	1043
Sierra Leone	1977[b]	1	36	287	4	327
Togo	1978, 1980	2	65	89	9	163
Upper Volta	1977-78	2	20	46	0	66
		East Africa				
Egypt	1978	1	0	376	0	376
Kenya	1979-80	2	0	0	0	0
Malagasy	1980	1	0	36	0	36
Malawi	1980[b]	1	0	141	0	141
Sudan	1979-80[b]	2	0	26	9	35
Tanzania	1978-79	2	0	168	7	175
Zambia	1980	1	0	72	0	72
Total		38	884	2809	249	3942

[a]Include wild rice species and rice samples not identified in reports. [b]Missions organized and/or supported by IBPGR.

will be stored. IITA is also in the process of acquiring additional funds to install another long-term seed store to accommodate all available germplasm, besides that of rice.

Rice seeds with viability percentage above 87% are dried to a moisture content of 6-7%, then sealed in aluminum cans for long-term storage at —18°C. Seeds under these conditions are expected to remain viable for more than 50 years.

At IRAT, a duplicate set of each germplasm accession is stored in 5°C cold store for preservation and another set is kept as a working collection in a storeroom with ordinary wall-type air-conditioners.

ORSTOM has a storeroom operated at 5°C for keeping a working collection of rice germplasm. A small quantity of seed of each rice accession is preserved in a deep freezer for use as a reference sample.

WARDA is in the process of installing two walk-in chambers with a total volume of 59 m^3 and capacity for 12,000 accessions.

GERMPLASM CHARACTERIZATION, EVALUATION, AND DOCUMENTATION

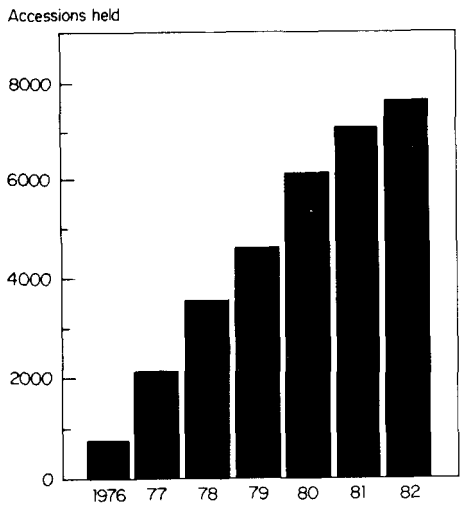
Characterization and evaluation of germplasm are a major activity of an active genetic resources center. They enable scientists to study the diversity of a species, search for material for direct introduction as cultivars, or provide genetic variability in breeding programs.

At IITA, the rice accessions are grown in the main growing season in the fields

Table 5. Rice germplasm accessions presently held at IITA, April 1983.

Country of origin	*Oryza* accessions (no.)								
	glaberrima	*sativa*	*longistaminata*	*barthii*	*stapfii*	*punctata*	*brachyantha*	*eichingeri*	Others
				African countries					
Benin Republic	0	28	0	0	0	0	0	0	0
Cameroon	64	79	0	3	1	0	0	0	0
Chad	15	21	0	11	0	1	0	0	0
Egypt	2	128	0	0	0	0	0	0	0
Gambia	39	262	0	0	0	0	0	0	0
Ghana	27	82	0	0	0	0	0	0	0
Guinea-Bissau	22	61	0	0	0	0	0	0	0
Guinea-Conakry	61	2	0	0	0	0	0	0	0
Ivory Coast	83	544	0	0	0	0	0	0	0
Liberia	643	711	0	0	0	0	0	0	1
Malawi	1	278	0	0	0	0	0	0	0
Mali	73	6	0	6	0	0	0	0	0
Nigeria	771	719	16	29	8	4	–	–	3
Senegal	73	411	0	0	0	0	0	0	0
Sierra Leone	27	311	0	0	0	0	0	0	2
Tanzania	3	266	0	0	0	0	0	4	1
Upper Volta	36	46	0	0	0	0	0	0	0
Zaire	1	46	0	0	0	0	0	0	0
Zambia	0	257	0	0	0	0	0	0	0
				Non-African countries					
Bangladesh	0	13	0	0	0	0	0	0	0
Brazil	0	76	0	0	0	0	0	0	0
Colombia	0	1	0	0	0	0	0	0	0
India	0	12	0	0	0	0	0	0	0
Philippines	0	18	0	0	0	0	0	0	0
Total	1941	4378 (+1222)[a]	16	49	9	5	0	4	9
				Overall total: 7633					

[a]In the process of multiplication.



1. Growth of IITA rice germplasm bank.

for agrobotanical characterization and evaluation, after the initial seed increase and purification. For each accession 44 agrobotanical characters are scored using the descriptors recommended by the IBPGR-IRRI Rice Advisory Committee (1980). During the growing period of rice for seed multiplication or characterization, IITA's rice scientists also evaluate the germplasm for such characters as resistance to insect pests and diseases and to select agronomically superior varieties.

The rice germplasm multiplication and characterization plots also serve as parental plots for use in hybridization by rice breeders. Very promising materials are selected for further testing.

Special efforts have been made to screen the rice germplasm for resistance to rice yellow mottle virus, to blast, and to insect pests of upland rice in Africa. Sources of resistance have been reported and some are in the process of further confirmation (Alluri et al 1982; IITA annual reports for 1976, 1977, 1978, 1979, 1980, 1982).

About 2,500 accessions of *O. sativa* and 1,500 accessions of *O. glaberrima* have been characterized. The genetic resources information was documented by computer at IITA (Ng 1982b).

Besides the standard characterization on morphology based on the IBPGR-IRRI descriptors list, ORSTOM-IRAT-IDESSA also characterized the isozyme pattern of every accession studied and pollen fertility on hybrids of interspecific crosses. This information is documented by manual recording in a logbook and by publishing the reports.

WARDA has evaluated 1,103 accessions for resistance to iron toxicity and grain discoloration. It also evaluated the germplasm for superior agronomic characteristics under non-iron-toxic conditions.

GENETIC RESOURCES TRAINING

Most African nations lack trained manpower to work on genetic resources collection and conservation. Since 1980, two plant exploration and conservation training courses have been conducted at IITA in collaboration with IBPGR. There will be another one at ORSTOM. In collaboration with IBPGR, a training course on seed technology and gene bank management will be held at IITA in August 1983.

FUTURE PLANS

Germplasm exploration and collection

Most of the major rice growing countries in Africa have been explored by IITA, IRAT-ORSTOM-IDESSA, and WARDA during the past. These countries are Benin Republic, Cameroon, Chad, Egypt, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Malagasy, Malawi, Mali, Niger, Nigeria, Senegal, Sierra Leone, Tanzania, Togo, and Upper Volta. However, many remote regions within those countries have not been explored. In other countries, such as Angola, Central Republic of Africa, Congo, Mauritania, Mauritius, Mozambique, and

Zaire, rice germplasm has not been collected.

IRAT and ORSTOM have done a good job of collecting wild species of rice with the genome A in West Africa. However, further exploratory surveys to tropical parts of Africa are needed to ascertain the areas for intensive collection.

The first primary areas for future exploration appear to be Angola, Niger, Malagasy, Upper Volta, Mozambique, southern Sudan, Comoros Island, islands of Tanzania, and Zaire.

The second priority areas are Central Republic of Africa, Mali, Togo, Mauritius, Ghana, Cameroon, and Congo.

The third priority areas are Mauritania, Gabon, Gambia, Chad, Senegal, Guinea, Benin, and Sierra Leone.

A joint effort of the African national, regional, and international institutes will be required to thoroughly explore the germplasm of African rices for preservation and use. Financial assistance for further exploration will certainly be needed by the various organizations operating in West Africa.

ORSTOM and IRAT have proposed to explore Malagasy, Niger, southern Sudan, Mali, and Togo. They would also like to be involved in exploration for wild species in Asia in the next 5 years.

IITA will reduce direct participation in rice germplasm collections but will operate through the African national programs in collaboration with IBPGR. IITA proposes to collaborate with the national programs to collect rice germplasm in Chad, Niger, Cameroon, Zaire, Upper Volta, Mauritius, Mozambique, Malagasy, and Sudan.

Characterization, evaluation, documentation, and distribution

ORSTOM-IRAT-IDESSA, IITA, and WARDA will continue to characterize and document the germplasm of African rices and to duplicate germplasm materials for storage at IITA and IRRI.

During the past decade ORSTOM staff carried out three types of evaluation studies on collected materials: isozyme analysis by electrophoretic techniques, phenotypic variability in morphologic characters, and interspecific hybridization. Valuable information obtained from the studies is being used to reset priorities in field collection, to improve sampling strategies, and to select appropriate areas for future collection.

Seed germination and processing laboratory

IITA and WARDA are in the process of equipping a seed laboratory for routine seed germination test and for processing seeds for storage.

Seed storage

IITA plans to purchase and install an additional seed store of about 200 m^3 to be operated at 5° C for storing the working collection of rice.

MALAGASY REPUBLIC

CLAUDE RATSIMBAZAFY

Malagasy Republic is an island in the Indian Ocean, 400 km east of Africa. Its area is a little less than 700,000 km^2 and its population is about 10 million. Geological structure is very diversified; many different climatic conditions due to latitude, longitude, elevation, and exposure are met; and many soil types are observed.

We therefore expect different environments for rice cultivation, which is besides very ancient: irrigated rice, flooded field, rainfed upland and lowland rice, medium or deep water conditions, saline, alkaline, and peat soils.

Considering history, and these various natural conditions, it is easy to find several native varieties adapted to such local conditions. This phenomenon is confirmed by prospecting.

RESULTS OBTAINED IS PREVIOUS YEARS

Prospecting and collection of local varieties, introduction from foreign countries, and plant breeding are conducted with the collaboration of IRAT. To date, a collection of 3,500 varieties has been constituted:

- 35% are native varieties from different parts of the country. More than 200 samples were sent to IRRI.
- 45% are varieties introduced from foreign countries such as Ivory Coast, Brazil, Senegal, and also from IRRI.
- 20% are hybrids and mutants created.

The collection contains the three principal types of *O. sativa* — indica, japonica, javanica — and intermediate types (ponlai or half-dwarf indica).

The collection is used in two ways:

- as cultivars for direct tests of adaptability as irrigated and rainfed rice in different locations, and
- as donors in plant breeding.

From the investigation, evaluation, and tests, 30 improved varieties were proposed for extension as irrigated rice and 8 as rainfed upland rice.

Problems

1. Only a few characters were described. An index seminum established for the 1,700 first numbers contains the following data:
   - tillering
   - seedling height at maturity
   - total duration cycle
   - awning
   - lemma and palea color
   - apiculus color
   - grain length and width
   - translucency
   - weight of 1,000 and 100 grains

- threshability
- culm angle
- culm strength

Information on this collection is incomplete and the chemical qualities of grains are unknown.

2. Collection was done only for cultivated rice. Wild species were not sampled. Nevertheless, it is to be noted that *O. longistaminata* was observed on the island.
3. There are no special or conditioned chambers for the preservation and maintenance of the collection; seeds are stored in wide-mouthed bottles or in packs of kraft paper. Short- and medium-duration seeds have to be rejuvenated every year and long-duration seeds every 2 years. The maintenance cost is thus very high.

PLAN FOR NEXT FEW YEARS

Plans for the next few years will focus on the following subjects:

1. Better understanding of the present collection.
   - Surveys on genetic variability will be undertaken:
     - description of phenotypic characters, with statistical methods.
     - electrophoresis of isoenzyme patterns.
   - Analysis of chemical qualities of grains.
   - Complements of evaluation, multilocation tests, tolerance for different stresses.
2. Continuation of prospecting and collection in leftover regions for cultivated rice species, wild species, and maybe weedy types.
3. Creation of a more rational and less costly system of seed preservation and storage of the collection.

NEED FOR OUTSIDE ASSISTANCE

At present, the number of scientists is still small, the budget for agricultural research is low; and the foreign currency for importation of materials, chemical products, and equipment is uncertain.

To carry out these programs, we shall need outside assistance of scientists, financial help, training, IRRI-IBPGR support for collection, and international collaborators.

LATIN AMERICA AND OCEANIA

Group discussion led to the following recommendations:

1. Traditional cultivars on the upland subsistence farms of Central America, southeast Mexico, and northern South America should be further canvassed and collected. CIAT is requested to contact institutions and develop a plan of action during the IRTP monitoring tours and workshops.
2. For the wild rices of Latin America, CIAT is requested to contact institutions and develop a preliminary plan of collection.
3. Institutions in Australia should be consulted to conserve the wild species of Oceania.

GLOBAL ROLE OF THE INTERNATIONAL RICE GERMPLASM CENTER AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

T. T. CHANG

HISTORICAL PERSPECTIVE

During the past 21 years the rice genetic resources program of IRRI has seen 4 milestones: 1) in 1961 IRRI began to assemble rice accessions from national centers for its germplasm bank (GB); 2) in 1971, upon the recommendation of 100 rice breeders, IRRI launched and coordinated the field collection of unimproved rices in tropical Asia; 3) in late 1977, IRRI built the Rice Genetic Resources Laboratory (RGRL) and developed a 5-year collection plan at the IRRI-IBPGR Workshop on the Genetic Conservation of Rice; and 4) in 1983, the program was reorganized as the International Rice Germplasm Center (IRGC) and a second Workshop on the Genetic Conservation of Rice Germplasm was held.

The first three developments were timely and rewarding. Since late 1961 the working collection has steadily grown into a base collection of the genus *Oryza.* From 1972 to 1977, rice workers and extension officers of 7 Asian countries collaborated with IRRI staff in canvassing the remote areas and collected 8,018 seed samples. Seven more countries in tropical Asia collected 10,997 more seed samples with their own staff and technical inputs from IRRI. Many government agencies, missionaries, service volunteers, and anthropologists also contributed efforts in assembling the unimproved germplasm.

After the 1977 workshop, workers of the participating countries enthusiastically implemented field collection activities. Table 1 shows the progress made in 14 Asian countries in 1977-83. IRRI staff collaborated in assembling 3,140 seed samples, while national programs along with inputs from the International Board for Plant Genetic Resources (IBPGR) and several teams funded by the Board added 12,850 seed samples to IRRI.

Since 1980 the IBPGR has been channeling to several Asian countries funds for 1) field travel, 2) shipping of collected seeds to IRRI, and 3) improvement of seed storage facilities at national centers. The scope and magnitude of the collection campaigns are indeed unprecedented in history.

During the past decade, centers in Africa, namely the IITA, WARDA, ORSTOM, IRAT, and FAO/UNDP, also implemented intensive collection activities with the collaboration of African countries such as Guinea-Conakry, Ivory Coast, Liberia, Nigeria, Senegal, and Sierra Leone. From such exploratory activities, IRRI received 4,118 seed samples of *O. sativa,* 861 samples of *O. glaberrima,* and 109 wild taxa of African origin.

As a result of the extensive collections and generous donation by numerous rice

Table 1. Rice seed samples collected from 14 Asian countries and deposited at IRRI, 1978-82.

Country	Rice seed samples[a] (no.)											
	1978		1979		1980		1981		1982		Total	
	D	I	D	I	D	I	D	I	D	I	D	I
Bangladesh	354	276	187	212	134	57	–	64	–	143	675	752
Bhutan	–	–	–	–	–	–	–	–	–	1,128[b]	–	1,128
Burma	–	13	–	–	–	–	–	561	–	–	–	574
India	–	–	–	–	–	888	–	380	–	998	–	2,268
Indonesia	712	590	344	753	304	–	–	48	–	1	1,360	1,392
Kampuchea	–	–	–	–	–	–	–	–	–	–	–	–
Laos	–	–	–	–	–	1	–	–	–	–	–	1
Malaysia	–	–	–	113	–	–	–	–	–	454	–	567
Nepal	–	9	–	16	–	–	–	720	–	376	–	1,121
Pakistan	–	–	–	1	–	–	–	–	–	4[c]	–	5
Philippines	438	1,159	–	441	–	49	72	–	–	44	510	1,693
Sri Lanka	364	402	231	6	–	145	–	–	–	1	595	554
Thailand	–	804	–	1,674	–	104	–	43	–	672	–	3,297
Vietnam	–	–	–	1	–	–	–	–	–	60	–	61
Subtotal	1,868	3,253	762	3,217	438	1,244	72	1,816	–	7,881	3,140	13,413

[a] D = with direct participation of IRRI, I = with indirect participation of IRRI. [b] Collected by an IBPGR-funded team from Bari and Kews-Wakehurst. [c] Collected by a Pakistan-Dutch Plant Collecting Team to Baluchistan.

workers, our bank now holds 63,458 accessions of *O. sativa* (Table 2), 2,600 accessions of *O. glaberrima,* 1,100 wild taxa, and 690 genetic testers and mutants. About 3,000 more seed samples have to be planted. Table 3 summarizes the magnitude of field collection activities from 1971 to 1982.

The tempo in field exploration and collection began to wane in 1981-82, especially after the IRRI advisor on field collection (Duncan Vaughan) left IRRI in mid-1981. Meanwhile, the time is ripe for all of us concerned to reassess the progress made since the first 5-year plan developed in 1977 and to make a new plan for the second 5-year period.

Since Director General M. S. Swaminathan took over the helmsman role in the spring of 1982, he has enthusiastically arranged for the joint IBPGR-IRRI sponsorship of a second workshop and to revive the interest of national centers in the genetic conservation phase. We are indebted to Dr. Swaminathan for his contributions to this workshop. Many of us remember that at the 1977 workshop, he delivered the opening address on behalf of the IBPGR and lent his personal support to the collection campaign in India. We are also grateful to the officers of the IBPGR for their collaboration and assistance.

This report briefly reviews the role of IRRI in the field collection and seed preservation activities, the constraints, and proposed remedies. Suggestions for future action are also outlined.

FIELD COLLECTION OPERATIONS

IRRI will continue to render assistance to the field collection phase by 1) providing the services of an adviser on field collection (Ian Roy Denton) either in field canvassing or training of local collectors, or both, 2) seeking IBPGR or

Table 2. Country listing of national collections deposited at the IRGC.[a]

Country	Total no. of accessions	Country	Total no. of accessions
Afghanistan	76	Liberia	1,159
Angola	5	Malagasy (Madagascar)	218
Argentina	73	Malawi	8
Australia	70	Malaysia	2,395
Austria	3	Mali Republic	28
Bangladesh	5,285	Mauritius	1
Belize	3	Mexico	118
Bhutan	107	Mozambique	6
Bolivia	11	Sepal	1,243
Brazil	779	Setherlands	14
British Solomon Islands	2	New Zealand	1
Brunei	106	Niger	1
Bulgaria	24	Nigeria	34
Burma	1,724	Pakistan	936
Cameroon	3	Panama	5
Chad	19	Papua New Guinea	13
Chile	7	Peru	64
China (mainland provinces)	3,767	Philippines	3,954
China (Taiwan)	1,185	Poland	10
Colombia	93	Ponape Island	8
Costa Rica	16	Portugal	69
Cuba	130	Puerto Rico	40
Dominican Republic	9	Romania	15
Ecuador	46	Rwanda-Burundi	6
Egypt	32	Saudi Arabia	1
El Salvador	47	Senegal	725
Fiji	10	Sierra Leone	522
France	35	Sikkim	6
Gabon	1	Spain	45
Gambia	20	Sri Lanka	2,069
Ghana	43	Sudan	12
Guatemala	14	Surinam	94
Guinea-Bissau	47	Tanzania	76
Guinea-Conakry	237	Thailand	2,906
Guyana	30	Togo	3
Haiti	75	Tunisia	1
Honduras	1	Turkey	54
Hongkong	10	Upper Volta	5
Hungary	95	Uruguay	5
India	14,585	USA	1,106
Indochina (unspecified)	8	USSR	312
Indonesia	7,840	Venezuela	26
Iran	165	Vietnam	1,634
Iraq	16	Yugoslavia	3
Italy	138	Zaire	41
Ivory Coast	642	Zambia	17
Jamaica	6	Zanzibar	I
Japan	978	Origin unknown	1,245
Kampuchea	906	Africa (unspecified)	57
Kenya	32	West Africa (unspecified)	42
Korea	1,023	Central America (unspecified)	2
Laos	1,431	South America (unspecified)	5
Total			63,458

[a] As of 23 April 1983.

Table 3. Indigenous rice varieties collected with IRRI's direct or indirect participation in 14 collaborating countries. 1971 to 1982.

Country	Years	Indigenous varieties collected (no.) with IRRI's		Subtotal
		Direct participation	Indirect participation	
Bangladesh	1973-82	2,451	3,060	5,511
Bhutan	1975-76, 1981	–	1,249	1,249
Burma	1973-74, 1976, 1980-81	225	1,528	1,753
India	1976, 1978-82		2,266	2,266
Indonesia	1972-76, 1978-82	5,103	4,730	9,833
Kampuchea	1973	280	–	280
Laos	1972-71	–	898	898
Malaysia	1973-81	–	1,422	1,422
Nepal	1971-72, 1979-82	–	2,408	2,408
Pakistan	1972-73, 1976, 1979	–	776	776
Philippines	1973-76, 1977-82	630	2,565	3,195
Sri Lanka	1972, 1975-76, 1978-81	1,675	551	2,226
Thailand	1973, 1975-76, 1978-82	–	3,365	3,365
Vietnam	1972-75, 1978-81	108	710	818
	Subtotal	10,472	25,528	
	Grand total = 36,000			

other funding sources to pay for the field travel of local collectors, and 3) providing information on the samples collected in the past. The modus operandi will remain the same (cf. Chang and Perez 1975).

Priority for IRRI's participation in a country or region is based on:

1. The rate at which improved cultivars replace local or traditional varieties.
2. The richness of genetic diversity and the range of environments within countries or areas.
3. The time and extent of past collection and preservation efforts.
4. The accessibility of potentially rich germplasm areas to field collectors.
5. The extent of local (in-country) support for collection.
6. Funding from an outside source.

We need to identify at this workshop the potentially rich areas where immediate action within the next 5 years is needed to conserve the dwindling rice germplasm.

We would welcome suggestions and comments from the participants of cooperating countries and centers.

PROCESSING OF COLLECTED SEED SAMPLES

We have encountered the following problems in processing collected seed samples. Remedial measures are given for your comments.

1. Information on collection sites is frequently lacking. This information is essential and needs to be recorded in the field collection form.
2. Variety names are sometimes indicated only by a collection number. The names of rice varieties are very important in sorting out duplicates and in tracing origin.
3. Nonviable seed. Dead seed could belong to the previous season's harvest, or could be due to poor handling (drying) of samples or to delayed shipment.

4. Mixtures in a seed sample. If only a few seeds are "atypical" (different from the majority), they could be removed as "mechanical mixture." If several types are present in a sample, we find it difficult to identify the "true-to-name" type. Perhaps it would be better to take the collected seed to the national center in panicle form and sort out the off-types at the center before sending the seed to IRRI.
5. Insect-infested seed. Seed treatment was either lacking or ineffective, or the seed belongs to an old lot.
6. Over dusting of fungicide. Some seeds have been so heavily dusted with chemicals that our laboratory technician finds it difficult to handle the offensive dust in an air-conditioned laboratory.
7. Different spellings of variety names in the seed list and on seed envelopes. We generally inquire from the collector; if no response is received, we use the name on the envelope.
8. Some national centers forget to inform IRRI about the originating or collecting station. We inquire from the national center.
9. Poor packing. Improper packing often leads to broken seed packets and the mixing of seeds from different packets. Thus, the usable seed quantity is also cut down by poor packing.
10. Insufficient seed. An extra cycle of planting is required to produce sufficient seed for field planting.
11. Varieties without a designation. We have many "Unnamed" varieties in our registry. We also need to know the culture type and special characters, if any.
12. Work load. During the last decade we received from 4,700 to 8,400 seed samples each year. The quantity has not only overloaded our capacity to grow the seeds but also delayed the initial planting of the collected samples.

REGISTRATION AND CHARACTERIZATION

Many incoming samples from neighboring areas and collected by different workers bear the same or nearly identical names. This poses difficulties for us, although we recognize that 1) some samples are obvious duplicates, 2) some are morphologic variants of a given cultivar, and 3) some are ecotypes of a given cultivar that has been dispersed and grown at different locations. However, it would take a long process of comparing grain characteristics in the laboratory and plant characteristics in the field (where probable duplicates are planted) before the duplicates could be sorted out. If several samples are obvious duplicates, we bulk the seeds to form one accession. We now assign accession numbers only after the initial planting is completed.

SEED REJUVENATION

The canning phase of preparing seed for storage in the medium-tem (MT) and long-term (LT) storerooms began in 1980. Since then we have planted 39,547 accessions for seed rejuvenation. Every seedlot is visually inspected and only the

well-developed, healthy and true-to-type seeds are selected for drying and canning. However, the accessions actually canned and stored amounted to only 10,284 or 25% of the plantings. The constraints were 1) low seed yield of many traditional varieties, 2) ravages of diseases and insects on the IRRI farm, and 3) mixtures in the original seeds, many of which came from the farmers' fields or bins. We often find it necessary to check with the seed file to identify the true-to-type seeds.

Beginning in 1983 we have rented a 5-ha farmer's field in Masapang (20-minute drive from IRRI) for seed rejuvenation. We found that pest incidences were minimal at the new site and good harvests are forthcoming. But neighboring farmers harvested a number of our exotic-looking bulu varieties before we had the opportunity to do so. The total planted area for *O. sativa* accessions in the 1983 season is 12 ha.

SEED PRESERVATION

Our conserved seedstocks are nearly halved between 1) old seedlots stored inside airtight glass jars in the MT storeroom, and 2) seeds at various stages ranging between initial seed increase and LT storage inside aluminum cans. Fresh seeds of 6,678 accessions were recently deposited at the US National Seed Storage Laboratory at Ft. Collins, Colorado, USA.

Aside from insufficient seed quantity, we also encountered a few other problems: 1) differential seed longevity among ecogeographic races or varieties of different national origin, 2) death of a small number of accessions during storage, and 3) suspected reduction in seed longevity of virus-infected plants. We were able to re-acquire seed of some "dead accessions" from the originating national centers.

On the basis of the control samples, we are scheduling seed rejuvenation cycles by variety-groups. We are also studying the effect of virus infection on seed longevity and have initiated comparative studies on seed drying temperatures and seed containers.

SEED DISTRIBUTION

The distribution of seed to rice researchers inside and outside IRRI has remained a major task of our global services. The number of seed requests processed and seed samples provided during 1973-82 are in Table 4.

Since 1962 our bank has provided more than 80,000 seed samples of the 2 cultigens and wild species to thousands of rice scientists around the world. The more than 2,500 requests indicate the magnitude of experiments for specific objectives being conducted by rice researchers in different countries. The bank has also supplied the IRRI staff with more than 300,000 seed samples, averaging about 30,000 samples a year during the last decade. Again, the statistics show the scope of IRRI's research activities under its Genetic Evaluation and Utilization (GEU) program, which was formalized in 1974.

The computerized data processing, storage, and retrieval services provided by

Table 4. Progress of the IRRI Genetic Resources Program in the preservation and distribution of seed of *Oryza sativa* cultivars, 1973 to 1982.

Year	Distinct accessions in germplasm bank	Inside IRRI		National programs	
		Samples distributed (no.)	Requests (no.)	Samples distributed (no.)	Requests (no.)
1973	24,162	8,275	66	9,777	95
1974	26,818	20,498	108	2,603	83
1975	30,332	22,155	151	4,043	150
1976	34,229	40,200	194	4,819	137
1977	36,956	50,354	196	4,126	148
1978	40,768	31,941	182	7,316	142
1979	47,743	26,694	268	3,260	157
1980	53,431	29,734	337	3,659	156
1981	57,027	29,053	319	4,376	206
1982	60,181[a]	33,975	279	11,075	154[b]

[a] About 4,566 recently received seed samples are yet to be grown and registered; 8,630 duplicate accessions and 4,823 nonviable seed samples were removed from the registry during 1973-82. [b] Excluding 19 requests of 254 samples delayed by quarantine clearance.

our Statistics Department have been most helpful in meeting foreign seed requests for specific requirements. Moreover, by providing researchers who made broad and general requests with a computer printout, we assisted the requesting scientists in narrowing down their requests to more manageable sizes.

The drawbacks in our services are 1) insufficient seed to meet requests for seed quantities above 50 g/request, 2) meager seeds of unadapted or pest-susceptible varieties, 3) two or more accessions with the same name but may be of different genotypic composition, and 4) an accession in the germplasm bank may remain as a bulk of slightly different genotypes although IRRI plant pathologists and entomologists may have produced by selection a population having more homogeneous reaction to a pest. Many rice researchers overlooked the need to record IRRI accession numbers and, therefore, the hybridization or experimental records are incomplete on this important item. Recently our Statistics Department started furnishing every requesting party with a printout of the accession numbers.

We have returned thousands of accessions to the originating countries when such accessions were no longer viable or available in the national centers. Recipients include Bangladesh, China, India, Indonesia, Kampuchea, Kenya, Nepal, Pakistan, Philippines, and Thailand.

EVALUATION AND USE

Throughout the last two decades, seeds furnished by our bank have provided most of the gene sources for high yield potential, early maturity, resistance to diseases and insects, tolerance for adverse soil factors, resistance to water deficit or excess, tolerance for extreme temperatures, and grain quality. The principal beneficiaries are the IRRI GEU scientists who tested the germplasm under the Genetic Evaluation and Utilization Program and used the promising sources for breeding.

Scientists in national programs either directly or indirectly draw on the IRRI collection for the desired genes. The IRRI accessions continue to serve as one of the major sources of entries in the International Rice Testing Program (IRTP).

When cultivars locally reputed to possess tolerance or resistance to climatic, biotic, hydrologic, or edaphic stresses were collected from areas having such ecological constraints, we channeled the seeds to the appropriate GEU scientist at IRRI for accelerated evaluation. Several outstanding sources have been identified through this process of advancing the testing sequence for the special types.

The profitable use of the IRRI accessions has been documented in other publications (Chang et a1 1975, 1982; Khush 1977; Chang 1980, 1983).

PLANT QUARANTINE

IRRI recently strengthened the plant quarantine measures before sending seeds abroad. A Rice Seed Unit was set up in 1981 to streamline the selection and treatment of seed and to ensure that all plant quarantine requirements of the importing countries are met. A trained seed pathologist is conducting plant health tests on seeds produced by IRRI.

Measures are also planned to strengthen the post-entry plant quarantine inspection of foreign accessions.

TRAINING

Our role in training has been confined to 1) short-term resident training on germplasm management, 2) short course on field collection in cooperating countries, and 3) assisting in other training courses on genetic resources, such as those held in India, Indonesia, and the Philippines. We need to strengthen graduate degree programs and to hold formal training courses on germplasm management.

TECHNICAL ASSISTANCE ON SEED STORAGE

We have directly or indirectly assisted a number of national research centers to improve or establish their seed storage facilities. We have also channeled IBPGR funds to purchase small pieces of equipment or spare parts for seed storage or processing units at national centers. This type of assistance will be continued.

CONCLUDING REMARKS

1. IRRI will continue to coordinate and assist (or catalyze) field collection activities by pooling financial and manpower resources. The goal is to complete within the next 5 years and to the fullest possible extent the field canvassing and assemblage of all indigenous germplasm in areas accessible to collectors. The wild species will receive more attention than in the past. I. Roy Denton and other IRRI staff members are ready to assist in the field collection activities.

2. IRRI will continue to collaborate closely with IBPGR on the field collection, training courses, and technical assistance toward the improvement of seed storage facilities at different national centers.

3. IRRI can reassure all donor agencies that the rice germplasm deposited at the IRGC will be given the fullest care in preservation. Meanwhile, the donors should feel free to retrieve their cultivars from the IRGC if and when needed.

4. IRRI can freely-supply morphoagronomic as well as GEU-traits data to any interested rice researcher to assist in research planning or for identifying appropriate test materials.

5. IRRI needs the collaboration and assistance of donor agencies in seed rejuvenation or, better still, for the supply of fresh seeds for canning in the case of unadapted or susceptible accessions. This will lessen the heavy burden on the IRGC and will improve the efficacy of preservation.

6. Duplicate sites of storage for all conserved stocks of major centers are desirable. IRRI will continue its dialog with NIAS, USDA, IITA, IRAT, WARDA, and other centers on this phase of cooperation.

7. IRRI will seek a greater extent of collaboration and assistance from all cooperating agencies by setting up an international advisory committee to the IRGC.

8. We thank each and every one of you for the magnificent cooperation received in the past. We look forward to a closer working relationship in the next 5 years with the increased input from the IBPGR. We also welcome your suggestions for further improvement of the collaborative efforts on a global basis.

GENERAL DISCUSSION ON THE STRATEGY FOR PLANNING AND IMPLEMENTING FIELD CONSERVATION

The following comments and suggestions were presented by the participants:

H. I. Oka: Field collection efforts should aim to capture 95% of the genes in existing populations. Efficient identification of duplicate samples is very much needed.

S. D. Sharma: I concur that if 85 to 90% of the variability in rice germplasm is collected, this pool would contain nearly all of the genes in various combinations.

T. T. Chang: Complete information on variety names, collection sites, and culture type should be recorded by every field collector.

The "Manual for field collectors of rice" (1972) needs to be revised. The participants are requested to send in their comments and suggestions toward improvement of the widely used manual.

I. R. Denton: An improved field collection form is presented for review and adoption (see p. 69).

M. Anishetty: The IBPGR is preparing a new collector's manual which will be studied by its Seed Committee. Cooperation with IRRI on the new manual is a definite possibility.

K. Miezan: Information obtained from primary evaluation is essential to the planning of future collecting activity. Such information should be more extensively used by the collectors in designing sampling strategy and size.

Intensified national involvement is needed to complete the conservation activities in Africa.

J. K Roy: For the collection operation in India, the IBPGR and IRRI should urge the state governments to mobilize workers at the village level to speed the collection process.

R. B. Singh: If we consider that roughly 60% of the indigenous forms have already been collected, the remainder (wild species and peripheral populations under different selection pressures and stress conditions) require a different collecting strategy, employing more specialized collectors.

The loss of material from gene banks in developing countries should be minimized by providing cold storage facilities.

In threatened habitats, government authorities should develop gene sanctuaries or protected natural conservation areas in an evolving dynamic system.

H. I. Oka and *S. D. Sharma* presented the following recommendations for collecting and conserving the wild species of *Oryza:*

I. Collection
   1. When the target species is common, sample as many populations as possible, preferably those in different environmental conditions.
   2. When the target species is rare, a collector must make an effort to locate

the site by examining the herbarium sheets and also by consulting the local people and asking them to serve as guides.

3. Sixty or more individual panicles should be collected at random from one population.
4. Environmental conditions of the habitat must be recorded, e.g., water regime, distance from cultivated rice fields, degree of disturbance of the habitat by man, presence or absence of natural hybrids with cultivated rice, ecological dominance over coexisting weeds, etc.

II. Seed multiplication

1. Populations of wild species are genetically heterogeneous. They continue to segregate and cannot be considered as fixed lines.
2. Seeds collected separately from single plants are suitable for regeneration by the pedigree method, to raise a number of inbred lines representing the population. When within-population variation is large and considered to be important, the pedigree method should be followed.

   When between-population diversity is considered more important than within-population diversity, the bulk method should be followed. This is useful when many populations are to be handled.
3. Isolation is necessary because wild species are cross-pollinated to different degrees. Isolation can be either by bagging (mainly by pedigree method) or by spatial separation (mainly by bulk method).

   Bagging for self-pollination consumes much human labor. The distance necessary for isolation is not well known but is assumed to be a minimum of 20 to 30 m.

   A checkerboard arrangement of regenerating populations, rather than rows, is recommended to reduce natural hybridization between neighboring populations.
4. For harvesting seed, bagging is necessary because in wild species seeds readily shed at maturity. The use of nylon bags to enclose a whole plant may be recommended. Each bagged plant should be supported by a bamboo stick.
5. Some wild species of perennial type have a very low seed productivity, 1 or 2 g/plant. With such type of plants, permanent conservation of living plants in isolated beds is recommended.
6. The regenerated population may be 60 or more plants per population by the bulk method, and 20 to 60 lines per population by the pedigree method.
7. The seeds of wild species are strongly dormant, and for germinating fresh seeds, special techniques for breaking dormancy are necessary. The longevity of seed in storage may differ according to species and initial physiological condition of the seed. But seed longevity may not be significantly different from cultivar longevity if fully matured seeds are kept in storage.

FIELD COLLECTION FORM

EXPEDITION/ORGANIZATION _____
COLLECTORS _____
SPECIES NAME _____
(if not *O. sativa*)
VERNACULAR/CULTIVAR NAME _____
_____
LANGUAGE _____
MEANING _____
LOCATION: Lat. _____ N _____ S
Long. _____ E _____ W
Alt. _____ (m)

VILLAGE (or distance and direction from nearest settlement) _____
_____
TOWN/CITY _____
DISTRICT/PROVINCE _____
GROWER'S NAME _____

COLLECTION SOURCE (circle one)

farmland	1	institute	6
threshing floor	2	bordering field	7
farmstore	3	wild	8
village market	4	others (specify)	9
commercial market	5		

STATUS OF SAMPLE

wild	1
weedy	2
primitive cultivar	3
others (specify)	4

TYPE OF SAMPLE

seeds	1	panicles	2	vegetative	3

HERBARIUM SAMPLE yes no

VARIETAL SAMPLE

single variety	1
varietal mixture	2

SAMPLING METHOD

random	1	non-random (specify)	2

ORIGIN

local	2	exotic (specify)	2 _____

VARIETY GROUP

indica	1
japonica	2
sinica	3
javanica	4
hybrid (intermediate)	5

FREQUENCY

abundant	1	occasional	3
frequent	2	rare	4

_____
_____
_____
_____

ACCESSION NO. _____
COLLECTION NO. _____
DATE OF COLLECTION _____
Photo No. _____
Map Sheet _____

CULTURAL TYPE:

irrigated	1
rainfed-lowland	2
deepwater	3
upland	4
tidal wetland	5

CULTURAL PRACTICES:

shifting	yes	no
terraced	yes	no
direct seeding	yes	no
double transplanting	yes	no
mixed stand	yes	no

SOWING DATE _____
TRANSPLANTING _____
HARVEST DATE _____
USAGE _____
_____

TOPOGRAPHY:

swamp	1
flood plain	2
plain level	3
undulating	4
hilly	5
mountainous	6
others (specify)	7

SITE:

level	1	summit	3
slope	2	depression	4

SOIL TEXTURE:

sand	1	silt	4
loam	2	highly organic	5
clay	3		

DRAINAGE:

poor	1	good	3
moderate	2	excessive	4

NOTES: (pests/diseases, special plant characters, status of genetic erosion, grain characters, other observations)

_____
_____
_____
_____
_____
_____

Collection No.	Collection No.
_____	_____
Date	Date
_____	_____

SEED PRESERVATION

SEED PRESERVATION FACILITIES AND PROCEDURES FOR NATIONAL CENTERS OF DEVELOPING COUNTRIES

E. H. ROBERTS

FACTORS AFFECTING THE LIFE-SPAN OF SEEDS IN STORAGE

Seeds start deteriorating as soon as they mature on the mother plant. The rate of deterioration depends mainly on seed moisture content and each temperature decrease of 5° C. Thus, to obtain high quality seeds it is necessary to harvest and dry the seeds promptly when maturity is reached and, for medium- or long-term preservation, to place the seeds in a cold store as soon as possible.

There are many symptoms of deterioration. At the cellular level there is a gradual loss of membrane integrity and enzyme activity, which leads to decline in vigor manifested in slower germination and decreased ability of seedlings to emerge from poor seedbed conditions. Changes, which also occur in the nucleus, result in some chromosome aberration and mutation. Ultimately the seed dies, i.e. loses viability. All these processes and thus loss of viability can be very markedly reduced (though not entirely eliminated) by storing seeds at low moisture contents and temperatures. However, even within a single accession stored under identical conditions, there is considerable seed-to-seed variation in longevity. This variation in individual life-spans is normally distributed and seed survival curves are typically sigmoid. The initial slow decline in germination percentage is followed by a rapid decline (most rapid at about 50% viability), and then by a gradual decline until the whole accession is dead.

The mean life-span of an accession in storage will therefore depend on three factors: the initial quality of the seeds, seed moisture content, and storage temperature. It is now known that under identical storage conditions there is genotypic variation in potential longevity: some genotypes store better than others. The initial seed quality therefore partly depends on genotype (which is outside the control of the seed bank) and partly on the environment experienced by the seeds before they were placed in store; hence the emphasis on prompt harvesting, drying, and processing. The shape of the survival curve indicates considerable deterioration after harvest. However, that is reflected only in minor percentage decreases in viability from the initial value. A high viability percentage when seed is placed in store indicates that the seed is of very satisfactory quality and will have a long life expectancy. If the initial tests show viability percentage values less than, say, 90%, that would indicate that the remaining viable seeds in the sample have already undergone a significant amount of deterioration and will have a considerably reduced longevity. Accordingly, when a considerable number of accessions have low initial viability, harvesting, drying, and processing procedures ought to be examined and improved where necessary.

SEED DRYING

Seed drying is probably the most important aspect of processing to prepare seeds for storage. It needs considerable care because inappropriate methods can lead to unnecessary seed deterioration. It should be obvious by now that if the seed is relatively moist at harvest, say 15% or more, the drying procedure should be started with as little delay as possible. Seed drying is a complex subject and only a few points will be emphasized here. Further details may be found in Cromarty et a1 (1982).

The safest general-purpose method for seed banks is to provide a drying room in which seeds are spread out to dry in trays in a controlled atmosphere: about 15° C and 10 to 15% relative humidity. If such facilities are not available, either sun-drying or systems based on forced ventilation with heated air may be used. Traditional sun-drying is carried out by spreading seed in thin layers on a drying floor and raking from time to time. Precautions are needed to prevent accidental mixing of accessions and, if rain showers are possible, it is necessary to guard against rewetting by removing or temporarily covering the seeds. In many cases rice seeds can be sun-dried to about 10-11% moisture content in 2 or 3 days. Seeds should be removed from the drying floor at nighttime since relative humidity often increases markedly as the air temperature drops.

It is usually difficult to dry seeds much below about 11% moisture content with sun-drying. This is adequate for short-term storage, but for long-term storage further drying is necessary. This can be achieved by desiccation of small batches with silica gel in sealed containers.

If a seed dryer based on forced ventilation with warm air is used, it is important to ensure that the air temperature does not rise above relatively safe values. The temperature of the air in the dryer should not exceed 40° C if the seed is very moist (25 to 30%), but could be increased to 60° C when the moisture content of the seed has been reduced to 20% or below. It would be simpler to dry at 40°C throughout, but in some humid tropical environments the reduction in relative humidity resulting from heating the air to this temperature would not be sufficient to allow the seeds to dry to the recommended 5-7% moisture content level (IBPGR 1982) for long-term storage.

MEDIUM- AND LONG-TERM STORAGE

Medium-term seed stores

Medium-term stores are classified by IBPGR as those in which the temperature is controlled within the range 0° to 10° C. They are often used for active collections. In such stores seed moisture content can be controlled indirectly by controlling the relative humidity of the air; in that case the accessions can be placed in any kind of container that does not have to be sealed, provided the relative humidity is sufficiently low to maintain the seed moisture content at the required level. Examples of approximate equilibrium moisture contents (percent wet weight basis) for rice seeds at various relative humidities (in parentheses) are as follows: 4.6 (10%), 7% (20%), 8% (30%), 10% (40%), 13% (60%), 15% (80%), 17% (90%); but

precise values vary with cultivar and seed lot.

Alternatively, moisture content can be controlled by drying to the required moisture content and then using sealed containers. The life expectancy for rice under a wide range of conditions has not yet been worked out, but for a rough guide as to what might be expected, the monograph published for barley could be consulted (Cromarty et al 1982).

Long-term seed stores

Long-term stores are those which are controlled at temperatures below 0° C, preferably in the range from –10° to –20°C. In this type of store it is best to control seed moisture content by using sealed containers. Any container which prevents the ingress of water vapor will do. Screw-capped jars or cans with rubber seals, sealed food cans, or heat-sealed laminated aluminum foil packets are all used satisfactorily by different seed banks. If screw-capped jars or cans are used, it is important to make certain the sealing gasket is adequate. Natural rubber is satisfactory and so are some plastics, but experience has shown that several plastics are not. Laminated foil packets are very convenient but are not suitable for large bulks (e.g. more than about 600 ml.). Robust specification should be used and the packets should be obtained from a reliable manufacturer. Some packets which have been tested are very porous and completely unsuitable. Whatever system is used, it is important to test that the container is moisture proof. One way is to fill it with water, weigh it, put it in a desiccator, and see if the weight changes over a period.

Because the moisture content of seeds in long-term stores is controlled by sealed containers, the design of such stores is relatively straightforward. All that is needed is a reliable cold room with a reliable electricity supply. But the electricity supply is not as vital as it would be, for example, in a meat store, for a temporary loss of refrigeration is not disastrous. There is no evidence to suggest that a *change* in temperature affects seed viability. If the temperature were to rise to ambient values for a few days, that would be no worse than delaying entry into the store by the same number of days. And, since the moisture content of the seeds will be maintained at the same low value throughout in the sealed container, the deterioration at ambient temperatures would be almost impossible to detect. Nevertheless, if the electricity is very unreliable, it is well to have a stand-by generator.

For small seed collections, conventional domestic deep-freeze cabinets are easily obtainable and very convenient (Cromarty et al 1982, Ellis and Roberts 1982). They vary in capacity from about 140 to 600 liters. Not all the internal volume is occupied by seeds because the packaging and retrieval systems take up space, but a 600-liter chest would accommodate more than 160 accessions, each of 16,000 rice seeds, or more than 1,600 accessions each of 2,600 seeds. Larger collections could be housed in several chests. Costs of running several units would be greater than those for a cold room of equivalent capacity and, if more than 10-15 m^3 of storage space are required, the capital costs of a prefabricated cold room are less (Ellis and Roberts 1982). Prefabricated portable cold stores of 25 to 55 m^3 can be purchased and are certainly preferable when storage capacity of this size is

required. The economics of constructing and running cold stores are dealt with in detail in a recent report (Cromarty et al 1982).

THE SIZE OF ACCESSIONS

It is not easy to decide what the size of an individual accession should be. Determining factors are ease of collection, the genetic variability within the accession, and estimates of the size and number of samples which are likely to be withdrawn from it in the foreseeable future. In addition to samples for distribution to working collections, a sample will be needed for carrying out an initial viability test and subsequently at, say, 10-year intervals for monitoring viability (see below). As a guide, IBPGR suggests that 12,000 seeds would be appropriate for genetically heterogeneous material and 4,000 seeds for genetically homogeneous material (IBPGR 1982). In the case of rice, collections from the wild or farmers' fields might be considered heterogeneous, whereas improved cultivars could be considered homogeneous. Local circumstances may suggest quantities different from those suggested by IBPGR.

GERMINATION TESTS TO MONITOR VIABILITY

It is necessary to estimate the initial viability of an accession when it is placed in store and to subsequently monitor its viability (at relatively infrequent intervals) to see when the accession needs regeneration, i.e. when plants need to be grown to provide fresh seed to replace those in store which are losing viability. Because of the induction of mutation associated with loss of viability and because of the possibility of genetic selection in storage in heterogeneous accessions (longevity is partially under genetic control), it is recommended that accessions be regenerated before the viability percentage reaches low levels.

The viability percentage at which it is decided to regenerate an accession is known as the regeneration standard. This is somewhat arbitrary and is a compromise between practical feasibility and the problems just mentioned. For cereals and many other arable crops whose initial viability is normally high, 85% viability is considered a suitable regeneration standard (IBPGR 1982). Under IBPGR recommended long-term storage conditions (−20°C and 57% moisture content) and assuming an initial viability of 95% or better, it is unlikely that rice regeneration would be necessary for several centuries (although of course we cannot be certain until seed banks have been running for much longer!).

It has also been suggested that the initial viability test be carried out on 400 seeds (using methods similar to those prescribed by the International Seed Testing Association). However, the methods for breaking dormancy suggested by ISTA may need to be modified by seed banks, which often have to deal with more dormant material than is encountered in official seed testing stations: seed banks need to store material as soon after harvest as possible and they often have to deal with primitive cultivars and wild material, which usually show more pronounced dormancy. Recent work (Ellis et al 1983) has shown that one ISTA recommendation, germination in an alternating temperature regime of 20°/30° C is probably

adequate for many *japonica* cultivars that show little dormancy; however, It is preferable that the higher temperature be given for 16 h and the low temperature for 8 h (and not vice versa as suggested by ISTA). The use of the other ISTA method (presoak for 24-48 h in water at 48°C) is not very effective and, more important, is damaging to seed of some cultivars. An alternating temperature regime of 34°/11°C (higher temperature for 16 h, lower temperature for 8 h) is preferable for *javanica* and *indica* cultivars. But where considerable dormancy is expected, i.e. in *O. glaberrima* and some of the more dormant *indica* cultivars of *O. sativa*, the following procedure has been found very satisfactory. Soak at 20° C for 24 h in 0.1 M HNO_3, then soak further for 25 h in 0.25 M H_2O_2. This is followed by germination in 0.01 M 2-mercaptoethanol in an alternating temperature regime of 16 h at 34° and 8 h at 11°C. (The temperature regime quoted is optimal, but some minor variation from it would not be significant.) This combines the effects of five stimulatory agents: hydrogen ions, nitrate ions, hydrogen peroxide, a sulphydryl compound, and alternating temperatures. It seems complicated, but in practice is simple to carry out. Alternatively one can use heat treatments on dry seeds (e.g. Carpenter and Roberts 1962, Chang 1976), but such treatments are inadequate for deeply dormant *glaberrima* cultivars.

The initial viability test should be carried out on a fixed sample size (400 seeds), but to obtain a reasonably accurate estimate of initial viability it is suggested (IBPGR 1982) that a different procedure be used in subsequent monitoring tests. This is because now the aim is to determine whether or not the viability percentage of the accession has fallen below the regeneration standard. To this end a *sequential-probability-ratio test* was developed. It answers the question more accurately than a standard germination test performed on 400 seeds and, on the average, uses about half as many seeds. The theory is complicated (Whitehead 1981) but the practice is simple (Ellis et al 1980). The total sample size is not predetermined, but emerges during the course of the test which is carried out using a sequence of subsamples, each of 40 seeds (Table 1). It begins with a

Table 1. Sequential germination test plan for a regeneration standard of 85% viability, using subtest groups of 40 seeds (Ellis et al 1980).[a]

	Instruction according to number of viable seeds in test		
Seeds tested (no.)	Regenerate if no. of viable seeds is equal to or less than	Carry out further subtest if no. of viable seeds is between	Regeneration not necessary if no. of seeds is equal to or greater than
80	64	65- 75	76
120	100	101-110	111
160	135	136-145	146
200	170	171-180	181
240	205	206-215	216
280	240	241-250	251
320	275	276-285	286
360	310	311-320	321
400[a]	345	346-355	356

[a]If no decision is reached after 400 seeds have been tested, it is suggested that regeneration be carried out since the probability is high that the viability of the accession will be very close to the regeneration standard.

germination test on two subsamples. If the number of seeds that germinate is 76 or more, it may be assumed that the viability percentage of the accession is above 85%. If the number which germinate is 64 or less, it indicates that viability is less than 85% and the accession should be regenerated. In either case the test ceases at this point. However, if the number of germinated seeds is between 65 and 75, then there is insufficient information for a conclusion and a third subsample of 40 seeds is set to germinate. The result is added to the previous tests. If the number germinated is 111 or more, it may now be concluded that the viability of the accession is above 85%; if it is 100 or less, the accession is below 85% viability and it is time to regenerate; but if it is between 101 and 110 there is still insufficient information to reach a decision and another subsample is tested and the result added to the previous results, and so on, according to Table 1. This procedure is continued until a decision is reached. When the viability of the accession is high a decision is normally reached in the first four subtests, and thus seeds are not wasted unnecessarily. The number of subtests increases as the viability of the accession approaches the regeneration standard. In this way, there is a considerable saving of seed while maintaining a high probability of taking the right decision. The test is simple to use, for the technician only has to follow the procedure in Table 1 to come to the right decision.

SEED STORAGE STUDIES AT IRRI

T. T. CHANG, VERENA TOLENTINO, MERCEDES B. PARKER,
and FLORA CREDO

Our findings from a number of seed storage experiments dating back to 1964 are excerpted. The information obtained has been most useful in providing guidance on the seed processing and storage operations of the International Rice Germplasm Center (IRGC). The salient points follow:

1. Rice cultivars differ markedly in seed longevity under short- and medium-term storage. There are indications that seed longevity is associated with grain dormancy levels and, probably, with chemical composition of the starchy endosperm.
2. High-temperature (50°C or above) drying is deleterious. Drying with repeated changes of activated silica gel granules inside a large airtight container helps to prolong longevity. IRRI presently uses low-temperature (38°C) heating by feeding chilled and dehumidified air (13°C at 8% RH) into the drying ovens. A seed moisture content of 6% is attained after 19 hours.
3. Airtight seed containers are a prerequisite for preservation of seed longevity. Polyethylene film and jars are good only for 4 years before they begin to leak air.
4. Rubber gaskets (seals) of metal cans should be of the solvent-based type, rather than the water-based type.

To sum up, the extra cost and time invested in preparing seed for storage will repay handsomely in the long run.

INTERINSTITUTIONAL COLLABORATION ON EXCHANGE AND PRESERVATION OF RICE GERMPLASM

Realizing that specific arrangements for exchange should be worked out by researchers, agencies; or countries involved, and with the expectation that all rice genetic resources shall be freely available for the benefit of all mankind, the following general principles are suggested:

1. For security, seed of each accession should be prepared at geographically separated duplicate sites within the originating country or in a second country. For maximum security and in line with the policy of IBPGR, whenever possible the alternate sites should be in another country.
2. The need to observe specific quarantine regulations of participating countries is recognized. However, it is hoped that arrangements can be made to modify quarantine requirements where seed batches are sent to alternate sites only for safekeeping.
3. For security purposes, freshly grown seed should be used in systematic exchange of batches destined for storage at an alternate site. For frequently used varieties, special arrangements should be made with the originating station or national center to supply limited amounts of seed on request. For large experiments of a continuing nature, it is usually necessary for the experimenter to make at least one seed increase on site to produce adequate seed supplies for such experiments.
4. Each center faces problems in seed increase or rejuvenation when the accession, especially a foreign introduction, is ecologically unadapted or highly susceptible to local pests, diseases, or soil problems. Therefore, cooperation and assistance from the originating center are sorely needed in seed rejuvenation, preservation, and distribution of such accessions.

CONCLUDING REMARKS

L. KÅHRE

I thank all participants for their fine cooperation during the intensive two-day workshop. My sincere appreciation goes to Dr. M. S. Swaminathan for all the courtesies extended by the IRRI staff. I am particularly grateful for the opportunity to attend the workshop and to learn more about the techniques and priorities in rice germplasm conservation. Because the planning for collection, preservation, exchange, and utilization of rice germplasm appears to be on safe grounds, I am encouraging all to adopt the philosophy, "the future is bright."

The discussions on wild species were most pertinent and valuable, particularly their potential for improving rice varieties grown under stress conditions. Perhaps current research in the techniques of genetic engineering may offer another promising tool for use by plant breeders.

My thanks go to Dr. T. T. Chang for the outstanding leadership he continues to give in this very important activity. We are working for the benefit of all mankind and meetings such as this workshop are necessary and have utmost importance, not only for IBPGR and IRRI, but primarily for all nations and all scientists involved.

I assure the participants that IBPGR will do its utmost to fulfill the expectations entrusted to it. But, at the same time, I wish to emphasize the importance of the mutual cooperative efforts of scientists and institutions at the global level.

CLOSING SESSION

M. S. SWAMINATHAN

As we close the workshop, let me summarize its major achievements.

Agreement was reached on a three-pronged approach to the conservation of rice germplasm, incorporating *national, regional,* and *global* components. The national approach will involve activities aimed at establishing well-defined strategies and programs of operation within countries. On a wider scale, a network of regional services and activities should be encouraged which, in turn, would be serviced and coordinated on a global basis.

• At the *national* level, the participating countries' reports describing their methodologies and activities in field collections, their priorities for future collecting, and progress made in evaluation and utilization programs were enlightening.

Adequate storage facilities, at least of the medium-term type, are a basic requirement for all national programs, for both the maintenance of national collections and the periodic replenishment of breeders' working collections. In many cases, rice is part of a larger, multicrop germplasm network.

Continual monitoring and documentation (particularly in local languages) of existing germplasm collections and an increase in the degree of training of field collectors to facilitate more thorough canvassing of target areas are needed at the country level.

I am encouraging the participants to articulate with their national leaders in formulating year-by-year work plans and to refine priorities in greater detail. This would greatly help to further the progress of national programs and strategies in the next five years.

Progress in developing regional and global activities can be attained through international coordination. The key services of IBPGR play a major role in the promotion of such organized cooperation.

• The *regional* approach is of particular significance where small countries encounter difficulties in organizing such essential activities as seed storage, documentation services, or training at the national level. Agreement between such countries to establish international germplasm conservation activities, coordinated on a regional basis, should be encouraged. International cooperation is well exemplified by the success of the Nordic gene bank in Sweden, which was established through the collaboration of Scandinavian countries.

During the workshop, it was decided that a regional meeting for Africa will be organized to discuss individual country requirements and plan future collaborative activities in germplasm conservation.

In the future, we will need to develop plant quarantine measures on both the regional and the national levels for more effective international exchange of germplasm.

• The *global* aspect, under the umbrella of the IBPGR and FAO and with cooperation from IRRI, can provide important services at the broadest level.

These agencies coordinate in appropriate storage techniques and international long-term storage facilities. They can assist in the establishment of alternative sites for security of the major rice germplasm collections and also provide guidelines on standardization of plant quarantine measures. At the global level some modifications may be required, e.g. a third-country quarantine facility for safekeeping of germplasm in long-term storage.

I wish to emphasize the importance of developing efficient systems of documentation as well as the need to expand training and manpower development in all aspects of germplasm conservation.

Global collaboration can also be useful in advancing research into such problems as seed rejuvenation for diverse ecological niches and adaptation of tissue culture techniques to germplasm conservation and utilization.

The importance of the wild rice species and the need for their collection, description, maintenance and evaluation as future sources of resistance to various production hazards cannot be over-emphasized. Early collection of the wild rices in isolated areas of South America should be high on our priority list.

The present IBPGR-IRRI Rice Advisory Committee should be continued because it functions as an invaluable think-tank, providing a source of ideas for the development and adoption of strategies on an international collaborative basis.

With the establishment of the International Rice Germplasm Center (IRGC) at IRRI, under the leadership of Dr. T. T. Chang, an IRGC Advisory Committee will be set up. Its functions will be to review, give advice, and guide the policies of the IRGC and monitor its progress. The Advisory Committee will have three major groups of representatives:

- scientists from the national programs,
- independent scientists (experts), and
- some members of the IBPGR-IRRI Rice Advisory Committee.

IRRI will publish an annual report on behalf of the IRGC. The report will provide information, solicited from the national programs, on progress in and constraints to global rice germplasm genetic resources activities. It will therefore provide a balance sheet and serve to review and update national priorities.

The IRGC Advisory Committee should give more attention to manpower development and training at all levels. Valuable training courses, such as that on the Conservation and Utilization of Plant Genetic Resources at Birmingham, UK, should continue and additional training centers of this type should be developed elsewhere around the world. We hope that IBPGR will favorably evaluate its support of the Birmingham course to ensure that in addition to its continuation, similar programs are organized in the major centers of genetic diversity. Such training should contain two main components:

- basic theoretical study, and
- an additional period, perhaps 9-12 months, of practical field training in collection and conservation techniques at an appropriate international agricultural research center.

The proceedings of the workshop should be published and the copies made available in time for the XV International Congress of Genetics to be held 12-21 December 1983 in New Delhi. The congress will have the theme, ‘Genetic

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PLAN FOR FIELD COLLECTION, SOUTH ASIA, 1983-87

Country	Coordinating and executing agencies [c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source [d]		
							N	L	0
			1983						
Bangladesh [a,b]	*BRRI* and Dept. of Agric. Extension	Rajshahi and Sylhet	Boro	I	May	25	X	X	
		Barisal, Bogra, Noakhali, and Rajshahi	Aus	I	Jul-Aug	50	X	X	
		Rajshahi, Pabna, and Rangpur	Wild and deepwater types	I	Oct-Nov	50	X		X
		Mymensingh	Tribal rices	I	Oct	20	X		X
Bhutan [a,b]	*Dept. of Agric.*	Western Region: Paro and Thimpu	Upland and cold-tolerant types	I	Sep-Nov	50			X
India [a]	CRRI, *NBPGR*, ICAR Res. Complex, agricultural universities, and State Dept. of Agric.	Andhra Pradesh, Bihar, Orissa, Uttar Pradesh, and upper Assam valley	Upland, lowland, coastal saline types and wild species	Uplands and coastal saline types	Sep-Nov	700	X		
Nepal [a,b]	*NRIP*, *ICP* and Regional Farm ADO's	Eastern Nepal: Tamur Kosi River belt to high altitude and isolated areas	Upland, cold-tolerant, irrigated, midland bulu-like, and tropical types	Upland, cold-tolerant, midland bulu-like, tropical types and wild species	Sep-Dec	200-300			X

Plan for field collection, South Asia, 1983–87. (Continued)

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[d] N	L	O
			1984						
Bangladesh [a,b]	*BRRI*, and Dept. of Agric. Extension	Jessore, Rangpur, Patuakhali, and Comilla	Aus, transplanted aman and wild species	I	Jul-Aug Oct-Nov	50 50	X		X
Bhutan[a,b]	Dept. of Agric.	Eastern Region: Tashigang, Mongar Kurthey and Lhuntsi	Wild and weedy types	I	Aug				
			Upland and lowland types	I	Sep-Nov	50			X
India[a]	CRRI, *NBPGR*. ICAR Complex, Agric. Univ. and Dept. of Agric.	Tamil Nadu, Uttar Pradesh, Jammu, Kashmir, and Arunachal Pradesh	Upland, lowland, cold-tolerant, and scented types, and wild species	Lowland and scented types	Sep-Nov	500	X		
Nepal[a,b]	NRIP, ICP, and Regional Farm ADO's	Far-Western Nepal: Mahakali and Seti River belts to high altitude valleys including Jumla	Upland, cold-tolerant, irrigated, midland bulu-like, and tropical types	Upland, cold-tolerant, midland bulu-like, tropical types and wild species	Sep-Dec	200-300			X
Pakistan,[a,b]	*ARC*	North-Western Frontier Province: Mansehra and Kurram Agency	Hill rices	I	Sep-Oct	100			X
Sri Lanka[a,b]	*CARI*	Wet zone: Colombo and Ratnapura. Dry zone: Badulla, Hambantota, Matale, and Monaragala	Traditional maha varieties and wild species	I	Jan-Feb	300-400			X

Plan for field collection. South Asia. 1983–87. (Continued)

Country	Coordinating and executing agencies[a]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[d] N	L	O
			1985						
Bangladesh[ab]	*BRRI* and Dept. of Agric. Extension	Chittagong Hill tracts	Tribal rices	II	Jul-Aug	25	X		X
		Faridpur and Tangail	Deepwater and wild species		Oct-Nov	50	X		X
Bhutan[a,b]	*Dept. of Agric.*	West-Central Region: Chirang, Wangdi and Punakha	Upland types	I	Sep-Nov				X
India[a]	CRRI, *NBPGR*, ICAR Complex, Agric. Univ. and Dept. of Agric.	West Bengal, Madhya Pradesh, Maharashtra and extreme N.E. India	Upland, lowland and saline types and wild species	Upland and saline types	Sep-Nov	500	X		
Nepal[a,b]	*NRIP*, *ICP*, and Regional Farm ADO's	Western Nepal: Karnali and Bheri River belts to high altitude and isolated areas	Upland, cold-tolerant, irrigated, midland bulu-like and tropical types	Upland, cold-tolerant, midland bulu-like, tropical types and wild species	Sep-Dec	200-300			X
Sri Lanka[a,b]	*CARI*	Remaining areas in dry zone	Upland types and wild species	II	Jan-Feb	300-400			X
			1986						
Bangladesh[a,b]	*BRRI* and Dept. of Agric. Extension	Sylhet	Tribal rices	II	Jul-Aug	20	X		X
		Kishorgang	Deepwater and wild species		Oct-Nov	40	X		X
Bhutan[a,b]	*Dept. of Agric.*	East-Central Region S. Tongsa and interior Shemgang	Upland and lowland	I	Sep-Nov	50			X

Plan for field collection, South Asia, 1983-87. (Continued)

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[d] N	L	O
			1986						
India[a]	CRRI, *NBPGR*, ICAR Complex, Agric. Univ. and Dept. of Agric.	Karnataka, Kerala and Maharashtra	Upland, lowland, salt-tolerant and fine-grained types and wild species	Lowland and salt-tolerant types	Sep-Nov	700	X		
Nepal[a,b]	*NRIP*, *ICP* and Regional Farm ADO's	Mid-eastern Nepal: Sun Kosi River belt to high altitude and isolated areas	Upland, cold-tolerant, irrigated, midland bulu-like and tropical types	Upland, cold-tolerant, midland bulu-like, tropical types and wild species	Sep-Dec	200-300			X
Pakistan[a,b]	ARC	North-Western Frontier Province: Swat, Dir, Chitral and Malakand	Hill rices	II	Sep-Oct	200			X
			1987						
Bangladesh[a,b]	*BRRI*, and Dept. of Agric. Extension	Remaining areas	All types	II	–	200	X		X
India[a]	CRRI, *NBPGR*, ICAR Complex, Agrric Univ, and Dept. of Agric.	Gujarat, Punjab, and Himachal-Pradesh	Rainfed, scented and cold-tolerant types and wild species	Scented and cold-rolerant types	Sep-Nov	400	X		
Nepal[a,b]	*NRIP*, *ICP* and Regional Farm ADO's	Central Nepal Bagmati and Gandaki River belts to high altitude areas	Upland cold-tolerant, irrigated, midland bulu-like and tropical types	Upland, cold tolerant, midland bulu-likc, tropical types and wild species	Sep-Dec	200-300			X
Pakistan[a,b]	ARC	Baluchistan: Khuzdar, Lasbella, Turbat and Sibi	Irrigated types	II	Sep-Oct	100			X

[a] Indirect technical assistance from IRRI — training of personnel and shipping of seed to IRRI. [b]Direct technical assistance from IRRI - IRRI staff to collaborate with local staff in germplasm collection and training. [c]Agencies italicized will serve as coordinators; in some cases, they will have a dual role (coordination and execution). For meaning of acronym, see pp. 99-100. [d]N = national, L = local, O = outside.

PLAN FOR FIELD COLLECTION, SOUTHEAST ASIA, 1983-87

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[b]		
							N	L	O
			1983						
Burma[a,b]	*ARI, Rice Division* and *AED*	Magwe Division	Upland, lowland and wild spp.	I	Oct-Nov Nov-Dec	20 50	X X	X X	
Indonesia[a]	*CRIFC* and *BORIF*	West Java (Baduj area)	Upland	I	May	50	X		
		South Sumatra, Bengkulu and Bangka Island	Upland and lowland	I	May- Jun	200	X		
Malaysia (W)[a]	*MARDI*	Pahang, Terengganu, Kelantan and Perak	Upland and lowland	Hill rices	Jan-Mar Jul-Sep	*d*	X		X
Malaysia (E)[a]	*Dept. of Agric.*	Sabah and Sarawak	Upland and lowland	Hill rices	Sep-Nov	*e*		X	X
Philippines[a,b]	*BPI-IRRI-UPLB,* BPI and BAEX (MA), BFD and ACAP	Regions of Ilocos, Cagayan Valley, S. Tagalog, Bicol, Visayas and W. N. and S. Mindanao	Upland, lowland and wild species	I	Aug-Dec	*f*	X		X
Thailand[a,b]	*RRI-PRRC, PWD-*TRC and PHTDC's	Lower North and southwest regions, Burma-Thailand border	Upland, irrigated and rainfed-lowland	I	Aug-Dec	120	X		X

Plan for field collection, Southeast Asia, 1983-87. (Continued)

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding soures[b] N	L	O
Vietnam[a]	*NIAS, UCCRRD* and *MDATI*	Central highlands	Upland and wild species	I	Oct-Dec	*g*	X		X
		Mekong delta	Floating, acid and saline-tolerant types, and wild species	II	Nov-Feb	*g*	X		X
			1984						
Burma[a,b]	*ARI Rice Division* and *AED*	Tenasserim Division	Lowland	I	Nov-Dec	20	X		X
		Kayah Division	Upland and lowland	I	Oct-Nov Nov-Dec	10 20	X		X
Indonesia[a,b]	*CRIFC* and *BORIF*	N. Sumatra (Nias) and Aceh (western Part)	Upland and lowland	II I	Feb–Mar Mar-Apr	50 200	X X		X X
Malaysia (W)[d]	*MARDI*	Pahang, Tereng-ganu, Kelantan and Perak	Upland and lowland	Hill rices	Jan-Mar Jul-Sep	*d*	X		X
Malaysia (E)[a]	*Dept. of Agric.*	Sabah and Sarawak	Upland and lowland	Hill rice	Sep-Nov	*e*		X	X
Philippine[a]	*BPI-IRRI-UPLB,* BPI and BAEX (MA), BFD and ACAP	Ilocos, Cagayan Valley, S. Tagalog, Bicol, Visayas and W. N. and S. Mindanao	Upland, lowland and wild species	I	Aug-Dec	*f*	X		X
Thailand[a,b]	*RRI-PRRC,* PWD-TRC and PHTDC's	Upper and Lower northern regions and Laos-Thailand border	Upland and lowland	I	Sep-Dec	250	X		X

Plan for field collection, Southeast Asia, 1983–87. (Continued)

Country	Coordinating and executing agencie[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[b] N	L	O
Vietnam[a]	*NIAS, UCCRRD* and *MDATI*	Central highlands	Upland and wild species	I	Oct-Dec	*g*	X		X
		Mekong delta	Floating, acid and saline tolerant types and wild species	II	Nov-Feb	*g*	X		X
		Northwest region	Upland and wild species	III	Apr-May	*g*	X		X
			1985						
Burm [a,b]	*ARI Rice Division* and AED	Kachin State, Mandalay and Sagaing Divisions	Upland and lowland	II	Oct-Nov Nov-Dec	30 80	X		X
Indonesia[a,b]	*CRIFC* and *BORIF*	Northern parts of E. and C. Kalimantan, central part of W. Kalimantan	Upland, lowland and tidal swamps	II	Jul-Aug	300	X		X
Malaysia(W)[a]	*MARDI*	Pahang, Tereng-ganu, Kelantan and Perak	Upland and lowland	Hill rices	Jan-Mar Jul-Sep	*d*	X		X
Malaysia(E)[a]	*Dept. of Agric.*	Sabah and Sarawak	Upland and lowland	Will rices	Sep-Nov	*e*		X	X
Philippines[a,b]	*BPI-IRRI-UPLB*, BPI and BAEX (MA), BFD and ACAP	Ilocos, Cagayan Valley, S. Tagalog, Bicol, Visayas and Mindanao	Upland, lowland and wild species	II	Aug-Dec	*f*	X		X
Thailand[a,b]	*RRI-PRRC*, PWD-TRC and PHTDC's	Upper North, Burma-Thailand and Laos-Thailand borders	Upland and lowland	II	Aug-Dec	230	X		X

Plan for field collection, Southeast Asia, 1983–87. (Continued)

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[b] N	L	O
Vietnam [a]	*NIAS, UCCRRD* and *MDATI*	Central highlands	Upland and wild species	I	Oct-Dec	*g*	X		X
		Mekong delta	Floating, acid and saline-tolerant types and wild species	II	Nov-Feb	*g*	X		X
		Northwest Region	Upland and wild species	III	Apr-May	*g*	X		X
			1986						
Burma [a,b]	*ARI Rice Division* and *AED*	Arakan State	Lowland and saline-tolerant	II II	Nov-Dec Nov-Dec	25 5	X		X
Indonesia [a,b]	*CRIFC* and *BORIF*	East Nusa Tenggara (Flores, Timor and East Sumba)	Upland	I	Apr-May	350	X		X
Malaysia (W)[a]	*MARDI*	Pahang, Terengganu, Kelantan and Perak	Upland and lowland	Hill rices	Jan-Mar Jul-Sep	*d*	X		X
Malaysia (E)[a]	*Dept. of Agric.*.	Sabah and Sarawak	Upland and lowland	Hill rices	Sep-Nov	*e*		X	X
Philippines [a,b]	*BPI-IRRI-UPLB,* BPI and BAEX (MA), BFD and ACAP	Ilocos, Cagayan Valley, Visayas, S. Tagalog, Bicol and Mindanao	Upland, lowland, and wild species	II	Aug-Dec	*f*	X		X
Thailand [a,b]	*RRI-PRRC,* PWD-TRC and PHTDC's	Upper North, Southwest and Burma-Thailand border	Upland and lowland	II	Aug-Dec	300	X		X

Plan for field collection, Southeast Asia, 1983–87. (Continued)

Country	Coordinating and executing agencies[c]	Province or district	Varietal types	Priority for collection	Time	Estimated no. of samples	Funding source[h] N	L	O
			1987						
Burma[a,b]	*ARI Rice Division* and AED	Chin State	Upland	II	Oct-Dec	5	X	X	
			and lowland	II	Nov-Dec	10	X	X	
		Mon State	Lowland	II	Nov-Dec	20	X	X	
			and deepwater	II	Nov-Dec	5	X	X	
Indonesia[a,b]	*CRIFC, BORIF,* and *MORIF*	S.E. Sulawesi	Upland	II	Apr-May	100	X		X
Malaysia *(W)*[a]	*MARDI*	Pahang, Tereng-ganu, Kelantan, and Perak	Upland and lowland	Hill rices	Jan-Mar Jul-Sep	*d*	X		X
Malaysia (E)[a]	*Dept. of Agric.*	Sabah and Sarawak	Upland and lowland	Hill rices	Sep-Nov	*e*		X	X
Philippines[a,b]	*BPI-IRRI-UPLB,* BPI and BAEX (MA), BFD and ACAP	Cagayan Valley, Central Luzon, S. Tagalog, Bicol, C. and E. Visayas and C. W. and N. Mindanao	Upland, lowland and wild species	III	Aug-Dec	*f*	X		X
Thailand[a,b]	*RRI-PRRC,* PWD-TRC and PHTDC's	Upper North and Burma-Thailand border	Upland and lowland	III	Aug-Dec	180	X		X

[a]Indirect technical assistance from IRRI — training of personnel and shipping of seed to IRRI. [b]*Direct* technical assistance from IRRI — IRRI staff to collaborate with local staff in germplasm collection and training, [c]Agencies italicized will serve as coordinators; in some cases, they will have a dual role (coordination and execution). For meaning of the acronyms, see pp. 99-100. [d]Total number of estimated samples for West Malaysia 1983-87 = 400. [e]Total number of estimated samples for East Malaysia 1983–87 100. [f]Total number of estimated samples for Philippines 1987-87 1,340. [g]Vietnam - total number of estimated samples by region 1983-85: Central highlands 500, Mekong delta 200, Northwest region 200. [h]N national, L local, O outside.

PLAN FOR FIELD COLLECTION, AFRICA, 1983-87[a]

Country	Coordinating andexecuting agencies[b]	Province or district	Varietal types	Priority for collection	Time
Angola	*IBPGR*		Traditional varieties and wild species	I	Apr-Jun
Comoro Islands	*IBPGR*		Traditional varieties and wild species	I	May-Jun
Mozambique	*IBFGR, IITA*		Traditional varieties and wild species	I	Apr-Jun
Zaire	*IBPGR, IITA*	Northeastern region	Traditional varieties and wild species	I	May-Jul
Upper Volta	National, *IBPGR,* I ITA	Southern region	Traditional varieties and wild species	I	Oct-Nov
Malagasy Republic	ORSTOM, IRAT	Northern, eastern and western regions	Traditional varieties and *O. longistaminata*	I	Jan-Mar May-Jul Aug-Sep
Tanzanian Islands	ORSTOM, IRAT	Zanzibar, Pemba and Mafia islands	Traditional varieties and wild species	I	May-Jun
Niger	ORSTOM, IRAT, IITA	Southern region	*O. glaberrima, O. sativa, O. longistaminata, O. barthii and O. stapfii*	I	Nov-Jan
Sudan	ORSTOM, IRAT, I ITA	Southern region - drainage basin of River Nile	Traditional varieties, *O. longistaminata,* and *O. barthii*	I	Oct-Nov
Central African Republic	*IBPGR*	Southern, south-eastern and central regions	Traditional varieties and wild species	II	May-Jul
Congo	*IBPGR*	Western and northeastern regions	Traditional varieties and wild species	II	May-Jul
Mauritius	*IBPGR*		Traditional varieties and wild species	II	May-Jun
Cameroon	*IBPGR, IITA*	Northern and southeastern regions	Traditional varieties and wild species	II	Oct-Nov
Ghana	National and *IBPGR*	Northern and southeastern regions	Traditional varieties and wild species	II	Nov-Dec
Mali	*ORSTOM, IRAT*	Inland River Niger delta	*O. glaberrima, O. sativa, O. longistaminata, O. barthii,* and *O. stapfii*	II	Oct-Dec
Togo	*ORSTOM, IRAT*		*O. glaberrima* and *O. longistaminata*	II	Oct-Dec
Chad	*IITA*			III	
Mauritania	*WARDA*			III	
Senegal	National and *WARDA*			III	

Plan for field collection, Africa, 1983-87.[a] (Continued)

Country	Coordinating and executing agencies[b]	Province or district	Varietal types	Priority for collection	Time
Benin					
Egypt					
Gabon					
Gambia			III		
Guinea					
Sierra Leone					
Uganda					
Rest of Africa					

[a]The countries are listed in order of collection priority; a detailed year-by-year collecting program will be formulated during the proposed regional meeting for Africa. [b]Agencies italicized will serve as coordinators; in some cases, they will have a dual role (coordination and execution). For meaning of the acronyms, see pp. 99-100.

COORDINATING AND EXECUTING AGENCIES FOR FIELD COLLECTION

SOUTH ASIA

Bangladesh
BRRI — Bangladesh Rice Research Institute
Department of Agricultural Extension

Bhutan
Department of Agriculture

India
CRRI — Central Rice Research Institute, Cuttack
NBPGR — National Bureau of Plant Genetic Resources, New Delhi
ICAR Research Complex — numerous research institutes functioning under the Indian Council for Agricultural Research

Nepal
NRIP — National Rice Improvement Program
ICP — Integrated Cereals Project
ADOs — Agricultural Development Offices

Pakistan
ARC — Agricultural Research Council, Islamabad

Sri Lanka
CARI — Central Agricultural Research Institute

SOUTHEAST ASIA

Burma
ARI — Agricultural Research Institute, Yezin
AED — Agricultural Extension Division

Indonesia
CRIFC — Central Research Institute for Food Crops
BORIF — Bogor Research Institute for Food Crops
MORIF — Maros Research Institute for Food Crops

Malaysia (West)
MARDI — Malaysian Agricultural Research and Development Institute

Malaysia (East)
Department of Agriculture

Philippines
BPI — Bureau of Plant Industry
UPLB — University of the Philippines at Los Baños
BAEX — Bureau of Agricultural Extension
MA — Ministry of Agriculture
BFD — Bureau of Forest Development
ACAP — Agricultural Colleges Association of the Philippines

Thailand
RRI — Rice Research Institute
PRRC — Phrae Rice Research Center
PWD — Public Welfare Department
TRC — Tribal Research Center
PHTDCs — Provincial Hill Tribe Development Centers

Vietnam
NIAS — National Institute of Agricultural Sciences, Hanoi
UCCRRD — University of Cantho Center for Rice Research and Development
MDATI — Mekong Delta Agricultural Techniques Institute, Hau-giang

AFRICA

IITA — International Institute of Tropical Agriculture, Ibadan, Nigeria
IRAT — Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières, Paris, France
ORSTOM — Office de la Recherche Scientifique et Technique Outre-Mer, Paris, France
WARDA — West Africa Rice Development Association, Monrovia, Liberia

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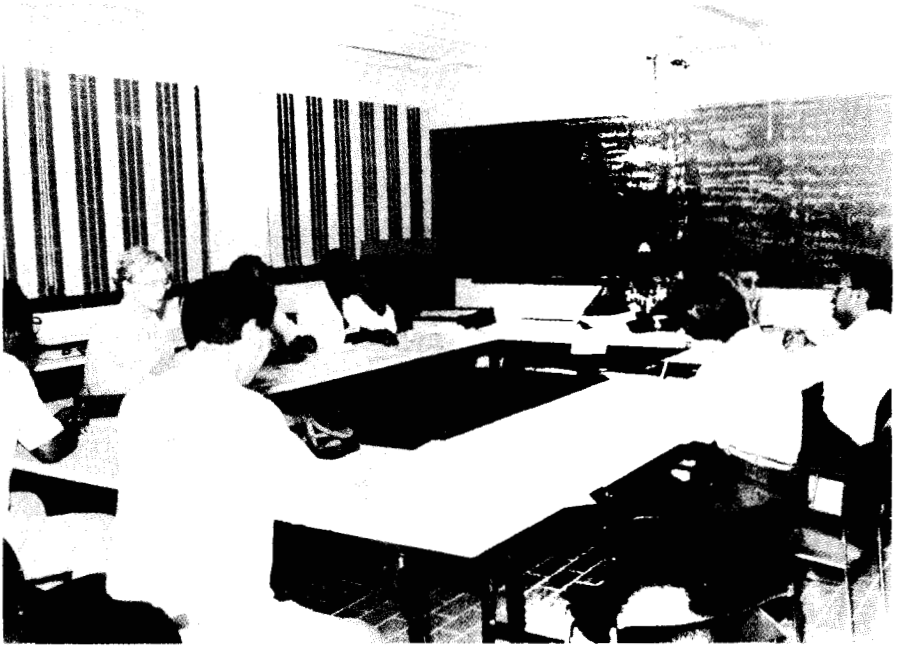
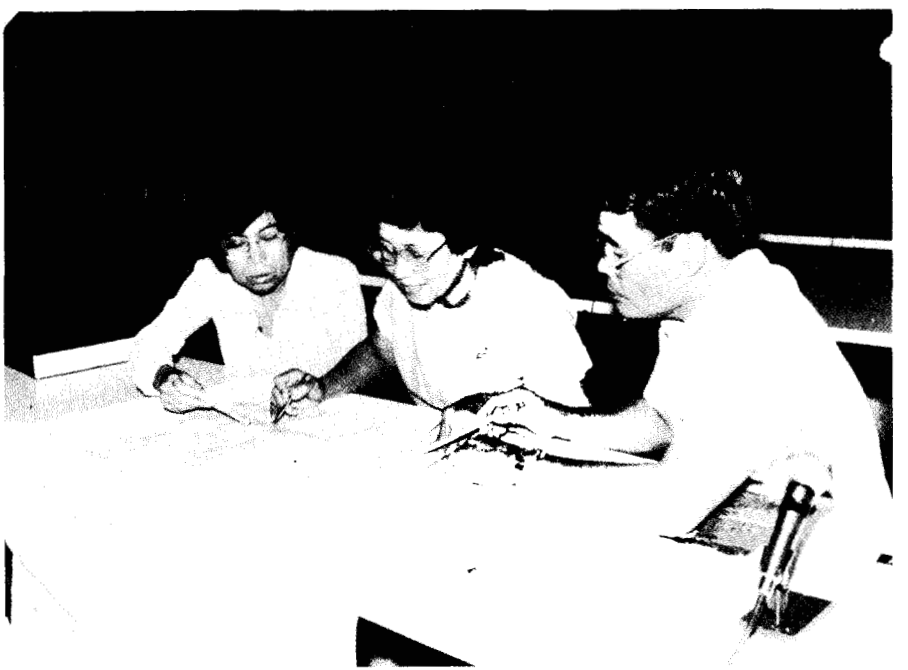
ACRONYMS AND LOCATIONS

ACAP = Agriculture Colleges Association of the Philippines (Philippines)
ADO = Agricultural Development Offices (Nepal)
ARC = Agricultural Research Council (Pakistan)
ARI = Agricultural Research Institute (Burma)
BAEX = Bureau of Agricultural Extension (Philippines)
BFD = Bureau of Forest Development (Philippines)
BORIF = Bogor Research Institute for Food Crops (Indonesia)
BPI = Bureau of Plant Industry (Philippines)
BRRI = Bangladesh Rice Research Institute (Bangladesh)
CAAS = Chinese Academy of Agricultural Sciences (China)
CARI = Central Agricultural Research Institute (Sri Lanka)
CRIFC = Central Research Institute for Food Crops (Indonesia)
CRRI = Central Rice Research Institute (India)
FAO = Food and Agriculture Organization of the United Nations (Rome)
IBPGR = International Board for Plant Genetic Resources (Rome)
ICAR = Indian Council of Agricultural Research (India)
ICP = Integrated Cereals Project (Nepal)
IDESSA = Institut des Savannes (Ivory Coast)
IITA = International Institute of Tropical Agriculture (Nigeria)
IRGC = International Rice Germplasm Center (IRRI, Philippines)
IRAT = Institut de Recherche Agronomiques Tropicales et des Cultures Vivrieres (France)
IRRl = International Rice Research Institute (Philippines)
ISTA = International Seed Testing Association (Norway)
MA = Ministry of Agriculture (Philippines)
MARDI = Malaysian Agricultural Research and Development Institute (Malaysia)
MDATI = Mekong Delta Agricultural Techniques Institute (Vietnam)
NBPGR = National Bureau of Plant Genetic Resources (India)
NIAS = National Institute of Agricultural Sciences (Japan)
NIG = National Institute of Genetics (Japan)
NRIP = National Rice Improvement Program (Nepal)
ORSTOM = Office de la Recherche Scientifique et Technique d'Outre-Mer (France)
PHTDC = Provincial Hill Tribe Development Centers (Thailand)
PRRC = Phrae Rice Research Center (Thailand)
PWD = Public Welfare Department (Thailand)
RD = Rice Division [now Rice Research Institute) (Thailand)
RRI = Rice Research Institute (Thailand)
SURIF = Sukamandi Research Institute for Food Crops (Indonesia)
TRC = Tribal Research Center (Thailand)
UCCRRD = University of Cantho Center for Rice Research and Development (Vietnam)
UNDP = United Nations Development Programme (New York City)
UPLB = University of the Philippines at Los Baños (Philippines)
USAID = United States Agency for International Development (USA)
USDA = United States Department of Agriculture (USA)
WARDA = West Africa Rice Development Association (Liberia)



Participant developing a plan for field collection in Africa From left N.Q, Ng A. Coly, A Ghesquire, K. Miezan, A. Faye, A. O. Abifarin, N M. Anishetty. and M. B. Parker



participant studying collection sites in the philippines. From left: G. C. Loresto, R. Bautista and T. Masajo

Participants developing collection plan for Thailand. From left: Chantaboon Sutthi, Boriboon Somrith, B. R. Jackson, and Songkran Chitrakon.

Participants discussing international collaboration on exchange and preservation of rice germplasm at duplicate sites. From left: Wu (interpreter), Yu-Shen Dong, J. Kawakami, T. T. Chang, K. Kumagai, H. I. Oka, E. H. Roberts, M. J. Rosero, and T. H. Johnson.