IPGRI

Plant genetic resources
conservation and use in China

Proceedings of National Workshop on Conservation and Utilization of Plant Genetic Resources, 25-27 October 1999, Beijing, China

Weidong Gao, V. Ramanatha Rao and Ming-De Zhou, ***editors***

ICGR CAAS








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Note from editors

This volume is based on the several presentations made during the National Workshop on Conservation and Utilization of Plant Genetic Resources in China, held in Beijing, October 1999. Due to consideration of size of the volume, only selected presentations are included. For some articles only abstract is available from these proceedings, however, readers can contact the authors of the paper for more information. The presentations have been selected based on the following criteria

- To provide the readers a broad understanding on plant genetic resources
- To inform PGR researchers in China the work that is being done in China as well as give a idea of what is happening outside in this field
- To represent a cross section of PGR related research activities in China
- To avoid repetitions, and
- To provide a good balance of conceptual and practical aspects of work done in China and elsewhere

It was also decided that the proceedings should be in both languages. Chinese version is to meet the needs of a large number of Chinese researchers and germplasm workers, policy makers and the general public in line with one of the objectives of the meeting i.e. to raise the public awareness on matters of plant genetic resources. English version is to reach out PGR researchers outside China to inform them what China is doing in this important topical discipline, i.e. plant genetic resources conservation and utilization. It is expected that such information exchange will help promote regional and international collaboration, either on bilateral or multilateral basis, especially through crop / commodity or geographic networks.

To bring a volume in two languages, back to back, is a challenging job. In addition, there are space and financial aspects to be considered. In consideration of these, the editors decided to split the space for references, tables, figures etc. So readers will note that, full list of references for each of the presentation is found at the end of each chapter in the English version. For tables and figures readers are also referred to the English version. We trust that this will not cause too much of a problem to the reader, since one would have to just turn the volume around and find the relevant pages.

We hope this volume will contribute to better understanding of the importance of plant germplasm in China and lead an increase in various plant genetic resources activities.

Weidong Gao, V. Ramanatha Rao and Ming-De Zhou, Editors

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Foreword

Awareness has grown globally of the need to conserve valuable plant genetic resources (PGR) for the immediate benefit of the present generations a swell as for the long term. China is rich in plant genetic resources due to its vast land with complicated clime and topographic conditions and long history of cultivation of agriculture. In the past decades China has made great progress in conserving and using plant genetic resources through collecting, conservation, characterization and evaluation, documentation and utilization. International Plant Genetic Resources Institute (IPGRI) has closely collaborated with China since early 1980s. One of the examples was to successfully organize the National Workshop on Conservation and Utilization of Plant Genetic Resources in China, held in October 1999 in Beijing. The workshop was jointly organized by the Institute of Crop Germplasm Resource of the Chinese Academy of Agricultural Sciences, Society of Crop Germplasm Resources Attached to the Chinese Association of Agricultural Sciences, and IPGRI. More than 80 scientists from 20 provinces and related officials from the Ministry of Agriculture and Ministry of Sciences and Technology, and IPGRI staff attended the workshop. The major challenges at the dawn of the 21st century remain ensuring food security, eliminating poverty and environment protection. Plant genetic resources are important for world food and agriculture. They contribute to the development by helping to increase food production, eradicate poverty and protect the environment. Based on this, the workshop was designed to strengthen the linkages between PGR specialists, breeders, forestry scientists and scientists working on medicinal plants to discuss national strategies for conservation and use of PGR, and to develop medium-term plan for national programme in China. IPGRI is pleased with the success of the workshop.

These proceedings are compiled and edited based on the papers presented at the workshop, dealing with all the major areas in conservation and utilization of PGR. It contains information on exploration and collecting, ***ex situ*** conservation, ***in situ*** conservation, characterization and evaluation, documentation and utilization of PGR as well as related research in China. It also contains the recommendations on strategies and approaches proposed at the workshop. These proceedings will provide useful information on PGR work and experiences in China. It will be a good reference book for scientists and technicians engaged in plant genetic resources. It is my hope that the publication and distribution will stimulate further the already vigorous activity in plant genetic resources in China and in some other countries.

Percy E. Sajise
Regional Director
International Plant Genetic Resources Institute
Regional Office for Asia, the Pacific and Oceania

Preface

China is a developing country with the largest population in the world and is rich in crop genetic resources. Effective conservation and utilization of plant genetic resources is important for food security for feeding 1.6 billion people, improving environmental conditions and sustainable development of agriculture. However, population growth, shortage of resources and deterioration of environment have led to unchecked expansion of the cultivated areas, intensive farming and application of chemical fertilizers and pesticides in large scale. As a result, the soil has been degenerated and the environment has been polluted. Cultivation of uniform varieties has, though increased production; it also has increased the vulnerability of cultivars in agriculture. Deforestation has destroyed the habitat of wild plant species. All these factors have threatened plant genetic resources and led to their erosion. In order to promote conservation and utilization of plant genetic resources and developments in the discipline of plant genetic resources, National Workshop on Conservation and Utilization Strategies of Plant Genetic Resources in China was convened by the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, in cooperation with International Plant Genetic Resources Institute and Society of Crop Germplasm Resources, attached to the Chinese Agronomic Association, held in Beijing on 25-27th October 1999.

Well known experts from home and IPGRI were invited to give presentation on the current situation and developments and views on several related issues were exchanged at the workshop. Strategies for development of work and research in plant genetic resources were discussed. The workshop was well accepted. These proceedings were complied and edited based on selected papers presented at the workshop. It is a crystallization of research and practice carried out by the Chinese scientists working in the area of plant genetic resources. It represents the new developments in conservation and use of plant genetic resources in China. Publication of these proceedings will promote the development of plant genetic resources discipline in the country.

These proceedings contain various subjects, including the current situation, problems and strategies, enhancement and utilization of underutilized crops (including fruit species) of plant genetic resources. This volume also contains application of biotechnology, information management, monitoring and early warning system, and erosion of plant genetic resources. Recommendations on strategies in conserving and using of plant genetic resources have also been included in these proceedings. It is expected that this book will be an important reference for researchers working in plant genetic resources.

Taking this opportunity I would like to extend cordial greetings and heartfelt respect to scientists and technicians working in plant genetic resources. I also express my thanks to IPGRI for financial support to the workshop and publishing the proceedings, and to Dr. Ramanatha Rao and other IPGRI staff in East Asia Office as well as my colleagues for their contribution to this proceedings.

Xu Liu
Director General
Institute of Crop Germplasm Resources
Chinese Academy of Agricultural Sciences

Summary and recommendations

Summary

Plant genetic resources for food and agriculture (PGR) provide the biological basis for world food security and, directly or indirectly, support the livelihood of every person on earth. Therefore, conservation and utilization of PGR have been a focus of attention in the world. In 21st Century, China will be faced with challenges of population explosion, increased demand for food and other agricultural commodities and environmental deterioration. In order to meet the needs of sustainable development of the country and of PGR for food and agriculture, the country needs a new strategy. A National workshop on conservation and utilization strategies of PGR in China was convened by Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, in cooperation with the International Plant Genetic Resources Institute and the Society of Crop Germplasm Resources, attached to the Chinese Agronomic Association in Beijing, 25-27 October 1999.

More than 80 scientists working in research on agriculture, forest, environmental protection, Chinese traditional medicine and related areas, participated in the workshop. The workshop also invited the international and national leaders, including Shen Maoxiang, Deputy Director, Rural Social Development Department, Ministry of Science and Technology; Yang Yansheng, Vice President, Chinese Academy of Agricultural Sciences; Ramanatha Rao, Acting Deputy Director; IPGRI Regional Office for Asia, the Pacific and Oceania; Zhou Ming-De, Coordinator, IPGRI East-Asia Office; Gao Shangbing, Section Chief, Environment and Energy Division, Science and Education Department, Ministry of Agriculture, Professor Sun Shixian, National Agricultural Technique Extension Service Center; Feng Feng, Section Chief, Agronomic Division of life Sciences Department, National Natural Science Foundation of China.

Vice President Yang Yansheng delivered the opening speech in which he highlighted that PGR was a global subject of great topical interest. In recent years, Chinese government has been paying more attention to it. PGR research made considerable progress under the great efforts made by scientists over the country. Vice President Yang also pointed out that the present workshop was organized to bring scientists from all over the country in the areas of agriculture, forest and Chinese traditional medicine, with substantial and useful content. It was suggested that the meeting could develop reasonable proposals related to PGR to Chinese government, in order to preserve the genetic resources safely, to put resources to rational use, to enhance new genetics and to serve the human beings in general. Finally Vice President Yang wished the meeting success.

IPGRI East Asia coordinator professor Zhou Ming-De congratulated all present for organizing the workshop. She said that the conservation and sustainable utilization of PGR was the key to improve agricultural productivity and sustainability, thereby contributing to national development, food security, and poverty alleviation. The workshop provided a good opportunity to genetic resources scientists from different research areas to meet and discuss and to strengthen the cooperation with different department as well as different institutes. Professor Zhou also appealed for a medium term proposal on conservation of PGR to government.

The workshop reviewed the present status and presented new ideas on the following topics, in the form of reports and group discussion.

1. General situation on PGR of food and agriculture - current situation, issues and policy of conservation and utilization of crop, vegetable, fruit, forest and Chinese traditional medicinal plant germplasm.
2. Exploration, collecting and documentation of PGR.
3. Characterization and evaluation of PGR, including the use of biotechnology.

4. ***Ex situ*** conservation of PGR and regeneration of conserved germplasm.
5. Exchange and benefit sharing between counties.
6. Enhancement and utilization of PGR.
7. ***In situ*** conservation of agricultural biological diversity and wild related species.
8. Conservation and utilization of genetic resources which have not been fully exploited, including fruits.
9. Information management, monitoring and early warning system on PGR.
10. Erosion status of PGR and counter measures.

Furthermore, the participants held in depth discussions about the following issues:

1. Formulation of a medium-term strategy on national PGR.
2. Ways to promote national PGR system.
3. To assess genetic erosion and genetic diversity in different crop, forest as well as other species genetic resources.
4. To have a better understanding of intellectual property rights as related to PGR.
5. To promote the links between conservation and utilization of PGR.
6. To formulate a general strategy for conservation and utilization of national PGR.
7. To set up an action plan related to the implementation of FAO's Global Plan of Action (GPA).
8. To establish efficient conservation strategies for germplasm of different crop, forest as well as other species.
9. To enhance the human resources and awareness of policy makers and public in general of the importance and the need to protect the PGR.

Deputy Director Maoxiang Shen, from the Department of Rural Social Development of Ministry of Sciences and Technology participated in the meeting on 26 October. He highlighted the accomplishments in PGR conservation and use in China and provided information on international and national status as well as development situation of national PGR, focusing on aspects of discipline development, social-economic development, availability of trained human resources and information exchange. He pointed out, from PGR point of view, the main activities should include collecting and conservation, providing service, promoting utilization and genetic enhancement. National scientists have made their contributions in the area of collecting and conservation and have laid a firm foundation for national programme on PGR. But there is still a long way to go in the other three aspects. From socio-economic development point of view, PGR activities are fundamental, which belong to public welfare and should focus on human society, especially the farmer, plant breeder and research institute. From human resources and information points of view, Director Shen said that human resources was the most important issue, not only a national research team on PGR was needed, but also a 'crack' technology team; otherwise, he warned that China would fall behind others in the field of PGR. It was clear that we should collect and conserve the PGR in form of dynamic resources, the number of accessions conserved should be raised from 400 000 to 500 000. At the same time, we should make a clearheaded appraisal of the present situation, fix a position considering all the key factors. The collection and selection of PGR should be transformed from quantity into quality. Finally, Director Shen encouraged the participants to improve research capacity, to improve productivity, and to achieve the greater goals.

During the meeting, more than 80 scientists from 20 provinces working in various disciplines of plant genetic resources related to agriculture, forest, environment protection and Chinese traditional medicine participated. The participants exchanged ideas, held wide-ranging in-depth discussions on topics of food security, the alleviation of poverty and environmental problems, and formulated a medium-term strategy on conservation and utilization of national PGR. They also made a suggestion for immediate development strategy and measure of national PGR strategy according to the key problems of conservation and utilization of PGR. The workshop, which was considered to be a great success, resulted in the following recommendations.

Recommendations

Conservation and utilization of PGR have become a global concern. In the 21st Century, China will encounter many problems such as population explosion, sharp increase in the demand for food and environmental deterioration. A major element in finding solutions to these national level problems is the genetic diversity that exists in the abundant plant genetic resources in the country. Through the information exchange and discussions, the participants proposed the following strategies and measures for the development of PGR in the future.

Collecting and conservation

1. To ensure optimal operation of the national genebanks including germplasm nurseries, which includes necessary water and electricity supplies, germplasm multiplication and entering into genebanks, viability monitoring, regeneration, and germplasm as well as genebank management etc.
2. To collect germplasm in regions where collecting has not been done (e.g. the Changbai Mountains and the islands in Chinese seas), and in special ecological environments and for specific materials (e.g. wild, semi-wild relatives of crops)
3. To strengthen assembling and preservation of introduced and enhanced materials.
4. To establish and improve management of national medium-term genebanks and regeneration bases in large ecological zones
5. To strengthen safe movement (quarantine) of germplasm

Utilization

1. To strengthen germplasm characterization, evaluation and screening for
   a. Basic agronomic characters
   b. Target traits of interest by breeders and in production
   c. Germplasm suited to arid / semi-arid and remote regions
   d. Famous, special, quality and rare germplasm
   e. Quality and processing traits, and to carry out
   f. Molecular characterization
2. To enhance germplasm based on requirements of breeding and production
   a. To establish core collections of major crops (mainly rice, wheat, maize, soybean, barley, sorghum, foxtail millet, rapeseed and sesame)
   b. To set up and strengthen a germplasm distribution system

Basic and strategic research

To carry out research on PGR focusing on

1. Genetic diversity studies
2. Origin, evolution and systematics and classification
3. Genetic integrity of conserved germplasm during regeneration
4. New technologies for extending longevity in storage and germplasm conservation
5. Cost-effective technologies for germplasm regeneration
6. Feasibility studies on technologies of ***in situ*** conservation

Personnel

1. To maintain the research teams related to germplasm
2. To strengthen scientific and managerial skills of PGR researchers
3. To strengthen scientific exchange at the national level and international level
4. To improve the living standard of researchers

Financial aspect

1. The government should steadily and continuously support the field of PGR as a basic public undertaking
2. To obtain financial support through multi-channels
3. To strengthen international cooperation
4. To obtain funding from enterprises if possible

Policies and management

1. To establish genetic resources commissions in agricultural, forestry and medical sectors, and then a national committee on PGR to coordinate conservation and utilization activities.
2. To formulate regulations and rules of germplasm management (introduction, germplasm and information exchange, registration, distribution, conservation, benefit sharing etc.)
3. To strengthen intellectual property rights as related to PGR
4. To raise public awareness: scientific popularization bases and demonstration gardens related to PGR, Internet websites, and popular materials including different media products

Information

1. To strengthen decision support system of germplasm management
2. To establish genebank information management system
3. To establish Chinese Germplasm Information Network
4. To establish and run germplasm networking

Keynote address by Mr. Maoxiang Shen, China Ministry of Science and Technology

Great progress has already been achieved on studies of crop germplasm resources in China. However, we have to be clear that there are many gaps and problems in playing more important role in crop breeding and sustainable development of agriculture in China. Here, I would like to highlight several aspects of crop germplasm research based on my personal opinions.

Research status of crop germplasm resources in China

The main work of crop germplasm resources collecting and conservation, service function, germplasm utilisation and enhancement. Chinese Scientists have done much work and made great achievements in collecting and conservation of crop germplasm resources. However, little has been done on the other three aspects, on which we should be paying greater attention in the near future. First of all, we have to know if we have the capacity to meet the service demands for customers. Secondly, we need to know how many accessions of the collected resources have been used. The purpose of conserving resources is for sustainable development of our own country and the world. Finally, genetic enhancement is our weakest aspect in crop germplasm research. What we should do and how to do genetic enhancement are the questions we have to consider. I believe in that there are large areas for us to work on exploitation, utilisation and enhancement of germplasm.

Development of crop germplasm sciences

Germplasm conservation is not easy. It is not just storing seeds. Conserving resources in –18°C genebank is not the final goal of germplasm research. We have to answer questions such as what we have done so far for safe conservation, how safe are the conserved accessions and how we characterize, evaluate, and access the collections while they are still in the genebank. On the aspect of germplasm research, are the available 90 characteristics reasonable and enough for each accession and what new methods could be used for their development? How many new varieties have been created through the use of our collections? In order to improve our reputation in the world, we have to constantly enhance the genetic background, fully use them and make our Genebank more abundant. In this regard, we’d better increase the Genebank's capacity dynamically from present 400 000 accessions 500 000 accessions in future.

Genetic resources and development of social economy

I agree that crop germplasm science is basic and is public work. It should provide materials and basic technologies to others. Therefore, scientists of genetic resources have to hold some unique basic materials and techniques in order to get funds from the government. We should do more work than just conserving resources. We should also make sure that our work is recognised and authoritative. We’d better know what is our position in the society and our “markets”. Our research work is not theoretical but basic. We have to analyse the market’s requirements and find the key points to work on. Establishing our markets doesn’t mean earning money but knowing our priority research fields. Crop germplasm resources are necessary for people and beneficial to scientific research. Our markets are huge and our future is bright. We’d better go forward towards our target.

Talent and training

Qualified people are important for development of crop germplasm science. Without talented persons, our work will not be carried out properly. We have to have our own quality team and technically talented persons to do research.

Our government will continue to support basic research because it is very important for our country. On the other hand, besides government support, we should also look for financial support from other sources, for example, private companies. To do this, directors of institute must play an important role. They should open their mind and should be creative in thinking. At least, they have to know what to do during “the Tenth Five-year Research Program”. Our government is making outlines of plans for research during the next five-years. Resources are the main issue in these outlines. Germplasm is also included in it. However, how much money will be invested in germplasm research is dependent on our country’s financial capacity. We should search support from of multiple sources.

What shall we do next?

We have to think about how to assess our present situation and research tasks, and how to orient our research direction according to domestic and international situation. We’d better stand at higher level to adjust our objectives and to participate in the competition, which needs us to improve our research capacity and to provide international standard research capabilities and achievements. At present, China’s focus in agriculture production has already changed from quantity to both quantity and quality. Characterisation of crop germplasm resources should also be changed to be in line with the same trend. Farmers’ incomes are still very low and our economy is increasing slowly. We should contribute to improvements of this situation.

Whenever problems are mentioned, someone always blames the system. In fact, some problems can not be attributed to the system. They should be attributed to our research capacity or personal qualities. For instance, “stop as the red light on” is a universal traffic rule. However, some drivers seldom obey it, which should be attributed to personal quality. All work should be orientated according to the markets and our country’s requirements. The main point of our government’s work has already changed. We have to work in the same direction with our country’s needs and improve our own competitive ability. The government’s policy is to foster strong research capability on priory items. So it is important that you propose strong and innovative areas of germplasm research so that the funding for them would not disappear. Purchasing of seed of new crop varieties for commercial cultivation is a good example of the policy change. After a committee of scientists evaluate and prove the worth of a new variety, the breeder can get 500 000 to one million Yuan from the government.

Therefore, scientists of crop germplasm resources also have to improve our capacity of research, achieving great progress and creating our own “market”. Indeed, we have to improve quality of our research to take part in the competition.

Conservation and utilization of plant genetic resources

Role of IPGRI in promoting research on plant genetic resources conservation and use, and GPA implementation, with a focus on Asia and the Pacific

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Introduction

The Asia, the Pacific and Oceania (APO) Region possesses a great diversity of crop and forest genetic resources, along with high agroecological and biocultural diversity. Harlan, Zohary, Frankel and others (Frankel and Bennett 1970; Harlan 1975, 1992; Zohary 1970) recognize the major centres of domestication such as the Indian, Chinese, Southeast Asian and Pacific. Plant diversity that has arisen from this region in crops such as rice, bananas, Citrus, coconut etc. have spread around the world (Ramanatha Rao ***et al***. 1997; Watanabe ***et al***. 1998). In a similar manner, crops such as sweet potato and groundnut, which originated elsewhere, have moved to this region which subsequently has become a centre of significant diversity for these crops. This enormous plant diversity has arisen with the climatic and geographical diversity as well as with the great cultural diversity of the people, their farming systems and their knowledge of the plants that they use for food, shelter and income generation. No country is self sufficient in the plant genetic resources (PGR) that are required for its needs. Among all areas of PGR activities, exchange of germplasm is the most crucial for the future needs of conservation of PGR biodiversity and crop improvement (Ramanatha Rao ***et al***. 1997).

Many of the countries in the region are undergoing rapid changes in terms of trade, exports, urbanization, land-use pattern, and market-driven and uniform farming practices. Despite positive aspect of such changes, these have contributed to significant loss of diversity in the APO region. The loss is in terms of both biological diversity and agrobiodiversity. Although the importance of both biodiversity and genetic diversity has been better recognized in recent years, increased support has been hard to come by. We need to remedy the situation.

The importance of conservation and utilization of genetic resources is well recognized. During this decade, the importance of two global meetings has been further highlighted; namely the Convention on Biological Diversity (CBD) held in Rio, Brazil in 1992 and the International Technical Conference on the Conservation and Use of Plant Genetic Resources for Food and Agriculture in Germany in 1996 (FAO 1996a; FAO 1996b; Iwanaga 1994). Both conventions recognized the sovereignty of countries where the PGR occur within their borders, but the onus to conserve and use PGR rests with all countries and stressed the importance of equable sharing of these resources and technologies related to their utilization. The Global Plan of Action (GPA) developed by the Food and Agriculture Organization (FAO) outlines the actions needed on 20 priority activities.

An attempt is made in this paper to discuss the research needs of PGR conservation and use and the role of IPGRI in such efforts.

Research needs

For efficient conservation and use of PGR, based on scientifically sound footing, there are still several questions that need to be answered. Institutes conserving PGR can be more effective if they are able to undertake priority research activities to generate information needed for the sustainable management of PGR. Since much of the research required involves several disciplines, a multidisciplinary approach is needed. Based on the research findings, appropriate protocols and procedures need to be developed and used at genebank level. Perhaps most importantly, utilization of PGR depends on good research linkages with plant breeders as well as direct linkages with farmers and other users. An examination of the GPA document reveals several important research areas that need urgent attention by the PGR community in order to conserve and sustainably use the PGR available. Two different types of research are needed:

Strategic research is required to advance knowledge and improve conservation and use technologies in general. A broad range of strategic research topics related to PGR are listed below:

- Developing or refining methods for surveying, sampling and assessing inter and intraspecific diversity
- Research in ethnobotany and socioeconomics to understand the role of farmers and communities
- Population genetics and conservation biology to understand dynamics of genetic diversity ***in situ***
- Understanding scientific basis for ***in situ*** conservation
- Research in farmer participatory research and participatory plant breeding
- Development of improved ***ex situ*** conservation methods, including low cost methods, improved regeneration protocols, improved characterization and evaluation techniques
- Research on improved PGR information, documentation and management methods, including documentation of indigenous knowledge
- Improved methods of access and usage of PGR conserved, including core collections and rationalization of collections, genetic enhancement, prebreeding and base broadening
- Germplasm health and safe exchange
- Economic studies on the benefits from conservation and use of PGR which can lead to improved funding, and improved choices about what to conserve, how to conserve and how to better manage collections
- Policy and IPR issues
- Applied research may be the bulk of research on PGR in many countries, often concerned with use or deriving benefits from PGR. Applied research topics include:
- Selection and screening of germplasm or introduced lines
- Breeding and genetic improvement
- Assessment of diversity in a genepool
- Assessment of adaptation of species or genotypes to various ecological conditions found in the country
- Studies on local knowledge concerning specific types of plant or landraces
- Informal research, such as that carried out by NGOs or local community groups

International Plant Genetic Resources Institute (IPGRI)

The International Plant Genetic Resources Institute (IPGRI) is one of the 16 centres of the Consultative Group on International Agricultural Research (CGIAR). IPGRI's mandate is to advance the conservation and use of PGR for the well being of present and future generations. Its mission is to encourage, support and undertake activities to improve the management of genetic resources worldwide so as to help eradicate poverty, increase food security and protect the environment. IPGRI focuses on the conservation and use of genetic resources important to developing countries and has an explicit commitment to specific crops. To undertake and to fulfil its mandate, IPGRI does not seek to conserve and use PGR itself, rather it works with a variety of partners, including national agricultural research systems (NARS), universities, regional organizations, other international agricultural research centres (IARCs), private organizations and non-governmental organizations (NGOs). Through these partnerships, which in itself is a sort of network of different stakeholders, IPGRI supports countries' efforts to effectively conserve and sustainable use their own PGR, fosters international collaboration, undertakes joint research and supports information exchange and training on PGR.

IPGRI has three objectives (IPGRI 1999):

- Countries, particularly developing countries, can better assess and meet their own needs for PGR
- International collaboration in the conservation and use of PGR is strengthened
- Knowledge and technologies relevant to improved conservation and use of PGR are developed and disseminated

There are three programmes:

- Plant Genetic Resource
- INIBAP
- CGIAR Genetic Resources Support

There are two thematic groups, operating at our Headquarters in Rome:

- Genetic Resources Science and Technology (GRST)
- Documentation, Information and Training(DIT)

IPGRI's regional activities are carried out by 5 regional groups:

- Sub-Saharan Africa (SSA) in Nairobi, Kenya
- Central and West Asia and North Africa (CWANA) in Aleppo, Syria
- Asia, the Pacific and Oceania (APO) in Serdang, Malaysia
- the Americas (AME) in Cali, Columbia and
- Europe (EUR) in Rome, Italy

In the APO region, three offices carry out the regional activities. The main office is located in Serdang, Malaysia and the coordinating offices are located in Beijing, China (East Asia) and Delhi, India (South Asia). The priorities for our work in the region were determined through extensive consultation and are periodically updated based on the various consultations that occur.

IPGRI in Asia

From the beginning IPGRI (and its forerunner IBPGR), has been very active in Asia (Arora ***et al***. 1991; Ramanatha Rao ***et al***. 1995; Ramanatha Rao ***et al***. 1996; Riley 1996b). Given the complexity of issues related to PGR, it is recognized that there are numerous areas in which IPGRI should be involved in the region. However, with the limited resources available to us, we need to prioritize our activities. All our activities are aimed at achieving our objectives, which were explained earlier and are based on extensive consultation with our partners in the region. The work that IPGRI is doing in the APO region is described below according to institutional objectives.

Objective 1

Countries, particularly developing countries, can better assess and meet their own PGR needs. IPGRI's support to National PGR programmes aims to strengthen national programme capabilities, through a number of activities. These include

National visits: Staff visits and correspondence to assess status and provide advice is an important activity. Visits to national programmes by APO staff provide an opportunity to assess the situation and to provide necessary advice and information. Assistance is also given to national programmes in preparing proposals for funding that help strengthen the work on PGR management.

National PGR workshops: Organizing national workshops through which National Committees can function more effectively can result in stronger regional collaboration. National PGR workshops have proven to be of great value. Prior to the workshops, focal points in the country are identified and assistance is provided by IPGRI to organize the workshop to involve as many organizations that have a stake in the nation's PGR as possible. This serves as the forum, at the national level; to discuss various PGR related issues, including PGR committees, structure of the NPs, public awareness, etc.

Human resource development: Strengthening human resources is an important aspect of strengthening national programmes. On a broad level, we keep the national PGR coordinators informed about opportunities available in wide range of PGR-related courses and post-graduate programmes, and assist in placing selected trainees into such courses. IPGRI also organizes short courses in the APO region annually, such as the Regional Training Course on Bamboo-Conservation, diversity, ecogeography, germplasm, resource utilization and taxonomy held on 10-17 May 1988 in Kunming and Xishuangbanna, Yunnan, China; Regional Training Course on Plant Genetic Diversity: Measuring and Using held in December 1998 in Haikou and Danzhou, Hainan; and the Indigenous knowledge Documentation course held in September 1999 in Kunming, Yunnan. Training at technical and university levels is an important aspect of IPGRI's regional activities, including assisting universities in the region in the development of curricula.

IPGRI supported the University of the Philippines at Los Baños (UPLB) in initiating a MSc Programme in PGR, with assistance from the Asian Development Bank. This provides graduate-training opportunities in the region with support being channelled through a consortium of Southeast Asian universities called SEARCA. We also assisted the Indian Agricultural Research Institute (IARI) and the national bureau for Plant Genetic Resources (NBPGR), New Delhi as well as the University Putra Malaysia (UPM) and University Kebangsaan Malaysia (UKM) to develop similar capabilities. Sri Lanka has also made a request, which is being followed up. Some the work done is described in various annual reports of IPGRI as well as other publications (Arora and Ramanatha Rao 1998; Nghia ***et al***. 1995; Riley and Ramanatha Rao 1995b; Upadhyay ***et al***. 1994)

Objective 2

International collaboration in the conservation and use of PGR is strengthened.
Our second objective is to promote international collaboration in the conservation and use of PGR, by encouraging and supporting the formation of networks, based both on crops and geographical regions/sub-regions. This is now very appropriate in the context of GPA, making regional and international collaboration as the corner stone for the PGR conservation and use (FAO 1996a). The involvement of FAO, other UN organizations, International Centres (such as ICRISAT, CIP, IRRI and IPGRI) and regional programmes such as RECSEA-PGR, SANPGR, EA-PGR will all be important in helping to exchange germplasm, information,

develop and adapt conservation technologies and promote public awareness that can improve the management of PGR in a country. The international linkages can assist national efforts in technology transfer, exchange of information, and scientific and technical cooperation (Ramanatha Rao and Riley 1996a; Riley 1994). IPGRI is involved with a series of crop and regional networks in APO that enhance exchange of information, germplasm and technologies among member countries. Such networks can also help prioritize research and training activities that IPGRI and network members can undertake (Ramanatha Rao and Riley 1996a,b; Riley and Bari 1997).

Regional networks: The IPGRI offices in Serdang, Beijing and New Delhi are presently acting as secretariats in facilitating 3 subregional networks- RECSEA-PGR (Regional Cooperation in South East Asia on Plant Genetic Resources), EA-PGR (Regional Network for PGR Conservation and Use in East Asia), and SANPGR (South Asia Network on Plant Genetic Resources) respectively. The need for a Pacific subregional network is recognized. These regional networks help to focus on common needs and opportunities among countries in strengthening PGR activities in the region through collaboration. Such networks, which generally meet once in two years, also assist in enhancing personal linkages among PGR workers in the region and assist in the exchange of information and germplasm.

Crop networks: Crop networks focus on the conservation and use of a particular crop genepool or groups of plant species. Such networks vary greatly in size and style of operation, depending on priority and funding. IPGRI works closely with other partners who often take the lead in developing and sustaining these networks. Several crop or commodity based networks are supported by IPGRI. These include: Okra network (IBPGR 1991), Coconut Genetic Resources Network (COGENT) (Batugal 1998; Ramanatha Rao and Batugal 1998; Santos ***et al***. 1996), International Network for Bamboo and Rattan (INBAR) (Karki ***et al***. 1996; Ramanatha Rao and Rao 1996; Ramanatha Rao and Rao 1998; Rao and Ramanatha Rao 1999; Rao ***et al***. 1998; Williams and Ramanatha Rao 1994), Tropical fruit species (Arora 1994; Arora 1995; Arora and Ramanatha Rao 1995; Ramanatha Rao 1998), Underutilized crops (Arora and Riley 1994; Dajue ***et al***. 1993; Mathur ***et al***. 1998; Ramanatha Rao 1996b; Ramanatha Rao and Zhou 1993; Ramanatha Rao and Riley 1995; Zhou and Arora 1995; Zhou and Arora 1996).

Networks with other International Agricultural Research Centres: IPGRI collaborates with other IARCs, which take the lead in developing networks with NAPS for the conservation and use of their mandate crops. IPGRI collaborates with the International Potato Centre (CIP) on conserving sweet potato biodiversity in Asia through the Asia Network for Sweet Potato Genetic Resources (ANSWER) (Nissilä ***et al***. 1998; Mariscal ***et al***. 1997; Ramanatha Rao 1996a; Ramanatha Rao and Schmiediche 1996; Riley 1996b).

IPGRI sees networks as tools that can promote more effective collaboration and efficient use of available resources. A lot of resources are needed to strengthen national programmes, promote exchange of information, and develop improved technologies for conservation and use. Our resources are limited. However, we believe that working in a network mode will alleviate this problem to a considerable degree. Consultations were held to further strengthen this idea under the Asia-Pacific Association of Agricultural Research Institutes (APAARI) (Riley and Bari 1997).

Objective 3

Knowledge and technologies relevant to improved conservation and use of PGR are developed and promoted.

IPGRI's third objective is to develop and promote improved strategies and technologies for PGR conservation. This objective is closely linked to effective germplasm management and the development of complementary conservation strategies. A number of technologies and research approaches are now under development, which can offer national programmes improved methods for PGR conservation and use.

Germplasm management: Although several years of research and development have gone into it, the ***ex situ*** conservation of PGR still suffers some crucial problems. The conservation of seed in cold storage appears to be straightforward. However, the problems that arise during the seed regeneration need to be sorted out and guidelines developed. Additionally, although numerous genebanks have been established in the last 20 years, the management of many of them should be significantly improved to become more rational and cost-effective. Low-input storage technologies need to be developed to allow resource-poor NPs to store their germplasm efficiently at low cost. Currently, the only way to conserve genetic resources of recalcitrant seed and vegetatively propagated species is in field genebanks. There are, however, several serious problems with field genebanks. There is a strong need to develop and refine in vitro conservation technologies, including cryopreservation. Solving these problems can only be achieved by involving NPs from developing countries in the research activities as much as possible. The work undertaken by IPGRI encompasses genebank management issues such as acquisition, conservation, regeneration, characterization, and distribution of accessions and complementary conservation strategies.

Germplasm regeneration: Maintenance of genetic diversity is a very important aspect of genetic resources activity, since crop improvement objectives change over time, and future needs cannot be predicted. Regeneration of germplasm held in genebanks is one of the most important genetic resources activities, which influences the preservation of the variability in and among the accessions.

The best way of conserving the genetic integrity and making it cost-effective is the long-term storage of seeds under optimum conditions. However, even then regeneration is necessary from time to time, either due to the loss of viability of seeds over time and/or lowering of seed stocks held in genebanks. The survey on regeneration procedures, which started around the end of 1991, resulted in putting together information on the managerial, as well as the genetic aspects of regeneration procedures. An analysis of the data, which was completed during early 1995, highlighted the fact that most of the regeneration in genebanks is carried out for seed stock reasons and less for viability loss. The analysis was presented at a consultation meeting on the regeneration of germplasm of seed crops and their wild relatives in December 1995 at ICRISAT (Engels and Ramanatha Rao 1998).

The work on the determination of effective pollination control methods and isolation techniques was carried out in collaboration with Institute fur Pflanzenbau und Pflanzenzuchtung (IPP) of the Bundesforschungsanstalt fur Landwirtschaft (FAL), Braunschweig and the Institute fur Pflanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany and was concluded in 1995. The investigation indicated the need to study further: 1) the need for definite answers on pollination control methods; 2) need for defining insect densities for effective population; and 3) need for standardization of insect rearing and use techniques. The efforts are underway to publish guidelines for rearing of insects used in this study and using them for controlled pollination of genebank accessions (Schittenhelm ***et al***. 1997).

Work on determination of the extent of loss in genetic diversity in germplasm conserved in ex situ collections for 3-6 genepools using morphometric, biochemical and molecular techniques was initiated in collaboration with the Genebank, Bari and University of Potenza, Italy in mid-1993 and concluded in 1996.

Studies on regeneration methods for germplasm seed in genebank started at the end of 1993 at the Institute of Crop Germplasm Resources (ICGR), CAAS, Beijing, China is now concluded. This work resulted in defining the appropriate regeneration methods for multiflora bean, Chinese cabbage and common buckwheat.

Genetic stability: Work on the detection of changes and maintenance of genetic integrity of germplasm conserved in ***in vitro*** conditions was carried out in collaboration with the School of Biological Sciences, University of Birmingham, UK and Laboratory of Tropical Husbandry, and Catholic University, Leuven, Belgium. Screening of plantain off-types with ten-base random primers was continued. This work did not result in any definite conclusions on the use of molecular markers.

Guidelines: A consultation meeting on the regeneration of germplasm of seed crops and their wild relatives was organized, as part of the initiative of the CGIAR System-wide Genetic Resources Programme (SGRP), in collaboration with FAO and ICRISAT, in December 1995. It focused on the regeneration of seed crop germplasm and brought together experts from IARCs and NARS. The proceedings of the consultation meeting have been published (Engels and Ramanatha Rao 1998) followed by a technical guide entitled Regeneration of Accessions in Seed Collections: A Decision Guide (Sackville Hamilton and Chorlton 1997). The guide on regeneration is intended to facilitate the development of optimum procedures for regeneration of seed germplasm and deals with the timely identification of accessions with and inadequate quality or quantity of seed.

A publication of Guidelines for the Management of Field and ***In Vitro*** Germplasm Collections is also due by the end of 1999. These guidelines are intended to assist genebank curators by providing decision criteria and options for the establishment, management and maintenance of field and in vitro germplasm collections.

Field genebank management: In collaboration with the Malaysian Agricultural Research and Development Institute (MARDI), work has been done on the issues related with field genebank management of rambutan and sweet potato. The emphasis of this work is on improving linkages between conservation and use and supporting the long-term conservation of field collections. Collaborative work with the Philippine root and Tuber Crops Research and Training Center (PRCRTC), VISCA, the Philippines on some aspects of sweet potato field genebank management have been carried out. Currently, some work on the economics of field genebank has been started in APO.

Genebank management-Expert Systems: In 1993, the idea of using Expert Systems (ES) for regeneration in genebanks was discussed. ES are software that is developed to capture the heuristics of decision-making that are peculiar to experts. Participants of the regeneration meeting held in ICRISAT indicated the need for such system to assist curators. Work is currently in progress on analyzing the decision making process for regeneration in genebanks and is being carried out jointly with NIAR, Japan and ICGR, China, in the context of EA-PGR.

Ultradry seed storage research: Maintaining seed germplasm in cold storage is still a problem for many genebanks in the developing world. Hence, cheaper alternatives to expensive cold storage of germplasm seed are needed. One of the possible methods is ultradry seed storage, based on sound scientific principles. Therefore, IPGRI supported the Institute of Crop Germplasm Resources (ICGR), the Oil Crop Research Institute (OCRI) of CAAS, and Beijing Botanical Garden (BBG), Chinese Academy of Science (CAS) to carry out research and develop methodologies for ultradry seed storage (Zheng ***et al***. 1998). Experiments on a simple and low-cost method for ultradry storage were conducted at ICGR. The results showed that drying seeds with silica gel in laminated aluminium foil bags could be a cost-effective method for seed drying. Basic research was conducted in Beijing Botanical Garden to determine if there was any damage during ultradrying or ultradried storage to membrane lipid and other macromolecules of embryo. Support was provided to ICGR to participate in the global seed experiment and to carry out part of this work in collaboration with the two institutions mentioned above. The Satellite Symposium on ultradry seed storage and longevity was organized by IPGRI during the second International Seed Sciences and Technology workshop, held in Guangzhou, China, in May 1997 and was well attended. The world status of ultradry seed research was presented by IPGRI, National Seed Storage Laboratory (NSSL), USA and Reading University, UK. Apart from the above, representatives from IPGRI-supported projects on ultradry seed storage and scientists from the Chinese national programmes presented their findings in this area, for diverse crop species (Engels and Engelmann 1997).

Seed storage behaviour: Seed Storage Behaviour Compendium software was developed by IPGRI in cooperation with ICGR, CAAS, China in 1996. It is a DOS-based application and allows users to query the Compendium database to assist in the PGR conservation efforts worldwide.

Options for national PGR programmes: National PGR programmes or the departments dealing with it in the region are very diverse and vary greatly in size and quality. Major questions asked by most people concerned with the development of national programme are - What sort of programme is appropriate to the country? What are the options available? How to make choices? These crucial questions need correct answers. Towards this end, a consultant was supported to develop a guide on options for the organization of national PGR system and a report was circulated within IPGRI.

Since the CBD came into force, many countries have been reorganizing their PGR programmes. Countries that formerly were without any activity on PGR are putting programmes into place. The need to strengthen national programmes has been further emphasized by the GPA, which identifies building strong national programmes as one of the 20 priority activities proposed. Discussions with various partners has resulted in IPGRI-APO developing an information database (InfoBase) containing country information as a part of its efforts in strengthening national programmes.

Forest genetic resources: Within the forestry genetic resources work of IPGRI, work is in progress on in situ conservation of forest genetic resources. A research programme for the Western Ghats, India, is being carried out in collaboration with the University of Massachusetts at Boston (UMB), USA and the University of Agricultural Sciences (UAS), Bangalore. This represents a comprehensive approach to conservation and utilization of forest genetic resources in Southwest India, where rural and urban populations are heavily dependent upon the rapidly diminishing forests for a multitude of goods and services (Ganeshaiah ***et al***. 1997; Ravikanth ***et al***. 1999).

Distribution maps based on the data from different ranges of forests under development have been prepared, which will help to identify populations that are isolated to different degrees. Protocols for eight isozymes systems have been finalized for the seeding material in ***Santalum***. The protocols for the ***Phyllanthus*** are already available.

Within IPGRI's work on forest genetic resources, work on bamboo and rattan, in collaboration with the International Network on Bamboo and Rattan (INBAR) is significant. Work on species prioritization, ecogeographic surveys and patterns of species distribution, assessing patterns of genetic variation, processes regulating genetic diversity, ex situ and in situ conservation, human resource development and facilitating regional cooperation and networking have been in progress. Some important activities undertaken in the last year or two are briefly described here. A revised priority species list of bamboo and rattan has been published (Rao and Ramanatha Rao 1999). Surveys were carried out for several priority species in many countries and identification of populations for conservation has started. Population survey and genetic analysis of Phyllostachys pubescens and Dendrocalamus latiflorus is on going in China. Studies on species diversity and reproductive biology of a few species of ***Calamus*** in Western Ghats, India have been completed. Ecogeographic survey and phenology of rattan in Nepal has been carried out. The bamboo and rattan species of fourteen Asian countries were enumerated and lists prepared. Pattern of genetic variations of three rattan species in Malaysia has been studied. In collaboration with the National University of Singapore and University of Nebraska, Lincoln, nuclear DNA contents of over 20 species of bamboo and 15 species of rattan were determined by flow cytometry. Genetic diversity studies were conducted in Thailand and Malaysia on four important rattan species. Impact of human activity on genetic diversity of bamboo and rattan is being studied in Western Ghats of India. Studies on conservation of rattan germplasm in China, including biology and ecology have been carried out. Collecting strategy and conservation, handling, germination and viability testing methods of bamboo seeds has been developed. Studies on in vitro propagation and slow growth techniques were carried out on ***Gigantochloa levis*** and ***Bambusa bambos*** in collaboration with NPGRL, Philippines. Genetic diversity studies on ***Calamus*** species with a view to refine ***in situ*** and ***ex situ*** conservation efforts in Vietnam are going on. An IPGRI/INBAR/ICIMOD training course/workshop on bamboo was successfully organized during 15-17 May 1997 at Kunming and Xishuangbanna, Yunnan Province, China with 15 participants from 12 countries. Collaborated with INBAR in organizing the World Bamboo Congress. A memorandum of understanding (MOU) with INBAR is under development.

Ex situ ***storage technologies***: A number of crop species, predominantly tropical or sub-tropical, together with many tree and shrub species, produce recalcitrant or intermediate seeds which are unable to withstand much desiccation, are often sensitive to chilling and, therefore, cannot be stored dry at low temperature. The traditional method of conserving the genetic resources of these problem species is as whole plants in the field. There are, however, several problems with field genebanks, including exposure to natural disasters, attacks by pests and pathogens, and high maintenance costs. Moreover, germplasm distribution and exchange from field genebanks is difficult because of the vegetative nature of the material and the greater risks of pest transfer. Tissue culture techniques have great potential for collecting, exchange and conservation of plant germplasm.

In the APO region, there are a large number of problem species, for which it is necessary to develop in vitro conservation methodologies. Activities performed in the region in the area of ***in vitro*** conservation include the execution of research projects, the organization of individual training programmes for researchers, the participation in specialized training courses and co-organization of scientific meetings.

Research activities focus on the development of in vitro collecting, slow growth and cryopreservation techniques for various fruit trees, forest trees and vegetatively propagated crops. ***In vitro*** collecting techniques are being developed for ***Dipterocarps***. Slow growth techniques have been developed for medium-term conservation of citrus germplasm and are under experimentation for sweet potato. Cryopreservation protocols have been established notably for zygotic embryos of almond, tea, jackfruit, oil palm and several ***Dipterocarp*** species, and are under development for apices of yam, sweet potato, taro and apple. Several studies on mango, citrus, and jackfruit have been carried out with support from IPGRI (Engelmann

1997; Engelmann and Assy-Bah 1992; Engelmann and Ramanatha Rao 1996; Normah and Seti Dewi Serimala 1995; Withers 1991).

Several researchers in the APO region have received training on ***in vitro*** conservation techniques, either through individual training periods or through attendance in specialized training courses. IPGRI has also contributed to the organization of an international symposium on in vitro conservation of genetic resources, which took place in Malaysia in 1995 (Engelmann and Ramanatha Rao 1996).

Germplasm health: Germplasm health aspects need to be considered not only at the point of exchange, but also at any stage of germplasm management. During collecting, care must be taken that germplasm is collected only from healthy plants. In the regeneration and multiplication process, plant protection measures including pesticide application, may be required. If an evaluation of traits such as resistance to pathogens is carried out under conditions of high disease pressure, e.g. with artificial inoculation, a careful evaluation of the material with regard to its use in regeneration or exchange is essential.

Work is in progress on the development of PCR primers for the detection of ***Xanthomonas compestris*** pv. ***Vesicatoria*** in tomato and pepper seeds in collaboration with AVRDC and the University of Florida. Another study on seed transmission and detection in seed with PCR and seed washing test is ongoing in partnership with AVRDC and the Bonn University. A study on detection and characterization of Allium viruses was carried out jointly with AVRDC and the Federal Biological Research Centre in Braunschweig, Germany. Research on pathogenicity testing of viroid-like sequences in coconut was done in collaboration with the Philippine Coconut Authority Albay Research Center, the Philippines.

Establishment and use of core collections: Work on developing core collections in sesame in CAAS, China and NBPGR, India was carried out. Sesame is a priority-underutilized crop in APO. Work on conserving crop PGR has always been concerned as much with the effective use of the resources as with conserving variation per se. With the increasing number of genebanks and size of collections, one of the major issues is the need to improve the accessibility of collections to users. Generally, plant breeders (and most users) are interested in having a fairly small number of genotypes, which either possess, or are likely to possess, the traits needed in breeding programmes. The development of core collections (minimal sets of accessions chosen to contain the genetic diversity present in the whole collection), is one of the ways suggested to increase accessibility and use, as noted in the Global Plan of Action.

IPGRI supported the work on developing core collections in India and China, which also provided information on optimum procedures for core collection development in national genebanks. The work in China was carried out at the Oilseed Crops Research Institute (OCRI), Wuhan and in India, it was at NBPGR, New Delhi (Hodgkin ***et al***. 1995; Zhou 1995).

Biodiversity of taro and indigenous knowledge: Taro is an important crop for APO. A pilot study on the linkage between genetic diversity and ethnobotany was carried out, in collaboration with the Institute of Vegetables, Flowers and Biotechnology Research Centre of CAAS and the Kunming Institute of Biology. The project aimed to integrate ethnobotanical information with genetic information and efforts will be made in the locating of genetic diversity in taro in Yunnan province, China. It also attempts to link ethnic group diversity with taro intraspecific variation, number and identity of species grown, types and cultivars grown, farmer selection, distribution of varieties over the survey area and indications of genetic erosion. A joint meeting of all the partners was held during December 1998 and plans to extend this study have been made.

Documenting Indigenous Knowledge: Indigenous knowledge (IL) is closely related to the environment that the people who live in it and is a living knowledge that will change over time in the same way that crops adapt to their changing environment. Other factors modifying the knowledge are changes in social structure and values plus interactions with other communities. The close interactions between PGR, the environment and the farmers, generate the basic sources of IK in the community in the area of PGR conservation. Hence, IK is a valuable source of knowledge in the ***in situ*** conservation of PGR and in situ conservation in turn will help to maintain that living knowledge.

In APO, work on IK was initiated in 1995. Further discussions with NPs indicated that there is the need to address the issue of farmers' rights and the ability of the community to re-use the knowledge. This was addressed by the suggestion that farmers' rights could be run as a parallel system to the scientific knowledge system already present. To understand this further, a study on IK documentation was initiated with the Yunnan Academy of Agricultural Sciences in December 1996. The use of the IK Journal approach in a way addresses the knowledge holders' rights. With rights being recognized, the equitable sharing of benefits will follow in same manner as scientific knowledge and the possible unity of knowledge systems (Quek 1995a; Quek 1995b). A farmers training workshop was held recently to train farmers to document their knowledge so that their community can benefit from it.

Dissemination: IPGRI provides an international information service to inform the world's PGR community of both practical and scientific developments in this field. Technical and scientific publications will be the major media through which the results of studies and new technologies will be conveyed to national programmes. The types of information that we provide includes descriptor lists to assist genebank curators and other PGR users, information that can be used to collect, manage and use germplasm samples, directories for different crops/commodities providing information on where particular germplasm is conserved and available for exchange, etc. The List of IPGRI publications contains all the titles published so far. Additionally, an effective public awareness programme has been put in place to increase the awareness on PGR issues among the general public as well as policy makers (public and corporate levels) so that PGR conservation will receive appropriate support at all levels.

It would be useful to highlight our work on PGR documentation and information management, which are usually given little importance. Our aim is to strengthen the national capacity to develop and sustain an effective national PGR information network, and a network information system (NIS)(Mathur and Quek 1998; Mathur and Quek 1997). Of particular importance is the support provided to our partners to document and make better use of their own accessions in genebanks. A Data Interchange Protocol (DIP) has been developed to enable one genebank to receive and read information from another genebank using a compatible format. The DIP format is now being used to develop electronic germplasm catalogues by genebanks in the regions. Software known as Genebank Management System (GMS) developed by IPGRI is used to train genebank curators in genebank documentation and management. GMS training has been carried out in many countries in the region. Our work on information management also supports development of tools for information exchange such as the DIPVIEW software, which has been, tested (Yongsheng ***et al***. 1995). The InfoBase, an Internet database of links to NPs web sites has been developed. It is recognized that a well-organized and well-maintained information system is an essential part of an effective conservation programme. IPGRI will support national programmes to develop such national PGR information systems (Quek and Ramanatha Rao 1995; Quek and Zhang 1995; Riley and Ramanatha Rao 1995a).

Rapid progress is being made in all the areas of technology development described earlier. The Internet is an example where it's rapid development has impacted the way we distribute information. It is important that national PGR programmes should keep in touch with what is going on around the world. International collaboration is one of the ways to keep up to-date information on new developments and their adoption at national level. IPGRI also assists in providing such information to its partners through newsletters and publications. Additionally, it organizes or supports several conferences or meetings to facilitate interaction of PGR researchers. Some examples in the recent years include the workshop on users' perspectives to promote multipurpose uses and competitiveness of coconuts in May 1996; regional coconut genebank planning workshop in February 1996; regional workshop in Lathyrus resources in Asia in December 1995, third Southeast Asian symposium on genetic resources in August 1995, international workshop in ***in vitro*** conservation of PGR in July 1995; international symposium on research on conservation and use of PGR in June 1995 and SPC/DAL/IPGRI/FAO Taro seminar in June 1995. Support was provided for meetings on seed technology, citrus germplasm conservation focusing on rootstocks and biotechnology in 1997.

Concluding remarks

IPGRI considers the national programmes as the basis for a global system of PGR. Strengthening national programmes in terms of organization, technology, human resources and information is the basis of IPGRI's work on PGR. National programmes can best use such assistance when there is a clear recognition of the importance of PGR in a country and identification of organizations/individuals responsible for taking the work forward. From the initiation of the programme in the APO region, IPGRI has been supporting the organization meetings such as the present one to help the PGR workers in the country to come together and discuss freely and chart out a programme of action for the country. The programme also should consider all the issues discussed together and identify the appropriate level of activity for each country as well as for working in collaboration. IPGRI is willing to support to the extent it can, mainly in the areas of techniques and advice, to assist national PGR programmes to implement various actions required under the GPA and fulfil country's responsibility for sustainable conservation and use of plant diversity.

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In situ conservation on-farm

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Introduction

In situ conservation is concerned with maintaining plant populations in the habitats in which they occur. ***In situ*** conservation of cultivated species, sometimes referred to on-farm conservation, is primarily concerned with supporting the on-farm conservation of traditional crop genetic resources in the production system in which they have evolved and continue to be maintained. On-farm conservation concerns entire agroecosystems, including immediately useful species (such as cultivated crops, forages and agro-forestry species), as well as their wild and weedy relatives that may be growing in nearby areas. In this paper we discuss the following five areas: 1) Why is ***in situ*** conservation on-farm important and to whom? 2) What information is necessary to support on-farm conservation of crop genetic resources? 3) The importance of and methods for linking different partners from different disciplines and formal and informal institutions and sectors including community sensitization and farmer involvement, 4) Methods for collecting and analysis the needed information and 5) Using this information for social, economic, ecological and genetic benefits for farmers and society.

Why is *in situ* conservation on-farm important and to whom?

Understanding why we want to conserve genetic diversity on-farm is important because it can help to identify the specific needs of an on-farm conservation programme. In addition to the conservation of agricultural biodiversity for its potential to supply crop breeders and other users with germplasm for the future of global food security, on-farm conservation has other major benefits, which make it unique among the options available to conservationists. These benefits not only relate to genetic diversity but also to ecosystem health and human well being. The conservation of agrobiodiversity at all levels within local environments helps ensure that the ongoing processes of evolution and adaptation of crops to their environments are maintained within farming systems. This benefit is central to ***in situ*** conservation, as it is based on conserving not only existing germplasm but also the conditions that allow for the development of new germplasm. On-farm conservation may be an important way to maintain local crop management systems for agroecosystem sustainability by ensuring soil formation processes, reducing chemical pollution and other waste emissions from farms, and restricting the spread of plant diseases.

Farmers are likely to know the nature and extent of local crop genetic resources better than anyone through their daily interactions with the diversity in their fields. Given their expertise, incorporating farmers into the national PGR system can help create productive partnerships for all involved. This integration can happen in several ways, including developing systems to make genebank material more easily accessible to farmers, seeing farmers as partners in the maintenance selected germplasm, establishing a national dialogue on biodiversity conservation, sustainable use and equitable benefit sharing between farmers, genebanks and other partners, assisting the exchange of information with and among farmers from different sites and projects.

In situ conservation programmes also have significant potential to improve the livelihoods of farmers at the local level. On-farm conservation programmes can be combined with local infrastructure development or the increased access for farmers to useful germplasm held in national genebanks. Farmers will benefit from the continued agricultural diversity and ecosystem health that on-farm conservation supports. Local crop resources can be the basis for initiatives to increase crop production or secure new marketing opportunities. By building development efforts on local resources and through the empowerment of farming communities, they can lead to sustainable livelihood improvement. Resource-poor farmers, in particular, may benefit if development initiatives are not based on external inputs that may be costly or inappropriate for marginal agroecosystems.

What information is necessary to support on-farm conservation of crop genetic resources?

Before implementing an ***in situ*** conservation programme a thorough understanding of the factors that influence the level of crop genetic diversity on-farm is needed. While ***ex situ*** conservation is primarily a technical issue of how best to preserve germplasm, a complex range of factors shapes the conservation or erosion of genetic diversity in farmers' fields over time. These range from farmers' decision-making to local environmental change to interactions between and within crop populations. The combinations of these factors requires research to answer the following key questions:

1. What is the amount and distribution of genetic diversity maintained by farmers over time and space?
2. What processes are used to maintain this genetic diversity on farm? Who maintains this diversity on-farm (men, women, young, old, rich, poor, certain ethnic groups)?
3. Who maintains this diversity on-farm (men, women, young, old, rich, poor, certain ethnic groups)?
4. What factors influence farmer decision-making to maintain diversity on-farm?

The combinations of these factors are illustrated in the framework presented in the following figure (Figure 1) below.

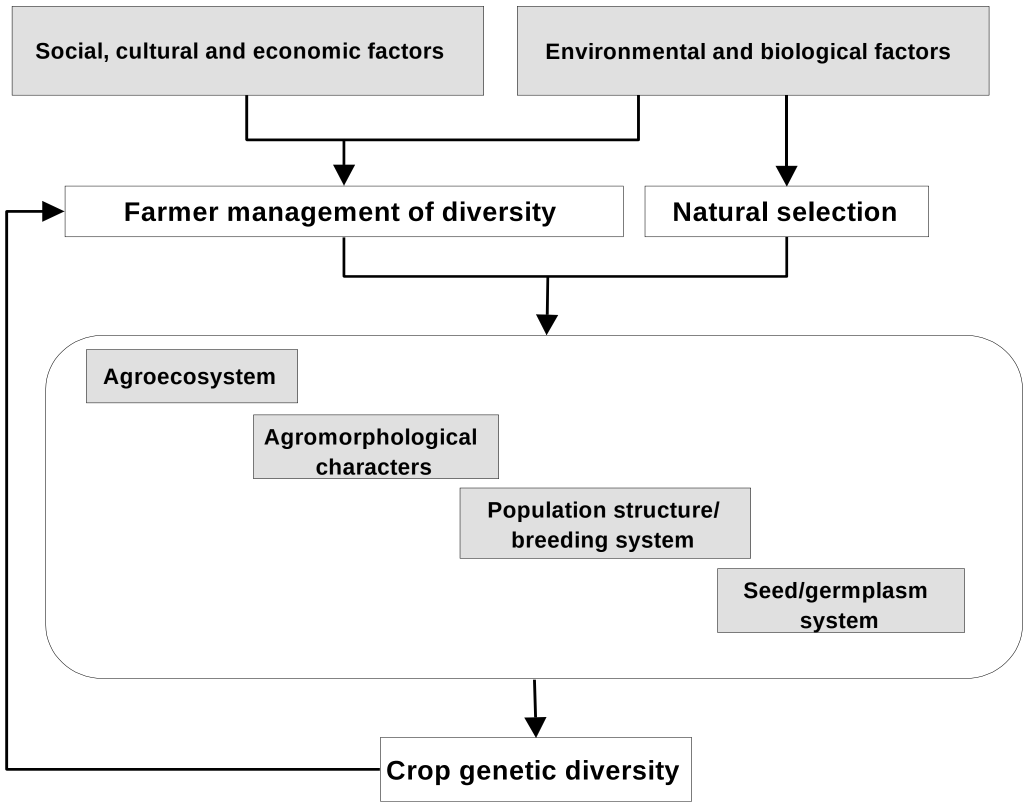

Fig.1. Link between farmer decision-making, natural selection and measures of genetic diversity (Jarvis ***et al***. 2000).

Social, cultural, economic, environmental and biological factors influence a farmer's decision of whether to select of maintain a particular crop variety at any given time. Farmers, in turn, make decisions in the processes of planting, managing, and harvesting their crops. Over time they may modify the genetic structure of the crop population. A challenge undertaken by on-farm conservation research is to quantify the effects of social, cultural and economic factors on farmers' actions with regard to the maintenance of crop genetic diversity. Understanding these relationships will provide insights into the conditions fostering landrace conservation and better enable the design of formal ***in situ*** conservation strategies.

Key questions to ask are:

1. What social, cultural and economic forces influence varietal choice?
2. What are the opportunity costs of conserving agrobiodiversity?
3. What are the appropriate social or economic categories for data disaggregation? (gender, age, ethnicity?)

The basic unit to be sampled should be centred with the farmers' management unit. For social, cultural and economic information this is normally the household. Some major social, cultural and economic factors that could influence farmers' choice of varieties and how they manage these varieties are listed above.

In addition, to social, cultural and economic factors, environmental and biological factors such as soil type, water availability, pests and diseases, may also influence a farmer's choice of variety that he or she may plant and manage. Agroecosystems provide the arena in which crop evolution occurs, presenting stresses, but also opportunities, to which crops must adapt in order to thrive. The farmers who manage these factors in terms of irrigation, nutrient input, pest control, land preparation, mixed / relay cropping and other practices are also a biotic component of agroecosystems. These factors vary over time, with seasonal, annual, and stochastic changes, and in space, from the micro-environmental to the eco-regional scale; as a result, local landraces adapt to the particular conditions of their immediate ecogeographic setting. These adaptations to local environmental stresses are likely to be reflected in genetic composition of a landrace over time.

Farmers easily recognize many of the phenotypic features of plants and use those features to identify and select their crop varieties. These agro-morphological criteria may take a wide range of forms and are usually linked to the genetic diversity of a crop. They are used by farmers to distinguish and name crop varieties and are commonly the basis for farmers' selection of planting seed. Because of this, we can say that species' agro-morphological characteristics are the link between farmers and the crop genetic diversity in their fields.

It is important to understand how farmers make use of their crops' agromorphological characteristics in three different capacities. First, agromorphological traits are used by farmers to identify, or distinguish, varieties and these identifying characteristics are often the basis for the names farmers give to varieties. Second, some of these traits are preferred, or valued, by the farmer; that is, the farmer chooses to plant a particular variety because certain of its distinguishing characteristics are desirable. Third, farmers select among the plants in the crop population to maintain these desirable characteristics and to increase the prevalence of other valued traits in the population over time. For instance, a farmer may identify a named variety of maize by its colour, leaf shape, and region of origin, value it for its cooking quality, and select for higher yielding plants to increase the yield potential of the variety.

Plant population genetics is a branch of plant population biology with three aims. These are (1) to describe the genetic diversity within and between the populations of a plants species, (2) to estimate the strength of evolutionary forces that shape these patterns of diversity, and (3) to develop theoretical models that predict the stability and change in these patterns. Thus population genetics is one the basic disciplines underpinning the scientific basis of on-farm conservation, providing a framework, and procedures for monitoring diversity.

The breeding systems of crop plants help determine how genetic diversity will be distributed within and between their populations, and also how new genetic diversity can arise in individual species. Farmers' decisions regarding the size and relative placement of their fields impact significantly on local crop diversity. Fields may be large or small, close together or widely separated. Depending on the reproductive biology of the crops in question, this structuring can have a range of effects on the genetic diversity of crops.

Each year the farmer decides how much seed to plant and where that seed comes from. In addition to the seed selected and stored from his or her own crop, the farmer may procure new seed from markets or other farmers. By planting seeds from sources beyond his or her own fields, the farmer makes a conscious decision to introduce new germplasm into the agroecosystem. Studying seed flows will enable a better understanding of the processes by which seed is stored and exchanged and the associated impact on the distribution of genetic diversity.

Linking different partners from different disciplines and formal and informal institutions and sectors including community sensitization and farmer involvement

The first step in the establishment of a national framework for on-farm conservation is the identification of partners and the creation of linkages between them-including diverse disciplines, institutions, and formal and informal sector organizations. Other important aspects of creating a national framework for long-term, sustainable research and implementation of on-farm conservation include training and equity. Enhancing national expertise through training male and female personnel in plant population biology, ecology, biogeography, conservation biology, economics, sociology and anthropology will create a foundation for sustainable research and conservation programmes. Training should target both farmers and project personnel and when possible should serve to strengthen the collaboration between them, such as training on participatory approaches to research.

On-farm conservation initiatives should also promote equity at all project levels, from farmer participation to research to project management and decision-making. Gender awareness is one important facet of national on-farm conservation projects, not only in the collecting of gender disaggregated data and the participation of women farmers in the project, but also in the involvement of women and men as members of research and management teams. Increased women, minority, and farmer participation in decision-making is essential to ensure that diverse perspectives are incorporated into project objectives and that all stakeholders feel ownership in the project.

Methods for collecting and analysis the needed information

On-farm conservation research should be implemented with a participatory approach at all stages of the process. Participatory research refers to techniques that emphasize researchers and participants learning together, rather than the extraction of information by researchers from participants. The use of participatory methods can serve to include farmers in the research process and to incorporate their knowledge on local socio-economic and agroecological conditions, their crop and seed management practices, and the characteristics and origins of their varieties into project data. An exploratory approach-one which is not based on preliminary hypotheses-is initially useful because it does not presuppose or assume the different categories or reasons underlying farmers' knowledge and enables farmers to employ their own values and standards of measurement. Techniques can be structured to allow for the collection of quantitative data, or semi- or unstructured to elicit qualitative data.

Empirical data can confirm a farmer's perception of his or her surrounding system.

Empirical data also should add information that may be invisible to the farmer or may be outside the farmer's expertise, or may be at a higher spatial or temporal level than the farmer household or community. The information on these topics comes from different levels and disciplines. The different sources and levels of information include the variety, the crop, the parcel or plot, the household, the village or community, the landscape or region. Likewise information from one aspect may be useful to answer more than one question. What is important is that the information collected at the level of the household or farmer's plot may not be the appropriate scale for analysis for crop diversity conservation.

Appropriate sampling is important to ensure that adequate representation of the situation or site is reflected in the information collected. Regardless of the approach chosen, some part of the diversity in human, environmental and genetic diversity factors will not be sampled. Sampling strategies must consider resource constraints along with scientific needs. How many subsamples of households, plots, and plants are necessary to have a representative sample of the site or population in question? The objective is to determine the smallest number of samples to adequately characterize the region in question. Stratifying to structure date becomes extremely important when more than one discipline is involved in a sampling procedure. For example: a community or village containing 1000 households is selected as a study site. Ten percent or 100 households of the village are sampled for social and economic variables. In each household, a farmer grows four target crops. For each crop, the farmer manages an average of three varieties grown in a particular field with certain soil and topographical characteristics. For each variety a minimum of thirty samples are needed for an adequate study of the population. Thus, in order to compare household characteristics, plot characteristics and varieties, we end up collecting 30 samples X 3 varieties X 4 crops X 100 households or 36 000 samples for analysis. Of course this number of samples is unreasonable given time and resource constraints. How is this problem solved? One method is to return once again to the key questions that the study is trying to answer - what is the amount and distribution of genetic diversity maintained on farm, by what processes is this diversity being maintained, by whom and why - to structure the data collection.

Using this information for social, economic, ecological and genetic benefits for farmers and society

Effective management and conservation of genetic resources on-farm takes place where the resources are valued to meet the needs of local communities. In order for local crop systems to be maintained by farmers, resources must have some value and/or be competitive to other options a farmer might have. Benefits may be social, cultural, economic, ecological and genetic and may be for farmers, communities and society.

When on-farm conservation research has identified genetically important crop populations and farming systems that are priorities for conservation, it may be appropriate to assess different options for "adding value" to these populations, or in other words, increasing the benefits that farmers get from cultivating diverse local crop resources in a given social, economic, and ecological context. When we refer to "enhancing the benefits" for farmers of local crop diversity, we mean the ***net*** benefits (total benefits minus costs), as there may also be costs to farmers associated with participation in these options. General means of enhancing the benefits of landrace cultivation for farmers include improving the landrace material and production system, increasing farmers' access to a diversity of varieties, and increasing consumer demand for products using a diversity of varieties.

Increasing farmers' access to diverse crop genetic resources, as well as information about these resources, could serve to broaden farmers' options regarding varietal choice while fostering diversity conservation. Access to new and diverse varieties can be improved through community genebanks and community biodiversity registers, strengthened seed exchange networks, and the incorporation of landraces into national extension programmes, while information regarding these resources can be disseminated through community-level public awareness activities like Diversity Theatre and Diversity Fairs.

If diversity can be more highly valued in the marketplace through the creation of consumer demand for certain products and farmers can access those markets and this can be an excellent incentive to maintain diversity. Strategies to increase consumer demand for diverse crop resources include improved processing, packaging, and marketing of landrace products, public awareness initiative to educate consumers about the value of agrobiodiversity, and linking with other types of products in demand, such as organic produce.

Training agricultural extension personnel in the value of local crop genetic resources and the importance of landrace conservation could be an important step in creating extension programmes that support, rather than hinder, maintenance of diverse crop resources on-farm. This training could be incorporated into the curriculum of extension workers at a national level or offered as in-service training to experienced extension workers. If extension personnel recognize the importance of local landraces for conservation and local livelihoods, their work could act as a means of spreading local crop diversity and knowledge while strengthening the relationship between farming communities and national PGR systems.

The general "respect for the environment" has gained prominence in much of the developed world through widespread association with indigenous peoples and traditional ways of life. This has been achieved largely through public awareness campaigns that use the media to disseminate messages about the potential success of ecologically sound environmental management practices. Although they have played a relatively small part in such media campaigns to date, local agricultural systems could figure prominently in to these types of messages, disseminating information about the processes and implications of genetic erosion, as well as the importance of on-farm conservation.

Particular agroecological management practices may also serve to support production of crop diversity. Low chemical input or organic farming with local varieties can serve to promote agroecosystem stability and health. Such improvement strategies must necessarily be local in order to be used for a diversity of landrace materials.

Improving diverse crop populations or the production systems in which they are grown is one possible means of increasing benefits to the farmers who grow them. Plant breeding strategies have been developed to improve varieties locally and according to farmers' interests, like Participatory Plant Breeding and seed cleaning treatments. In addition, seed storage practices could be strengthened to prevent losses to diseases, pests and deterioration.

The role that national economic and agricultural policies plays in the support, or lack thereof, of farming systems maintaining crop diversity remains to be investigated. If market failures are identified that prevent the farmer from capturing the full benefits of the market's valuation of diverse landraces, policy changes can serve to correct these market failures. Current national policies may serve to deter the maintenance of landraces. Farmer varietal classification systems often do not fit the criteria of uniformity required for seed certification through national systems, which may hinder local-level seed innovations. In addition, linkages are weak between public agricultural research and commercial seed providers, limiting distribution of farmer varieties. The supporting farmer seed marketing systems may be necessary for landraces to become widely available beyond the local level.

However, the effects of specific policies on farmers' choice of varieties are not fully understood. For example, an extension programme promoting an agronomic package of modern varieties, fertilizers and pesticides may discourage landrace cultivation. On the other hand, even if farmers adopt these packages, the increased income that may result could enable farmers to continue to maintain preferred varieties on smaller land areas.

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Agrobiodiversity and development of sustainable agriculture in China

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Introduction

As part of biodiversity, agrobiodiversity is an important resource and the material basis for human welfare. Agrobiodiversity includes not only the domesticated species and their genetic material in terms of varieties planted at any period and any location, but also semi-domesticated and related wild species. It also includes the species that people use by picking, cutting, digging and for grazing animals. Thus it means that more abundant diversity is, greater the potential for people to improve available varieties and develop new varieties. Agrobiodiversity not only provides people with material for food and shelter, but also provides nutritional and medicinal products for their wellbeing. Most importantly, it provides humans a good living environment. It is also the vast genetic resources for people to improve existing cultivars and develop new ones and basic material for biotechnology research. It is important to point out that some precious and rare plant species, especially those in danger or extinction, are not only valuable for science and environment, but also for human culture and economic uses.

With increasing population, food crisis is the major problem in the world. However, increasing food production can not depend on increasing cultivated area because there is little arable land to expand and developing new fields would be harmful to both environment and biodiversity. In order to make agriculture sustainable, high yield is the only way to increase food production. Among factors affecting high yield such as irrigation systems, fertilizers and other cultural methods, superior varieties are the most important ones. Developing superior varieties is dependent on the availability of plant genetic diversity. At present, a gene can not be produced by any technology, it can only be transferred, copied or modified. Many useful plant genes are available in variable cultivars (from ancient or current times, domestic or foreign origin) and their wild relatives. All of these are the crop genetic resources or crop germplasm resources. It is recognized that breeding is in fact the re-processing of germplasm resources. Therefore, conservation of agrobiodiversity is central to sustainable agriculture.

Agrobiodiversity in China

Types of agrobiodiversity in China

China covers large land area with diverse ecological conditions and long history of agriculture. Through both natural and artificial selection from ancient times, PGR for agriculture are very abundant, diverse and unique. According to available statistics, about 10 000 species are used for agricultural purposes, belonging to 22 types of plants in 4 groups (see below). Because some plants are multifunctional, the statistical data may include some duplicates.

Edible plants: Edible plants include plants for two different kinds of uses, direct and indirect. Directly used plants contain 100 species for food, 100 for oil, 50 for sugar, 700 for vegetable, 300 fruit species and 50 species for drink. Indirectly used plants include 500 species for feed and 2500 for forage.

Plants for industrial use: Plants used for industrial use include 2000 species for timber, 1200 for fibre, 50 for rubber, 100 for gum, 350 for aromatic oils, 500 for industrial oils, 300 for tanning oils, 60 for pigments, 300 for parasitic creatures from which industrial products are derived, 50 for weaving and some species for producing insect gum.

Plants for medicine: About 5000 plant species are used in human medicines, 500 species in animal medicine and 200 species for agricultural chemicals.

Plants for environmental conservation: These plants include 500 species for horticulture, 160 as indicators, and some others for sand and dirt protection and nitrogen fixation and so on.

The plant species used for agricultural purposes can be divided into two types: domesticated and wild species. It is estimated that there are about 600 domesticated plant species in China, of the 1200 in the world. Among the domesticated plants, more than half were originated in China or have been cultivated in China over 2000 years.

Abundant variation of plant genetic resources of agriculture used in China: A large number of crops are not the only feature of Chinese agriculture; in fact, each crop has many different cultivars, landraces and types. For example, there are 50 000 accessions of rice in China, belonging to ***indicia*** and ***japonica*** subspecies. Both of these include paddy and upland rice and glutinous and non-glutinous rice. Their hulled grain colours are white or brown. According to the seasons to which particular cultivars are adapted and according to their growth period, they can be early, medium or late in duration. There is also great diversity in characteristics such as grain shape, glume hairs, glume colours, length of panicle bases and plant height.

One can also find in the Chinese varieties the genes for disease resistance, stress tolerance, early maturity, high yield and high quality. China is the centre of origin for glutinous genes of grain crops. Rice, millet, foxtail millet, sorghum and so on have many ancient glutinous cultivars. Corn has not originated in China, however, after 500 years of cultivation, waxy corn appeared in Yunnan province in China. China is also the original centre for dwarfing genes of many grain crops. For instance, dwarf genes, ***Rht3*** and ***Rht10*** in wheat, Sd1 in rice originated in China. ***Rht3*** and Rht10 came from wheat cultivars named Da Mu Zhi Ai and Ai Bian No.1, respectively. The semi-dwarf gene ***Sd1*** that was found in rice cultivars of Di Jiao Wu Jian, Ai Zi Zhan and Guang Chang Ai played very important role in breeding of IR series of rice varieties in International Rice Research Institute (IRRI). China is one of the original centres for male sterility genes. Cytoplasmic / genetic male sterility gene from ***Oryza rufipogon*** in Hainan Province has been successfully used in breeding of hybrid rice. At present, more than half of rice fields planted with hybrid rice varieties, thus greatly increasing rice production in China. The nuclear male sterility gene, Ta1, in wheat was used for backcrossing and a number of superior germplasm of wheat has been developed. The well-known wheat variety, Chinese Spring, contains ***Kr1*** and ***Kr2*** genes that make it a necessary parent for wide crosses of wheat in the world. In brief, cultivated plant genetic resources are very rich in China and further research and development on them will be necessary.

Loss of biodiversity of cultivated plants

With the development of science, a technological industrial revolution occurred in the eighteenth century. Since then, human's production ability has been changed incredibly. Uniform agricultural practices resulted in a decrease of number of crops as well as number of crop cultivars. As a result, the cultivated varieties are becoming more uniform and the genetic background of varieties very narrow. Cultivated varieties gradually become vulnerable to unpredictable environmental changes, biotic and abiotic stresses.

Decrease of types of crops planted for agriculture

There are about 10 000 to 80 000 plant species that can be used in agriculture in the world, but humans have used about only 3000 species from ancient times. Among them, only 1200 species have been domesticated and about 150 species are cultivated widely. According to an analysis, more than 90% of food production is from 29 plant species, including seven grains (rice, wheat, corn, sorghum, barley, millet, and triticale), three root and stem tuber species (yucca, potato, sweet potato), eight legumes (groundnut, garden pea, chickpea, soybean, faba bean, common bean, cowpea and pigeonpea), seven oil crops; two sugar plants (sugarcane and beet) and two tropical crops (banana and coca) (Albert ***et al***. 1991).

The major crops in China are mainly food crops of rice, wheat and corn. According to statistical data in 1996, of the 150 million ha of cropped area, 110 million ha (75%) were planted with food crops. In that year, 30 million ha (27%) were planted with rice, 30 million ha (27%) with wheat and 25 million ha (22%) with corn. Of the total production of 490 million tonnes, the production from these three crops was 430 million tonnes (about 88%) (Liu ***et al***. 1993).

Uniformity of planted varieties and narrow genetic base

Due to the uniform farming practices and development of improved varieties after the World War II, many cultivars of many crops went out of cultivation. From 1945 to 1986, more than 95% of wheat cultivars were eliminated in Greece. In 1970s, France had only 12 varieties of apple planted in the country, but there were more than 2000 apple varieties 100 years ago. During 1940s, there were more than 46 000 rice cultivars in China, but at present only about 1000 varieties are planted, among which only 322 varieties are planted widely. The sown area of each variety was more than 6700 hectares in 1991. Mostly improved varieties and hybrid varieties are planted now and only a few landraces are planted. There were more than 13 000 wheat cultivars planted in 1940s, which consisted of 81% landraces, 14.9% improved varieties and 4.1% foreign varieties. However by 1970s, there were only 1000 cultivars used for production, consisting of 91% improved varieties, 4% foreign varieties and only 5% landraces. By 1990s, only about 500-600 wheat varieties were used for production, with 331 planted in large areas. Corn cultivars in 1940s numbered 10 300. At present, only 152 are cultivated and the hybrid varieties take up 85% of the total area ***(***Dong 1996 Personal Communication, Qian ***et al***. 1982***)***.

The varieties used for agricultural production are not only limited in number, but also lack wide genetic base. For example, most of rice varieties used in production are hybrid varieties whose male sterile lines are mainly “abortive wild type” and the restorer lines are mainly from IR series of rice varieties developed at IRRI. Similarly, more than half of the wheat varieties have the genetic background from “Nan Da 2419”, “Funo”, “Abbondanza”, “Orofen” and their derivatives. Most of genes for disease resistances are from “Lovrin” series that contain the genetic background of rye. It is estimated that more than half of hybrid corn varieties use selfed-lines of either “Mo17” or “Huang Zao 4” or their derivatives as the parents. Other crops and other countries have similar situation (Dong 1996 Personal Communication; Dong 1998; ECAPBP 1996***)***.

A study by the Academy of Science of US indicated that the genetic diversity of most crops planted in America is rather narrow. For instance, 40% of the wheat areas is planted to only two varieties. There are only six major soybean varieties planted and over 95% groundnut production was from nine varieties.

Losses caused by few crops, uniform varieties and narrow genetic backgrounds have occurred several times in human history. For example, in 1846, more than 500 000 Irish died of hunger and over 2 million of that survived emigrated to America. The main reason for this Irish famine almost total loss of potato production due to infection by leaf blight as the few varieties grown then had no resistance to the blight disease. Another example is the Southern corn leaf blight of 1970 in southern states in the USA. The corn production in the USA in 1970 decreased by about 25% because of this disease. The farmers there lost more than 1 billion dollars. In the former USSR, because of several successive warm winters, a winter wheat variety was planted 15 m ha in the cold region (Albert 1991). However, the freezing winter of 1972 decreased wheat production by 10 mt. A similar problem occurred in China. In 1964 when a wheat variety named "Bima No.1" was cultivated for several million hectares due an epidemic of rusts causing a severe loss of wheat production (Jin 1996). In 1990, wheat rusts occurred again and almost all wheat varieties with genetic background of "Lovrin" were damaged causing a loss of 26 500 tons (Guo 1997).

From analyses above, we can conclude that genetic diversity is a safety factor contributing to the tolerance of crops to adverse climate and epidemics of diseases and pests. The more genetically uniform the cultivated varieties are, the more susceptible they are to drought, viruses, bacteria and pests. Wide genetic diversity of a crop and the wide genetic base of a variety are the safe ways to keep the production stable.

Damages of agrobiodiversity in China

After the establishment of P.R. China, especially after the implementation of open and reform policy, our government and related agricultural departments have focused on conservation of agrobiodiversity. The main policy is "collect widely, conserve safely, evaluate comprehensively, study further, enhance actively and utilize thoroughly". Through several decades of efforts, much has been achieved. The number of accessions stored in long term ranks first in the world, though the number of accessions collected and documented are less than in USA (410 000 accessions) and USSR (370 000 accessions). However, about 80% of the genetic resources conserved in USA and 50-60% of those in USSR are from foreign countries while it is only 19% in China.

To date, 318 000 accessions of crop genetic resources have been collected, documented, evaluated and stored in the National Genebank and in safely duplicated in other genebanks. Another 37 000 accessions of perennial and vegetative crops are conserved in 32 national nurseries (including 2 ***in vitro*** conservation facilities). However, we have to note that among the conserved genetic resources, only 250 000 accessions are landraces or cultivars, others are improved varieties and foreign cultivars. With the development of industry, transportation, urbanization and environmental pollution, uncontrolled extraction and damage to forests and changes in land-use patterns, genetic resources have been eroding and the wild crop relatives have been seriously threatened. It has been estimated that about 15-20% of plant and animal resources is in danger, much higher than the global average. Most seriously, some wild relatives of crops and rare crops are rapidly disappearing. For example, scientists found ***Oryza rufipogon*** at 26 locations in Yunnan in 1968, but it could be seen in only 2 locations in 1980. Even at these two locations, only several clumps survived only because of efforts by scientists and local governments. In a location in Guangxi, a total area of 28 hectares was occupied by wild rice in 1979, but now it is hardly found. In 1979, wild rice grew for more than 35 kilometres along the river of "Haojiang" and its up-stream in Wu Xuan County, and in some places it occupied more than 13 hectares. Most of these have already disappeared. In 1978, 7-8 locations of wild rice were found in Dongxiang, the most northerly location of ***O. rufipogon*** in the world but it now found only 2 locations protected by fencing. Several years ago, several hundred hectares of wild soyabean were found at the entry of the Yellow River to the sea. Farmers used to harvest several tonnes of wild soybean seeds every year. At present, only a few scattered populations of wild soybean are found. Similarly, tea trees, fruit trees, mulberries and herbs have been damaged in some places (Pang 1996, Dong 1997).

Conservation and utilization of agrobiodiversity

Sustainable agriculture depends on conserving and using agrobiodiversity. In order to develop sustainable agriculture, we have to conserve crop plant genetic diversity, discover new crops and promote underutilized crops, maintain superior varieties with diversity and enhance the genetic background of superior varieties.

Discovery of new cultivated plants

Agrobiodiversity makes it possible for us to increase types of food. As noted earlier, of about 50 000 species of plants in the world that could be used for the purpose of food, only 3000 species (6%) have been utilized in human history, only 2.4% (1200 species) were domesticated and only 150 species (0.3%) were planted widely. Therefore, there is a potential to develop new edible, medicinal plants industrial plants. It is necessary to study many plants in tropical, arid and semi-arid regions to utilize their rich genetic diversity and to improve characteristics of cultivated plants as well as diversity of plants planted.

Since the beginning of last century, people have tried to utilize the rich resources of wild species. ***Actinidia chinensis*** is a wild species of Chinese gooseberry. In 1906, New Zealanders took some of these to New Zealand from Wuchang. Through several years of study, they improved varieties (Called it 'Kiwi') with large fruits and delicious flavour. These varieties are planted more than 2000 ha and earn more than 300 000 dollars for New Zealand annually and thus Chinese gooseberry became an important foreign exchange earner for New Zealand and its now the "National Fruit" of that country. This indicates the potential to develop wild fruit trees in China. Jojobo (***Simmondsia chinensis***) is a bushy plant belonging to Buxaceae family. The fruits of this plant contain a type of oil, smilar to whale oil, which can be used in tanning industry and extensive efforts are underway to further develop this species. The United States established its first garden of jojobo plants and harvested 130 000 tons oil from them annually from 1990.

Oil palm was cultivated from the beginning of last century and the palm oil production was about 2% of all edible oils. In 1980s, its share went up to 17% (Albert 1991). It is one of the most popular edible oils in the world now. One of the reasons for its rapid development was the application of tissue culture, which made it possible to select and propagate quickly. Oil palm is being planted in south China in recent years.

Olive oil is the only kind of oil extracted from fresh fruits without heating. Due to its rich nutritional and medicinal value, it is called "friend of human's health" and "queen of plant oil" by western nutritionists. In 1964, Premier Zhou introduced common olive from Albania to China. It is planted in its adapted areas in China now. Its yield in China is similar to that in Mediterranean. However, olive oil makes up of only 3% of all edible oils in the world at present. The price of olive oil is 4-8 times higher than other common oils. Therefore, it is important to study and develop further olive in future.

Potential for developing underutilized crops

Human life mainly depends on the diversity of cultivated plants. Though we generally live on a few crops to provide our food, shelter and income, we can not depend solely on a few major plant species. To date, agricultural research has focused only on the main / major crops; minor crops (or underutilized crops) have largely been ignored. Generally, underutilized crops are planted in areas with marginal conditions (not very good in terms of soil and environment) such as mountains, drought-prone areas, saline soils and so on. One underutilized crop in country may be a major crop in some countries or regions (such as cocoyam, tuber crops in Andes and naked barley in the Plateau of Qinghai-Tibet). Some international organizations and agricultural scientists are starting to pay more attentions to underutilized crops. A workshop on genetic resources of underutilized crops in East Asia was organized by IPGRI in 1991. A 3-year research programme, "Status of Conservation, Utilization and Breeding for Genetic Resources of Potential Underutilized Crops", was initiated in 1993 by IPGRI. Government departments and scientists in China are also paying attentions to underutilized crops. For example, buckwheat, because of its short growth period, is used in regions where disasters often occur. Oat and buckwheat have been discovered to contain nutrients that are good for human health and hence, they are also now being developed for medicinal and nutritional purposes.

Genetic enhancement of cultivated plants

Most crops were domesticated from wild species and during the long domestication period (about 10 000 years), the selection pressure greatly influenced the diversity of crops. Since the World War II, production needs have made crops increasingly uniform and the genetic base of commercial varieties has tended to become narrow. Studies of molecular markers by Professor Jizeng Jia indicated that the genetic base of improved varieties is the narrowest, those of landraces are wider and wild species (including wild relatives) have rich genetic diversity (Jia ***et al***. 2000). Restriction fragment length polymorphism (RFLP) technique was applied to detect the polymorphism at 472 loci of 14 common wheat accessions. The results revealed that 283 of 472 loci were polymorphic. The variety of “Synthetic”, which was improved by double cross between ***Triticum durum*** and ***Aegilops tauschii***, had 175 unique loci. Varieties with genetic background of wild relatives had 27 unique loci, landraces 12 unique loci, but improved varieties (products of crosses between commercial varieties) had only 0-7 unique loci. A study on genetic distance among loci of 21 chromosomes for 10 improved varieties has shown that these improved cultivars were quite similar (80%). From this study, we can see that modern improved varieties have so narrow genetic base that there is need to enhance their genetic base by using wild species and landraces.

Wild germplasm (including wild relatives) and landraces are characterized with rich genetic diversity and many desirable genes, which are important for agriculture. However, because of the linkage of desirable genes with undesirable ones, in addition to difficulties of evaluation and hybridization, breeders are often unwilling to use them in crop improvement. Since 1980s, development of biotechnology has provided increased opportunities to use wild germplasm and landraces in crop improvement. A number of genes for disease resistance, stress tolerance have been identified using molecular markers. For example, Feldman (1993) studied the backcrosses of cultivated varieties and ***T. turgidum*** and ***T. dicoccoides*** with molecular markers, and he found that it was possible to obtain varieties with 19% higher yield than commercial varieties. Xiao (1997) identified 2 QTLs in wild rice with low yield, these QTLs could help increase the yield of commercial hybrid varieties by 17% or more. There was no linkage of negative effects.

There are 250 000 accessions of wild germplasm and landraces of crops that have been collected, documented and conserved in China and about 150 000 more will be collected soon. Therefore, with successful application of molecular technology, these resources could play increasingly important role for sustainable agriculture in China.

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The utilization of germplasm conserved in Chinese national genebanks

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Introduction

China has established the national conservation system, which is composed of one national long-term genebank at the Institute of Crop Germplasm Resources of the Chinese Academy of Agricultural Sciences (ICGR-CAAS), Beijing, one long-term security backup genebank at the Qinghai Academy of Agricultural Science, Xining, several national medium-term genebanks for germplasm exchange. It also included 32 national nurseries and 2 ***in vitro*** genebanks for perennial and vegetatively propagated crops, as well as 21 local and provincial active collections responsible for germplasm regeneration, characterization and distribution. By September 1998, the crop germplasm collections had reached 355 000 accessions. Among these are 318 000 accessions of 161 crops belonging to more than 600 species of 174 genera and 30 families conserved in the national seed genebank, and 37 000 accessions of more than 50 crops belonging to 1026 species or subspecies preserved in nurseries (Gao and Wang 1997).

Over the past 15 years from 1984-1998, Chinese genebanks have distributed thousands of germplasm samples to various institutions and researchers at home and abroad. In which how these samples have been used by the recipients is not fully understood. Therefore, it is necessary to carry out a survey to document the use of germplasm in China.

The survey were carried out on 10 target crops including rice, wheat, soybean, maize, cotton, citrus, tea, mulberry, Peking cabbage and cucumber. During the survey, a total of 249 questionnaires were received from relevant scientists, more than 120 papers and other documents on germplasm utilization in China, published in a range of journals, were reviewed. Some major references are appended at the end of the chapter, giving details of the type of work associated with germplasm use (Sheng 1997; Li ***et al***. 1998; Wu and Yu 1998; Ying 1999).

A workshop was organized by ICGR-CAAS in May 1999 and discussed the status of germplasm distribution, utilization, problems and solutions for the 10 target crops. This paper is the part of the analysis results on the survey data.

Based on the survey information, it was found that the amount of germplasm of the ten crops that has been distributed was significant (Table 1) . Almost 185 000 germplasm samples were supplied to 8635 recipients covering crop breeding, basic research, production and education. Most samples were cultivars (39%), advanced breeding lines (33%) or landraces (22%), with smaller numbers of wild relatives (4%) and genetic stocks (2%). Rice samples represented the largest proportion (31%) closely followed by wheat (29%). The number of soybean and cotton samples was also quite high (about 10% and 8% respectively).

Patterns of germplasm utilization

In this survey, we evaluated the status of germplasm use for the ten target crops. Germplasm use can be classified as screening, breeding, basic research, others (including direct use in production), or not used (only conserved in the recipient's genebank or nursery). Respondents received 136 802 accession samples over the past 15 years (Table 2). Although over 21% of the samples were characterized or evaluated, only 8% were used in breeding, and 9% for basic research. The overwhelming majority (almost 60%) was requested for no apparent use other than conservation. It is obvious that the efficiency of using released varieties or cultivars for breeding is the highest (13%), while the efficiency of using wild relatives for breeding is the lowest (less than 1%) although their potential is noteworthy.

As for the type of germplasm used for different purposes is concerned, both landraces (23.8%) and breeding lines (17.6%) were screened to identify useful traits; genetic stocks were requested mainly for basic research (57%); wild relatives for screening (9.4%) or basic research (9.5%) and cultivars were requested for screening (25.8%).

Table 1. The status of germplasm distribution by germplasm holders for 10 target crops (1984-1998)

Crops	*Landraces*	*Advanced lines*	*Genetic stocks*	*Wild relatives*	*Cultivars*	*Total (%)*
Rice	8 586	26 700	450	949	21 065	57 750 (31.26)
Wheat	2 517	23 566	1 989	1 508	23 430	53 010 (28.69)
Maize	800	1 000	100	10	3 000	4 910 (2.66)
Soybean	8 850	2 500	250	1 500	5 000	18 100 (9.80)
Cotton	31	4 510	135	55	10 269	15 000 (8.12)
Citrus	10 440		744	1 417	7 310	19 911 (10.78)
Peking cabbage	2 500	900	45		60	3 505 (1.90)
Cucumber	2 200	750			30	2 980 (1.61)
Tea	4 500		300	2 175	910	7 885 (4.27)
Mulberry	1 000	85	35	50	522	1 692 (0.92)
Total	41 424 (22.42%)	60 011 (32.48%)	4048 (2.19%)	7 664 (4.15%)	71 596 (38.75%)	184 743

Table 2. The basic information of germplasm use for the target crops received by users (1984-1998)

Type of germplasm		*Landraces*	*Advanced Breed. Lines*	*Genetic stocks*	*Wild relatives*	*Cultivars*	*Total*
Germplasm received		40 701	54 114	1 348	6 729	33 910	136 802
Used for screening	No.	9 668	9 562	160	634	8 731	28 755
	%*	23.8	17.6	11.9	9.4	25.8	21
Used for breeding	No.	2 390	4 258	57	27	4 345	11 077
	%*	5.9	7.9	4.2	0.4	12.8	8.1
Used for basic	No.	3 557	3 028	769	638	4 286	12 278
research	%*	8.7	5.6	57.0	9.5	12.6	9.0
Used for others	No.	605	1 305	50	35	712	2 707
(including direct use)	%*	1.5	2.4	3.7	0.5	2.1	2.0
No apparent use	No.	24 481	35 961	312	5 395	15 836	81 985
	%*	60.1	66.5	23.2	80.2	46.7	59.9

* Percentage in germplasm received

The use in breeding programmes

The 13 breeding institutions surveyed received 111 839 germplasm samples and 23 650 of these were used in crop improvement (Table 3). A total of 1281 varieties were bred out using 1487 accessions, accounting for 1.33% of total germplasm received. Among 1487 accessions, 892 were from genebanks (and nurseries), accounting for 0.8% of total germplasm received. The cumulative growing area of the 1281 varieties bred using germplasm received as parents reached almost 37.5 million ha in the past 15 years, accounting for 25.2% of the cultivated area of the target crops in China. The growing areas of rice, wheat, maize and cotton varieties bred using germplasm received as parents were relatively larger, with 18.5 million ha, 10.2 million ha, 6.6 million ha and 1.8 million ha, respectively.

Table 3. The status of germplasm used at the 13 main breeding units in China.

Crops	*No. of germ-plasm received*	*No. of germplasm used for breeding*		*No. of varieties bred*	*No. of germplasm involved in development of released varieties*		*No. of germplasm from genebanks and involved in development of released varieties*		*Growing area in 15 years (0 000 ha)*
		No.	*%*		*No.*	*%*	*No.*	*%*	
Rice	35 000	3 260	9.3	376	393	1.12	303	0.87	18 497.67
Wheat	53 010	13 252	25.0	267	424	0.8	213	0.4	10 207.40
Maize	4 523	733	16.2	120	141	3.1	87	1.92	6 609.09
Soybean	13 300	4 633	34.8	292	71	5.3	36	0.27	300.80
Cotton	1 662	1 170	70.4	192	281	16.9	163	9.8	1 789.29
Citrus	700	138	19.7	8	17	2.43	11	1.57	2.54
Cucumber	1 474	400	27.1	64	106	7.19	32	2.17	66.90
Tea	1 772	34	1.92	109	34	1.92	34	1.92	4.11
Mulberry	398	30	7.5	19	20	5.03	13	3.27	3.92
Total	111 839	23 650	21.1	1 281	1 487	1.33	892	0.8	37 481.72

* Peking cabbage was not included

Currently, the area covered by modern varieties for major crops in China has reached over 85%. Yields have increased by more than 20% in 1984-1997, and for rice, wheat, corn, soybean and cotton these vary between 21 and 46% (Table 4). We believe that germplasm has played a very important role in breeding the modern cultivars.

Table 4. The yields of main crops(1984-1997)

Crops	*Yields (kg ha^{-1})* 1984	*1997*	*Increased*	*%*
Rice	5 100	6 319	1 219	23.9
Wheat	2 850	4 101	1 296	46.2
Corn	3 623	4 387	764	21.1
Soybean	1 290	1 764	474	36.7
Cotton	765	1 024	259	33.9

Rice

The institutions surveyed have developed 376 rice varieties (Frey 1998; Li ***et al***. 1998; Lin and Min 1991; Sheng 1997; Xiao ***et al***. 1995; Ying 1999; Yu 1996; and Zhou ***et al.*** 1998). Among them, 270 were bred through hybridization, 56 by single plant selection, 4 by cyto-engineering, and 46 by mutation breeding. Some accessions were used for many times as parents, e.g. (1) Japonica rice: Zhongdan 1, 79-51, Yangjing 1, Bing 627, Wuyujin 3, Yueguang, Wuxiangjing 1, Ewan 3, 4243, Sishangyu, IR 8, Nongken 58 Xixuan, Ce 21, Xianghu 25, Shan 41, Xiayi, Shishoubaimao, Nonglin 11, Shoudao, Xiabei, Dongnong 363, Jijing 6, Kongyu 131, Aoyu 269 and Liming; (2) Indica rice: Simei 2, IR 30, IR 29, Fengxuan 4, Chikuai'aixuan, Zhefu 802, Keqing 47, Erjiufeng, Zaoben 6, Shuiyuan 287, HA 7, Xiangzaoxian 3, 81-280, Xiangzaoxian 9, Zhulian'ai, 2279, 73-63, Youmaizao, Hongmeizao, IR 8, G.E. 456, Erjiu'ai 7, 677, IR 36, Guishanzao, Qiguizao 25, Qiyouzhan and Guichao 2.

The success of rice hybrids is a breakthrough in the history of rice breeding. Today, there are five types of cytoplasm in male-sterile lines:

1. Yebai type: it was derived from common wild rice (***Oryza rufipogon***) collected in Lingshui County of Hainan Province, and major sterile lines using it as parents include Zhenxian 97A, V 20A, Bo A and Longtepu A

2. Aibai type: it was derived from common wild rice collected in Dongxiang County of Jiangxi Province, and major sterile lines using it as parent include Xieqingzao A, etc.
3. Gang type: it was derived from Gambiaka Kokoum, a cultivated rice germplasm in West Africa, and major sterile lines using it as parents include Gang 46A etc.
4. D type: it was derived from Dissi D52/37, a cultivated rice germplasm in West Africa, and major sterile lines using it as parents include D Zhenxian and 97A (D Xian A), etc.
5. Yinshui type: it was derived from Shuitiangu 6, an Indonesian indica type, and major sterile lines using it as parents include II-32A and You I A.

The growing area of rice hybrids involving Yebai type and Aibai type accounts for 70% of the total area of rice hybrids. In addition, Gang type, D type and Yinshui type are good examples of using the crosses between Chinese dwarf cultivars and geographically remote cultivars.

The geographic distribution of the restorer genes for sterile lines of indica rice hybrids is different because of the differences in the source of cytoplasm. Presently, the restorer lines for the Yebai type are mainly derived from IR8 and its derived IR series (Lin and Min 1991). Some restorer lines, e.g. Gui 33 (IR36/IR24), Minghui 63 and Minghui 66, derived from IR30 (IR24/TKM6//IR204/***O. Nivara***), and Ce 64-7, derived from IR36, have played a key role in the production of rice hybrids. Particularly, Minghui 63 is the most important restorer. Since 1983, Hybrid Xianyou 63, D You 63, Xieyou 63, II You 63 and Teyou 63 which used Minghui 63 as the restorer have been developed subsequently, with the growing area of 6.2 million ha in 1993. Weiyou 64, Xieyou 64 and Boyou 64, which used Ce64-7 as the restorer had reached the growing area of 1.66 million ha in 1993.

Wheat

A total of 267 new wheat varieties were released during 1984-1995 (Li ***et al***. 1996; Zheng 1996; Zhuang and Du 1996). Among them, 266 were bred through hybridization, involving 213 accessions provided by the national genebanks in the development of these new varieties. Among 213 accessions, 61 (28.6%) are from other countries. Germplasm which were used for many times were: Luo and its derived germplasm (i.e. 1B/1R material, including Lovrin 10, Lorvin 13, Avrora and Kavkaz etc.) and 42 new varieties developed, accounting for 15.7% of total number of varieties released; Mexican wheat germplasm including Bainimo 62, Yekaola F70 and Sharuike F70, developed 28 new varieties accounting for 10.5% of total number of varieties released. Other parents used more frequently include Taigu Hebuyu wheat containing Taigu nuclear sterile genes, Punong 3665, Bainong 3217, Sumai 3, Aimengniu, Fu 66, Fan 6, and some spring wheat germplasm such as Jinghong 1 to Jinghong 9, Jing 771, Jing 772, Zhong 7606 and Zhong 7605.

Maize

All the 120 corn cultivars were developed through hybridization. Among 3124 maize inbred lines listed in the "Catalogue of Maize Genetic Resources in China", 2112 were developed in China and 1012 from other countries (Wu 1983; Yu and Zhu 1996; Wu and Yu 1998; Zeng 1990; Peng and Liu 1998; Wang 1986). It was estimated that basic materials used in the development of maize inbreds are single-cross hybrids accounting for 52.51%, synthetics (10.44%), three-way hybrids (10.44%), improved populations (5.22%), double-cross hybrids (1.2%), exotic germplasm ×adapted germplasm (2.24%), backcrosses (2.41%), introduced populations or synthetics (6.06%), landraces (3.21%) and others (2.41%).

In the past 15 years, 77 maize hybrids were developed, with the accumulated growing area of 35 773 000 ha. Most of these hybrids involved nine inbred lines, namely 1) Huangzaosi selected from Tangsipingtou (a landrace) and Dan 340 selected from Ludahonggu (a landrace) for 24 single-cross hybrids; 2) Mo17 introduced from the U.S.A. for 14 single-cross hybrids; 3) Zi 330 and E28 selected from the progenies of crosses between inbred lines and introduced inbred lines for 5 single-cross hybrids; 4) 7922, 5003, 478 and U8112 selected from foreign hybrids for 27 single-cross hybrids.

These parents originated from four major core germplasm (group), namely 1) Lancaster group, including Mo17 and Zi 330, accounting for 34.7%; 2) Reid group, including 478 5003 and Ye 107 (28.5%); 3) Ludahonggu group, including Dan 340 and E28 (20.6%); and 4) Tangsipingtou group, including Huangzaosi (14.4%). It is obvious that the genetic basis of germplasm used in maize breeding is considerably narrow.

Soybean

Of the 292 cultivars, 243 were developed through hybridization, mutation or hybridization plus mutation, with landraces, released varieties or breeding lines as parents. For example, Deqing Heidou, a landrace was one of the parents of Zhechun 2, a highly resistant to SMV and strongly tolerant to acid soils, developed in Zhejiang Province. Another was Yanhuang 1, an improved variety suited to grow on the red / yellow soils. Twenty nine were developed by pedigree breeding, for instance, Andou 1 was selected from Liuzhi Liuyuehuang and 20 by other methods during 1986-1995. Seventy four varieties were developed using foreign cultivars as parents during 1991-1995, accounting for 65% of total number of varieties developed (110) while it was 94 varieties during 1986 to 1990, accounting for 52% of total number of varieties developed (182).

It is worth noting that the role of foreign cultivars in soybean breeding has increased greatly. For example, 52 varieties were developed using Shishengchangye from Japan as a parent, and 61 using Mamotan from the USA.

Cotton

A total of 192 cotton varieties were developed during 1984 to 1998 and an estimated 281 accessions were used in their development. Of these 165 were bred by sexual hybridization, 19 by single plant selection, 3 by cyto-engineering, 3 by transgenic technology and 2 by other methods. The germplasm which have been frequently used in the past 15 years include Heishanmian 1, and 86-1, and a series of varieties bred by Cotton Institute of CAAS such as Zhongmiansuo 10 and Zhongmiansuo 12 etc. About 75 varieties were developed using the above as parents, accounting for 57.7% of total number of varieties developed and released. Important germplasm also included some accessions introduced from other countries, such as PD series, Uganda 3 (Zhongmiansuo 7), Lambright GL-5, etc., from which 91 varieties were developed (42.3%). Particularly, the introduction of the special germplasm Lambright GL-5 has played very important role in cotton breeding for low-phenol content and research on proteins of cottonseed as feed; two varieties have been initiated in recent years. Moreover, Zaotan series selected from Camde has characteristics of early maturity, high-yielding, early bolling and strong stress resistance and is grown in area of 6700 ha in Henan and Xinjiang (Huang 1996).

Citrus

Since 1984, by using the germplasm distributed, 8 citrus cultivars have been developed, of which 4 were bred through hybridization, 2 by pedigree breeding, 2 by transgenic technology. Zhongyu 7, Wanmi 1 and Wanmi 2, and Xinshengxi 3 have been grown in Yunnan, Guizhou and Sichuan in area of about 26 500 ha annually, accounting for 0.2 % of total growing area of 13.75 million ha.

Peking cabbage

Currently, there are 17 major varieties of Peking cabbage in production, with a total growing area of 79 000 ha. Among them, the popular varieties are Shandong 4 (19 000 ha), Lubai 8 (12 000 ha) and Shandong 7 (9000 ha). The provinces with large growing area of Peking cabbage include Anhui (66 000 ha), Hebei (11 000 ha) and Ningxia (1300 ha).

Cucumber

Since 1984, totally 64 cucumber hybrids have been released for cultivation, with three times of cultivar replacement. Presently, hybrids account for about 89% of all cultivars. It was estimated that 32 cultivars were developed by using the germplasm in the medium-term genebanks and 30 accessions accounting for 2.0% of all germplasm preserved were involved (Chen 1989; Li ***et al***. 1999; Zhang ***et al***. 1998).

Major cucumber cultivars developed by pedigree breeding include Hanhuanggua Xinpingxi 815 (Laolaishao / Xiaoxiangkou), Changchun Wuci (selfing of Beixing from Japan), Aisheng 1 (natural mutant from Jinyan 1), Xiaqing 3 (from selfing of Ci 75 / Suiqing), Luhuanggua 5 (from selfing of Zaofeng 1), Jixuan 1 (natural mutant from Changchun Mici), and Jinong 2 (selfing of Ningyang Daci / Xiaobacha).

There were 56 cucumber hybrids such as Luchun 32 (S124 / S65112), Jinza 1 [(76-1-5-17) (Jinyan series) / 77-17-7-1)], Zhongnong 5 [Ci 371 [((Tiepiqing / Japan F_1) / Beijing Cigua) / Inbred 476], Changza 1 (Shanghaiyanghang / Changchunmici), Jinchun 4 (Jiin-90-3 / 76-2-1-1-6-4), Zhongnong 202 (G5224 / Inbred 106 BE), etc.

Tea

Since 1984, 109 new varieties of tea trees have been developed, which are the major cultivars used in making various types of tea in China and are the basis of clones grown in tea plantations. For instance, Longjing 43 and Longjing Changye developed by the Tea Institute of CAAS have become the primary varieties of choice by many regions of tea production, with the growing area of 2400 ha in nine provinces. A red tea cultivar "Yunkang 10", selected from Nannuoshan Dayecha of Xishuangbanna by the Tea Institute of Yunnan Academy of Agricultural Sciences, is grown in 2600 ha. Anji Baicha with good quality has developed rapidly in the tea regions of northern Zhejiang in recently years. Although multiplication rate is slow for this perennial plant and the extension of new cultivars takes a long time, the total growing area of the new cultivars has reached about 41 000 ha.

Of the 109 cultivars developed, 35 were bred through sexual hybridization, 70 by pedigree breeding and 4 by single plant selection. Pedigree analysis of cultivars shows that two accessions were used many times, i.e. Yunnan Dayecha from the centre of origin of tea trees, and Fuding Dabaicha which is a green tea cultivar with strong aroma and good quality. These two cultivars have 48 half-sib lines, from which 12 varieties were bred, accounting for 55% of total number of all new cultivars. It indicated that the genetic basis of tea cultivars was narrow and the rich genetic diversity of tea trees was under-utilized.

Mulberry

By using elite mulberry germplasm distributed during 1984 to 1998, about 19 mulberry cultivars and some elite lines were developed. Among the 19 cultivars developed, 9 were bred through sexual hybridization, 8 by pedigree breeding, and 2 by other methods. Yu 2, Yu 151, Yu 237, Yu 71-1, Xiang 7920, Jihu 4 and Jialing 16 were released nationally, and others were released provincially. Yu 71-1 was recommended as the major mulberry cultivar by the Ministry of Agriculture. Xiang 7920 with strong growth vigour and high leaf production has been extended to Hunan, Hubei, Sichuan, Yunnan, Guizhou, Jiangsu and Zhejiang provinces. Fengchisang, an elite mulberry hybrid, grows rapidly and yields are high. Yu 2, disease resistant and high-yielding characteristics inherited from its female parent "Guangdongsang" has played a key role in controlling yellow wilt (Sun ***et al***. 1988; Cao ***et al***. 1997).

The pedigrees of major mulberry cultivars are: Yu 2 (Guangdongsang × Husang 38), Yu 151 (Zaoqingsang × Yu 2), Yu 237 (Zaoqingsang × Yu 2), Yu 71-1 (Yu 54 × Yu 2), Fengchisang (Zhongsang 5801 × 5801 × Huasang), Yunsang 798 (Cangxi 49 × Yu 2), 8002 (7707 × Xinyizhilai), Jihu 4 (Jijiu × Husang 2), Jilusang (Jianchi × Heilusang), Nanji 7681 (Cangxi 49 × Yu 2), Nan 7637 (Zhongsang 5801 × 6031), Chuan 724 (Cangxi 49 × Tongxiangqing), Chuan

852 (Yizhilai × Tongxiangqing), Fu 1 (selected mutant from irradiated Yizhilai), Fu 151 (selected mutant from irradiated Yu 151).

The direct use in production

Over the survey period a total of 178 landraces were directly used in production, with a cumulative growing area of 12.7 million ha. Thus this accounted for only 0.9% of the total cultivated area of the target crops over the 15 years (Table 5), a point of significance with respect to the cultivation of landrace varieties is their length of cultivation. Generally, the production life of improved varieties of field crops is 3-7 years, for tea trees and mulberry it is 5-15 years, and for vegetables, between 2-4 years. Farmers use landraces for much longer. For example, the wheat landrace Xiaohongmai has apparently been grown in the Inner Mongolia for at least 100 years because of its drought tolerance. The rice landraces Zhubao and Yabao have been grown in Lingshui county of Hainan Province (where the Li ethnic group lives) for at least 30 years. Therefore, landraces grown in specific areas not only protect biodiversity but also contribute to the sustainable development of local communities. However, landraces have been replaced by new varieties that are attractive because of high yield, good quality and resistance to diseases and pests in most regions, although some landraces are still cultivated in remote regions where ethnic minorities live. For instance, it was estimated that nearly 10 000 wheat landraces were used in production in the 1950s (Qian ***et al***. 1982), but currently no more than 300 improved varieties are used in China.

Based on the survey information, it was found that about 66 major rice landraces were used in production, with a cumulative growing area of 9.9 million ha, constituting 77.5% of the total growing area of rice landraces during the survey period. For soybean, there were 13 major landraces grown in about 8.3% of the total area grown to landraces. Notable landraces of other crops are listed in table 7 of the Chinese version.

Table 5. The status of direct use of landraces for the 10 target crops (1984-1999)

Crops	No. of landraces used	Reasons for use	Growing area (ha.)	Notable landraces
Rice	66	Disease resistance	9 909 000	Laohudao, Laolaiqing, Hongkewang
Wheat	1	Stress tolerance	1 000 000	Xiaohongmai
Maize	10	Disease resistance, early maturity, drought tolerance	46 031	Ludahonggu, Tangshipintou, Jinhuanghou
Soybean	13	Large grain, used for vegetables, early maturity	1 064 050	Shizhuzhuyaozhi,Juhuang, Jingningdahuangdou
Cotton	0		0	
Citrus	15	Good quality, high yielding, early maturity	39 700	Zhuhongju,Huangpiju
Peking cabbage	/		/	
Cucumber	4	Disease resistance, cold tolerance	124 500	Shandongxiaobacha, Tangshanqiougua
Tea	50	Good quality, high yielding	16 055	Ruchengbaimaocha, lanshankucha,
Mulberry	19	High yielding	163 388	Huosang,Dahuasang, Dayeban
Total	178		12 722 724	

Use in basic research

A total of 12 278 accessions were used in basic research (Table 2), which focused mainly on genetics and the mechanisms of heterosis (Yu ***et al***. 1998), botany, plant taxonomy (Zhu 1988), biological diversity (Li ***et al***. 1999), plant physiology, plant biochemistry (Nie 1991), phytopathology and the mechanisms of resistance (Zhang ***et al***. 1990; Luo ***et al***. 1998), molecular biology, genetic engineering, cytological engineering (Zhuang ***et al***. 1995; Qian ***et al***. 1996).

Use in genetic research

Yu ***et al***. (1998) constructed a rice genetic linkage map involving 151 loci using the segregating populations of Xianyou 63, a hybrid widely grown in production. Thirty-two QTLs controlling yield and its components were mapped and it was found that epistasis was the important genetic basis of yield performance and heterosis. In maize, Zhang ***et al***. (1998) classified the maize heterotic groups using inbred lines such as Dan 340, Zi 330, Mo17, Huangzhaosi, Wu 134, P138, Qi 319 and Qi 205. In 1992, researchers in Hainan Academy of Agricultural Sciences first found a thermo-sensitive male-sterile gene (designed as Qiong 6Qms) in a maize inbred line "77". They used this specific germplasm to successfully develop two thermo-sensitive male sterile lines, i.e. Qiong 68Qms and Qiongzhong 21Qms, the latter's sterility conversion temperature being 23 ± 1^{o}C. Li ***et al***. (1986) analyzed the chromosome number and karyotype of 40 landraces of tea trees from southwest China, South China and the regions along the Yangtze River, and found that the basic chromosome number in somatic cells was 15 and it is highly inherited. They also found a number of cells that were haploid (2n=15), triploid (2n=45), tetraploid (2n=60), euploid and aneuploid. The chromosomes in tea trees had stable centromeres, less-variable tolemeres. This showed much of the heterogeneity observed in tea trees could basically due to chromosomal rearrangement. Symmetric analysis of the karyotypes showed that the degree of symmetry of tea trees from southwest China (mainly southwestern Yunnan) was highest and the lowest along the Yangtze River, which indicated the evolutionary pathway from high altitude down to low altitude.

Use in botanical and taxonomic research

Luo ***et al***. (1998) classified the rice germplasm using 287 recombinants of Lemont/Teqing, three species of wild rice, and a landrace "Baike Jinfeng". Using 83 orange germplasm and numerical taxonomic methods, Zhu (1988) analyzed electrophoretic bands of soluble protein in leaves and studied the taxonomic status of specific ecotypes of oranges.

Use in molecular marker studies

Qian ***et al***. (1996) established a rice F_2 population containing 58 plants whose female parent was Nanjing 11, an indica type, and male parent was a mutant with huge embryo of Jinnanfeng, a japonica landrace. Totally 74 loci were mapped in the linkage map based on DNA markers. They found that the gene conferring huge embryo was tightly linked to RG678, with the genetic distance of 6.2 cM. Using DNA marker techniques, Jia (personal communication) found a new gene controlling stripe rust resistance (designed as YrHe) from a wheat landrace "Heshangmai" collected from Longhui of Hunan Province. This recessive gene conferred the resistance to the epidemic race of stripe rust in China at all stages and expresses at both seedling adult stages. Using microsatellite markers, the gene was located on 1BL and the genetic distance between the gene and WMS11 was 26.2 cM.

Use in plant evolution and genetic diversity studies

Sun ***et al***. (1997) selected 642 rice accessions from Asia and Africa and analyzed the genetic variability at ten loci for five isozymes to study the relationships between rice cultivars from South Asia and those from East Asia. In the past 14 years, Yang (1996) and his colleagues carried out research on morphology anatomy, biochemistry (six isozymes, sugar, protein, etc.)

and toxins involved in disease resistance and its genetic mechanism, using 3500 soybean accessions. They also established 20 near isogenic lines resistant to race 1 and race 7 of soybean grey spot disease and screened out lines resistant to type 1 and type 3 of virus strains. Li ***et al***. (1996) studied the mechanism of albinism in a tea variety, Anji Baicha, and found that it was a natural mutant with thermo-sensitivity. The temperature threshold of albinism on new leaves in spring was 12-23°C. Albinism was caused by low temperature, due to the abnormal development of chloroplasts and obstruction of chlorophyll synthesis, destroying the structure and functions of chloroplasts, accompanied by an increase in activity of proteinase. Chloroplasts then could not continue to develop and resulted in extra protein hydrolysis and thus the increase of free amino acids during albinism. This was confirmed by the fact that the amino acid content in Anji Baicha was twice that of ordinary cultivars.

Problems in germplasm use

The use of crop germplasm resources in China has improved since 1984. However, there are some factors limiting effective use (Table 6) as observed during the present survey. These include problems of financial resources, the level and scope of germplasm characterization and evaluation, germplasm exchange and communication, policies, and a range of other factors.

Table 6. Factors limiting germplasm utilization

Item	**Factors**	**Domestic (%)**	**Abroad(%)**
Germplasm received need further evaluation*	Yes	90	80
	No	8	20
Germplasm received which are used in breeding programmes	Yes	98	80
	No	2	20
Major limiting factors in using germplasm	Financial	45	33
	Policies	31	33
	Characterization & evaluation data	14	17
	Information	9	17
	Others	1	0
Most serious problems in germplasm enhancement	Policies	34	37
	Lack of useful germplasm	27	13
	Lack of information	19	25
	Other	20	25
Major approaches to access information of germplasm	Catalogues	34	33
	Journals	36	22
	Database system	7	28
	Oral presentation	20	17
	Others	3	0
Ways to share information & elite germplasm	Bilateral benefit	79	50
	Distribution free of charge	18	40
	Others	3	10
Major difficulties in germplasm exchange among breeders and curators	No policy guarantee benefits	55	33.3
	No mutual understanding	29	33.3
	Low genetic diversity of germplasm in genebanks	8	11.1
	Think that no elite germplasm in other peers	2	11.1
	Others	6	11.1

*2 % did not respond

Lack of funding

The level of financial resources is one of most important factors affecting the effective use of crop germplasm. Genebank budgets are insufficient for adequate germplasm regeneration and characterization. The cost for germplasm distribution is high, thus limiting the level that curators would like to see or achieve. Furthermore, breeders usually have no budget to screen germplasm. That is why they did not fully use the samples received from genebank curators.

Inadequate germplasm characterization and evaluation

The survey showed that there were few in-depth studies on the huge collections. Only basic characterization and phenotypic evaluation had been carried out. For many accessions, there was no information on resistance to diseases and pests or stress tolerances. For example, 38 000 accessions of wheat germplasm preserved in the national genebanks were characterized for agronomic traits, but only 22 000 accessions were evaluated for resistance to seven diseases, 15 000 for drought tolerance, 2000-3000 for cold and salt tolerance each, and 20 000 for crude protein and lysine contents. About two-thirds of maize germplasm had been characterized and evaluated for disease and pest resistance, stress tolerance and quality analysis.

Reluctant germplasm exchange

Medium-term genebanks are necessary in China for germplasm multiplication and regeneration, and to increase the effective use of germplasm resources. For many reasons, however, these facilities were not well established or maintained. Most medium-term banks are located in the different provinces and have responsibility for medium-term preservation of local germplasm only. In some provinces, there are no modern medium-term genebanks and the present conditions for preservation are poor. About 7% of the respondents have long-term genebanks, 20% medium-term facilities, 42% germplasm nurseries, 29% working collections and 2% no facilities at all. Moreover, due to lack of funds for germplasm regeneration, no materials are available for distribution, and some accessions have been lost.

Some provincial medium-term genebanks are not linked to the National Germplasm Information Database, leading to ineffective germplasm and information exchange between units working on germplasm and those working on breeding and basic research. Thus, some germplasm curators do not know the breeders' requirements, and breeders do not have access to germplasm information. This has contributed to the inaccurate targets of both curators and breeders.

Lack of policies governing benefit sharing

All respondents identified policy issues as important. The difficulties in germplasm and information sharing mainly result from the lack of benefit sharing policies. Currently, germplasm holders and users' intellectual property cannot be protected effectively. This is why some elite materials owned by breeders are not preserved in the national genebanks or nurseries, and cannot be used by others. The survey showed that more than half of the respondents proposed that sharing germplasm should conform to the principle of bilateral benefits. Germplasm providers should be acknowledged by germplasm users by sharing the benefits or financial compensation, which should encourage germplasm holders to share germplasm with others.

Other factors

In addition to the ones discussed above, there are some other factors limiting the use of germplasm conserved in genebanks, which include the limited work on germplasm enhancement that plays an important role in promoting utilization, particularly for wild relatives of crops. The lack of techniques to screen germplasm for useful traits such as disease resistance is common in both germplasm research and breeding sectors. Furthermore, the lack of cooperation between genebank curators and germplasm users hinders germplasm distribution and utilization.

Conclusions and suggestions

During the present survey on germplasm access and use, several suggestions were received from experts in different fields, which could improve germplasm use. After careful analysis of these suggestions, we conclude that the follow up on the following suggestions could help promoting the use of germplasm in China.

Strengthening characterization, evaluation and enhancement of germplasm

While germplasm collecting and conservation must continue, greater emphasis should be placed on characterization and evaluation, and in-depth study of germplasm. The applications of biotechnology including molecular markers, cell and genetic engineering offer great potential for germplasm enhancement, especially definition of genotypes. These efforts will lead, among others, to the transfer of favourable genes from wild relatives of crops to cultivars to generate new types of germplasm. Germplasm researchers should provide not only elite germplasm, but also the information on its characteristics and the genetic mechanisms that will facilitate greater use. More needs to be done to exploit the potential of germplasm, especially the wild relatives. Germplasm researchers should understand the advantages and disadvantages of different genebank accessions. This will contribute more effectively to their exploitation for crop improvement.

Promoting the exchange of germplasm and associated information

Lack of regeneration and multiplication efforts in China seriously affect the distribution and exchange of the many accessions conserved in genebank and nurseries. Hence there is a need to undertake regeneration and multiplication of accessions based on sound scientific principles. We believe that germplasm researchers should interact more with breeders and exchange germplasm and associated information. One way is to organise trials involving germplasm from different ecological regions that will provide more opportunities for interaction between germplasm researchers and users, including farmers. We also feel that a national information network could provide relevant information on germplasm conservation, characterization, evaluation and enhancement, and will promote their access by breeders and other researchers.

Formulating benefit-sharing policies

Benefit-sharing policies for using germplasm should be drawn up in line with international agreements, to encourage cooperation between germplasm curators and users. On the one hand germplasm providers could benefit from the use of their germplasm by breeders and other researchers, and on the other breeders would be encouraged to send their improved and elite materials to the genebanks for conservation, exchange and use. A germplasm service at cost may be one way to satisfy users and meet the needs of the market leading to sustainable germplasm management.

Strengthening financial support

The management of national germplasm resources is dependent upon continuous government support in terms of financial and human resources. The promotion of germplasm activities is also important. However, institutions working with germplasm have to take responsibility for research funds to identify, evaluate, enhance and provide useful germplasm for crop improvement and other purposes. Some of this could be achievd through joint evaluation and enhancement activities on cost sharing basis.

Establishing a national coordinating mechanism

In China, a national coordinating mechanism is essential for promoting the conservation and use of plant genetic resources. We believe that a national committee for PGR should be the coordinating and decision-making body in the country. The committee could be composed of officials and stakeholders from different sectors with and experts on conservation and use of PGR. It would have responsibility for formulating rules and policies for management and operation of PGR, making short, medium- and long-term plans of action. We believe that, establishment of such a committee, together with other proposals, can significantly enhance the use of the germplasm conserved in Chinese germplasm collections.

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Utilization of Chinese crop germplasm resources

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Introduction

China is a big and ancient country, which holds abundant crop germplasm resources. It has a long history and rich experience in using these genetic resources. By 1998, more than 355 000 accessions of crop genetic resources belonging to more than 210 genera have been collected and conserved in Chinese Genebank, including 50 000 accessions introduced from foreign countries. According to rough estimates, only a small part of these genetic resources (3% to 5%) have been used In the last 50 years, more than 5000 new crop cultivars have been released by using 10 000 accessions in the breeding programme. Available statistics indicate that using 1000 elite genetic resources 508 rice varieties have been developed during 1949-1979. Since 1986, Chinese researchers have evaluated 300 000 crop germplasm resources for various agronomic characteristics through Key Technologies R&D Programme. About 35 000 germplasm accessions with one or more desirable characters have been identified. About 3400 of these were provided to breeders and used in breeding programmes and in production, accounting for only I% of the total identified resources. About 30 000 new crop genetic resources have been collected in latest expeditions, and most of them have yet to be studied and utilized. Some minor crops, economic crops, horticultural crops, and even some wild species of those domesticated crops have wide genetic diversity, which needs further collecting, evaluation and utilization. Therefore, the utilization of Chinese crop germplasm resources have tremendous potential (Fang 1998).

Benefits by using Chinese crop germplasm resources

As a result of employing genetic resources in crop breeding, the main crop cultivars have been renewed for 3-5 times since the foundation of the People's Republic of China. The elite varieties covered up to 85% of the total cropped area, which played an important role in improving the yield of food, cotton, oil, and brought significant economic and social benefits to agriculture. According to available statistics, grain yield increased from 1050 kg ha^{-1} to 4300 kg ha^{-1} in China. The total yield increased from 1321 billion kg to 4900 billion kg. Thus, there has been an increase of little over three times for grain yield per hectare and 2.7 times increase in total yield. The increase in the production was mainly due to large scale cultivation of new cultivars. The yield of rice increased from 1890 kg ha^{-1} to 6212 kg ha^{-1} by means of renewing cultivars for four times. The discovery and utilization of "wild male sterile" rice made it possible to develop the three lines and resulting in quick dissemination of seed and growing it in extensive area. It's a revolution in rice production history, an increase of 2580 million tonnes of food has been achieved by 1995. According to official estimate, the discovery of dwarfing gene and male sterile gene in rice had great impact as each of these traits helped to increase the output by >20%. The yield of wheat improved from 630 kg ha^{-1} to 3734 kg ha^{-1} through four times of varietal replacement (PPBM and ICGR 1998). Meanwhile, the characters of wheat varieties have changed a lot, plant height has been reduced, 1000-seed weight was altered from small to high, disease resistance increased and maturity period was shortened. From 1949 to 1982, more than 120 wheat varieties with more than 67 000 ha of sown area for each have been released, 13 of which were planted up to 670 000 ha (PPBM and ICGR 1998). The extension of area under hybrid maize has accounted for 70-80% of the total maize area, which increased the output from 1335 kg ha^{-1} to 5200 kg ha^{-1}. By six cultivar replacements, more than 260 cotton varieties have been produced in China, which raised the production from 375 kg ha^{-1} to 750 kg ha^{-1} and made China one of the largest cotton producers in the world. About 225 ***Brassica napus*** rape varieties have been developed up to 1982. One ***B. napus*** rape cultivar, 'Qin You No. 2', was developed from three lines, it was the first hybrid rape that was grown on vast areas any where in the world, and its average yield was over 1800 kg ha^{-1} (PPBM and ICGR 1998).

Utilization of Chinese crop germplasm resources in the last 10 years

Rice

By crossing of wild rice and cultivated rice, a number of new breeding lines have been developed and used as parents in rice breeding. 'Gui Ye Si Miao' was produced by this way and became the main variety of rice in Guangdong province, and it has been extended to ten other southern provinces also (Fang 1995). A series of new super-high output combinations of subspecies such as 'Xie You No. 419', 'Xie You No. 413' were developed by using high restorer fertility line 'Zhong 419' which was produced by hybridization of japonica and indica rices. They have been planted in large rice production region of south China. High salt tolerant variety '82-210 was developed from introduced nonglutinous rice, and it was extended to a large alkali soil area along the coast (Fang 1995). The introduced nonglutinous rice 'BG90-2', together with 6 varieties derived from it, have been planted to more than 670 000 hectares. The drought-resistant rice introduced from Brazil began to be extended around the country; it would contribute a lot to water-saving cultivation in rice.

Wheat

Dwarf, and high-yielding new material 'Ai Meng Niu' with multiple resistance was developed by using three varieties-'Ai Feng No. 3', 'Meng Xian 20 1', and 'Niu Zhu Ta' (German). 12 cultivars were derived from it, which produced significant economic benefits. It was for the first time that transfer barley yellow dwarf resistant gene from ***Agropyron intermedium*** to common wheat was effected successfully. This was made possible by the production of a chromosome translocation line of ***Ag. intermedium***, which provided reliable source for barley yellow dwarf resistance. For the first time, several excellent genes were transferred from ***Ag. cristatum*** into wheat, including genes for powdery mildew resistance, stripe rust resistance, barley yellow dwarf resistance, scab resistance and drought tolerance (Fang 1995). A large number of stable new genetic materials have been developed and provided to more than 10 institutes for effective use. Among them, '96-143', a highly drought resistant line with more tillers, could make a breakthrough in wheat breeding. Winter-sown wheat '442M-I' was identified for salt tolerance and high output, it has been extended to a large area in the wheat-cotton multiple cropping area of Yellow River Delta.

Coarse cereals

'Hong Yu No. 9' was produced by using highly cold-resistant inbred lines of maize, and extended the maize cultivation to 51°30' north latitude. Hybrid maize that had 2-3 times higher oil content than common maize was developed by using high oil maize germplasm. Hybrid Chinese sorghum variety 'Shen Za No. 6' was produced by using two restorer fertility lines, one was smut-immune line '5-26', the other was sorghum aphid resistant line '5-27' (Fang 1995). The grand total of its planting area has reached over 65 000 ha. The introduction and adoption of millet cultivar 'Japan 60 days' controlled the harm caused by summer millet blast, which had been a problem for a long time in China. The planting area of introduced mung bean variety 'Zhong Lu No. I' accounted for one third of the total planting area, and brought about the first cultivar renewal of mung bean through the whole country (Fang 1995).

Cotton and fibre crops

By using Uganda cotton and 'Mexico 9l0', 'Zhong Mian No. 12' and 'Si Mian No.2' have been developed and extended through Huanghe and Yangzi River Valley. New cotton lines like 'Zhong Yin 97 I' and 'Zao Tan', introduced from U.S., have high yields and short boll period. The market of introduced colour cotton has a bright future, and its production and utilization has already started. The red fibre variety 'BG52-135', introduced from U.S., appears to be high yielding, disease-resistant and it has been found suitable for paper industry (Fang 1995).

0ilseeds

Glycine gracilis and ***G. max*** were crossed and a series of high-yielding, disease-resistant soybean lines were produced, from which the new soybean line '5621' and other varieties were developed. Among them, 'Tie Feng 18' has been planted over 350 000 ha each year. Innovated soybean material 'Zhong Ye No. I' with ***Glycine soja*** in its pedigree possessed good characters like high output, good quality, salt and alkali tolerance, drought tolerance, and it has been spread to North and East China (Fang 1995). A large number of groundnut (peanut) varieties with high yield, highly resistant to bacterial wilt have been produced by using resistant sources to this disease and have been planted in 200 000 ha of disease-prone areas in the south which has controlled this disease effectively. A series of promising groundnut varieties have emerged by using a multiple-resistant wild relative, ***Arachis correntina*** (Fang 1995). Among them, "336-7” has been extended to 20 000 hectares in Shandong province.

Fruits

The Fuji apple, which was introduced from Japan is planted in over 270 000 ha and has become one of the major varieties in the market in north provinces. By crossing breeding, a series of new elite varieties of grape were developed. 'Zhengzhou Seedless' was identified as the biggest seedless grape variety. With average fruit weight was 7-8 g, it has begun be spread over a large area (Fang 1995). Introduced Nectarine (***Prunus persica*** var. nectarine) and improved varieties developed from it have become popular with Chines people. Sweet orange 'Zhong Yu No.7', which was developed from the landrace 'Gold Orange' has been extended to a large area in Yunnan, Guizhou and Sichuan provinces producing significant benefits to its growers (Fang 1995). Early maturing, high quality and dwarf Xinjiang walnuts are expected to change the walnut production pattern in China if its cultivated is extended. Similarly, the extension of dwarf, short-branched and big-seeded Chinese chestnut will change the pattern of chestnut production. Heat-resistant strawberries with longer shelf life have become the main varieties in the strawberry production area in the south. The extension of good accessions of domesticated wild kiwi fruit (***Actinidia chinensis***) has made it into a new fruit. Many high-quality fruits like Japanese sweet persimmon, American red grape, European black plum, pearjujube and coloured pear of China are being introduced into fruit market. Further more, a large amount of fruit germplasm is being studied, and their benefits in the future are unpredictable.

Vegetables

By using outstanding landraces as parents, a series of chilli varieties from 'Xiang Yan No. 1 to 'Xiang Yan No. 10' have been developed and extended to 30 provinces in the country (Fang 1995). Yunnan black-seed pumpkin serving as cucumber grafting stock increased the output to 30-50% (Fang 1995). In the case of aquatic vegetables, four types of early, mid, and late ripening varieties of lotus root have been developed using its rich genetic resources and extended to 66 666 ha in 18 provinces. Many vegetable varieties such as kidney bean, cowpea, cucumber, Chinese cabbage, cabbage, hot pepper, and a large number of new introduced and recently developed vegetable varieties have entered the market, which have enriched our 'Vegetable Basket Project' greatly.

Problems and suggestions in using Chinese crop germplasm resources

Genetic resources have been used mainly in two ways, one using them as parents in breeding and the other is their direct use in crop production. Due to various reasons, both ways are restricted to a certain extent at present, which results in a passive situation that is hard to break in crop breeding. On one hand, we have plentiful genetic resources; on the other only a few accessions have been used as parents in plant breeding. The main reasons could be:

1. The accessions used in the breeding have narrow genetic base.
2. The characterization and evaluation remain inadequate, which tend to stop with phenotypic characters. Further evaluation for desirable genes and molecular characterization needs to be done. The lack of in-depth studies desirable traits and their genetics on large collections makes it difficult to realize their value.
3. Innovative research is weak. Little has been done to use the outstanding materials we already have, which has limited the widespread utilization of genetic diversity.
4. There has been no effective protection for the rights and interests of breeders or people who create new materials and hence it is difficult to bring their motivation into play.
5. Limited government budget constrained the research and utilization of these genetic resources. The government invested little and paid not much attention on the management of basic research, little financial support and old equipment limited the profound research on crop germplasm resources.

In order to profit more from genetic resources in the near future, my suggestions are:

1. Increase government investment on basic research of crop germplasm resources.
2. Develop and implement appropriate rules and regulations, co-ordinate the relationships in using the genetic resources and activate the enthusiasm of the breeders and germplasm researchers.
3. Enhance the study and utilization of elite materials of main crops, wild accessions and resources that have not been fully used.
4. Train a number of well educated, motivated young scientists who would like to devote their life into crop germplasm research.

For more details on the constraints and suggestions see the chapter by Gao *et al.* in this volume (Chapter ***The utilization of germplasm conserved in Chinese national genebanks*** Pp. 40-52)

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Exchange of crop germplasm between China and other countries in the world

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Introduction

Presently, about 600 crops are cultivated in China and half of them originated in the country. China is an agriculture country with long history of crop cultivation and the valiant and industrious Chinese people enriched crop genetic resources in the past several thousand years through selection and improvement in cultivation (Tong 1995). As a discipline, the systematic and large-scale activities in collecting, conservation and research on crop germplasm are relatively recent in Chia. The work on crop germplasm was scattered and spontaneous before 1950s. In the early 1950s, a large-scale collecting activity was organized by the Chinese Government at national level. About 200 000 accessions of 50 field crops were collected. However, some of them were lost due to improper management during 'Cultural Revolution'. Supplementary collecting missions were organized at the end of 1970s to early 1980s and about 100 000 accessions of 60 crops were collected. In 1978, the Institute of Crop Germplasm Resources (ICGR) was established in the Chinese Academy of Agricultural Sciences (CAAS), a national institute with specific responsibility of crop germplasm. The work plan of collecting, conservation, research and utilization of crop genetic resources was actually placed on the agenda. During 1980 to 1990, the ICGR organized collecting activities in Tibet, Yunnan, Guizhou, Sichuan and Hubei provinces or autonomous regions under the government support. As a result, 60 000 accessions of various crops were collected. Up to now a total of 350 000 accessions, including some duplicates, are conserved in China. In the past 10 years, work on storage was carried out as a rush job. Approximately 310 000 accessions of more than 600 species are stored in the national genebank for long-term storage (Tong 1995a).

International exchange of crop genetic resources in China

International exchange of crop germplasm is the exchange of genetic resources and scientific information between different countries. It promotes not only the development of science and technology in the world, but also friendship among the people in the world. Active crop germplasm exchange with other countries in the world has been our constant stand. Soybean (***Glycine max*** (L.) Merr) has been cultivated in China for at least 3000 years. It was brought to Korea and soon after to Japan in 200 B.C. It was introduced into North America some 200 years ago and even earlier to Europe. Later it was brought to South America. Now, soybean is an important commercial crop in countries such as the Brazil, USA etc. Quantity of soybean exported by some countries is much higher than that of China. It was reported that over 90% of the world's soybean are grown in the six countries of USA (46%), Brazil (20%), Argentina (14%), China (9%), India (3%), Paraguay (2%) (USDA 2000). Another example of such contribution from China is the wheat landrace "Chinese Sprig" (***Triticum aestivum***) which has been widely used in wide crosses as a bridging species and in genetic studies all over the world due to its good crossability with distantly related ***Triticum*** species. Some Chinese wheat germplasm with dwarf gene has also served directly or indirectly in breeding shortstraw wheat varieties in many parts of the world. Many of the special materials of Chinese crop genetic resources with characteristics of resistance to diseases, adverse environment conditions, good quality and high yielding were/are being used and have benefited many countries.

Chinese crop germplasm exchange with other countries increased rapidly after 1970s. By early 1990s, we established links with more than 90 countries, regions and international organizations in crop germplasm exchange. Tens of thousand Chinese crop germplasm were provided to many countries, accompanied with friendship. Meanwhile, we received many materials from foreign countries too (Tong 1995a). Under the financial support of the International Board for Plant Genetic Resources (IBPGR, now IPGRI), we multiplied more than 4000 accessions of 10 crops, including rice, barley, wheat, maize, sorghum, millet, cotton, soybean, rapeseed and vegetables. More than 1600 samples were sent to 44 institutions or scientists in 22 countries. In order to provide more seed materials to other countries in the world, 2500 Chinese cereal accessions were multiplied with the support of FAO. A set of the harvested seeds were sent to FAO Headquarters with 500 grains of each, including 910 accessions of rice, 410 wheat, 190 barley, 158 oats, 30 rye, 100 maize, 220 sorghum, and 482 foxtail millet (Tong 1995a). This made it possible to share them with other countries. If possible, multiplication effort will be expanded to meet the needs of scientists and friends in the world for use in their own programmes.

The problems on international exchange of crop germplasm in China

China is an agriculture country with big population involved agricultural activities. As it plays an important role in the development of Chinese economy, Chinese government always attached importance to agriculture. Although China is rich in crop germplasm, it still needs to exchange genetic resources with other countries along with science and technology (NEPG 1994). Therefore, we have always been very keen on international exchange of crop germplasm. China, however, is a developing country in the third world. The economic basis is weak and many things remain to be developed. As a newly developed and independent science, the establishment of specific institution in China that deals with plant genetic resources dates back to only 20 years. Some necessary organizations and facilities have not really been completed. Sometimes, coordination within the country is not very efficient. In addition, the international exchange of crop genetic resources sometimes is not satisfactory. The main problems are as follows.

Firstly, seed materials of crop germplasm in China were dispersed for a long time even in farmer's hands. The amount of seed sample were not enough for international exchange (Tong 1995b). In the last 10 years, the major emphasis of work on crop genetic resources in China was conserving them in long-term storage and more than 300 000 accessions of various crops are now stored in the national genebank. However, these materials are only for long term storage and can not be used for exchange.

Secondly, lack of budget for multiplication germplasm seed needed for international exchange is another problem (Tong 1995b). The amount of surplus seed from multiplication for long term storage is quite small and is not enough for exchange. In order to meet the needs of exchange, it is necessary to multiply and increase seeds. However, there is no financial support for seed multiplication. So, it restricts the international exchange.

However, we will continue to make increased efforts to collect and collate crop genetic resources in China, mobilize funding from home and abroad and expand varieties, landraces, cultivars and crops for exchange in order to meet the needs of international germplasm exchange.

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Current status of conservation and research of forest genetic resources in China

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Introduction

China's vast land covers tropical, subtropical, warm temperate, temperate and boreal climatic zones. However, its forest resources are poor owning to some historical factors. Although China is rich in arbor, shrub and vine species, The habitats in some areas were seriously degraded and most species were threatened. The number of endangered and gradually endangered population is large. All these factors have increased the need to conserve forest genetic resources (FGR). National research programmes on conservation of FGR have been carried out only recently. By mid and late 90s, a conservation system of FGR suitable for Chinese conditions has come into shape. This system includes ***in situ*** (natural stand), ***ex situ*** (field genebank or ***ex situ*** stands) and conservation of seed or ***in vitro***. In this paper, current status of FGR conservation and research is given.

Background

Forests in China have their own features compared with other countries rich in forests. For instance, except for parts of forest regions in the Northeast, Inner Mongolia, Southwest and the Yaluzangbu Canyon in Tibet, where a few of virgin forests remain, about 90% of the natural forests in the country have been damaged. Most of the remaining natural forests are secondary and disturbed ones because of many generations of selective cutting. China has 33 million ha plantations, ranking the first in the world, but only 20 species are used in afforestation in the country. About 50% of the plantations are made up of Chinese fir, poplar, Masson pine etc. This shows that species diversity is low and species structure and stand structure is simple. Most of the arbor and shrub species are left unattended, leading to serious loss of genetic resources.

Many seeds used for earlier plantations came from the poor selections. During the last 10 years or more, a large amount of seeds came from superior provenances, seed orchards and seed stands, hence the genetic structure and genetic resources is some what mixed.

Population expansion, urbanization and increased mining activities have led to the decrease in forestland. As a result, forest habitats gradually deteriorated and the secondary natural forests and the plantations overlaid each other. This caused the difficulties for the evaluation and conservation of FGR. Lack of good breeding strategies, poor selection and testing technologies, breeding programmes focus only on short-term benefits, large-scale planting of exotic species without sufficient experiments leading to genetic erosion have made troubles for the conservation of FGR(Gu 1990; Gu ***et al*** 1998).

China has more than 30 000 higher plant species, ranking the first in the world (Gu 1998). Woody plant species in China are numerous and many of these species are unique to China with a very ancient origin. China is one of the most important centres of plant origin. At present, there are 9000 woody plant species including 3000 arbor species, 6000 shrub and vine species. About 800 of them are cultivated, 210 are used as main afforestation species in China. There are 389 registered rare and endangered species. Due to the large number of species in need for conservation, wide range of land and complex environmental conditions, the FGR conservation is of great difficulty (Gu 1990; Gu ***et al*** 1998).

Development of conservation strategies and principles

Conservation strategy and objectives

After discussion and consultation with the expert group of FGR of the Chinese Academy of forestry (CAF) by the responsible department of the State Forestry Administration, taking account of a great deal of other opinions and on the basis of sustainable development, the conservation strategy of FGR with Chinese characteristics was developed. The strategy clarifies the responsibilities and obligations shared by the central and local organizations. Geographic zonation, species categorization, combination of short-term rescue and long-term conservation, integrated conservation, evaluation and utilization, full implementation and scientific management are the main features of the conservation strategy. Conservation centres will have to be established. Conservation efforts done so far have been based on individual species and populations, family lines and clones under each species, which have been the main concern for the conservation.

The objectives for three different stages are listed below:

1. Short-term objectives (1991-2000): Systematic conservation of breeding materials and superior genetic resources of important tree species, establishment of 10 conservation centres according to the forest flora in the 5 climatic zones, establishment of evaluation and utilization system and an FGR information system.
2. Mid-term objectives (2001-2020): Establishment of Chinese FGR conservation system using the 3 conservation methods, ***in situ***, ***ex situ*** (field genebank or ***ex situ*** stands) and conservation of seed or ***in vitro***, in a complementary fashion. The central and local institutions will share genetic resources and achievements, ensuring sustainable use of FGR.
3. Long-term objectives (2021-2050): Well-established FGR conservation system and optimal deployment of FGR in China will be the general goals of the conservation strategy. The institutions, science and technologies of conservation will be further developed.

Principles of FGR conservation

1. Integrated efforts of conservation, protection and rescue.
2. Combining the in situ and ex situ conservation efforts in a complementary mode.
3. Zonation of conservation according to ecological and geographic gradient axes.
4. Species-specific conservation with respect to genetic variation of each species.
5. Prioritizing conservation according to urgency and difficulty, to get the urgent and easier done first according to the local conditions.
6. Combination, conservation and utilization based on local needs.

Stratified conservation and categorization of conservation species

Conservation zonation based on tree breeding zones

A method has been developed to calculate the Ecological Gradient Axes (EGA), which integrates geographic and ecological factors into an aggregate value. EGA has been applied to studies of ecological genetics and forest tree breeding. The breeding zones were designed to include FGR and materials for breeding programmes. Therefore, the zone will be the basic unit for both long- and short-term conservation of FGR. China is divided into 10 large breeding zones, 97 breeding regions, 74 sub breeding regions and 31 basic breeding areas according to the research by (Gu 1995). A map of breeding zones has been developed. The tasks of conservation of FGR in each of the breeding zones are given in Table 1.

Table 1. Tree breeding zones and conservation zones

Tree breeding zones		***Main tasks of conservation of FGR***
Class	***Number***	
I) Large breeding zone	10	Development of conservation strategy establishment of national conservation centers, development of management support systems
II) Breeding region	97	***In situ*** and ***ex situ*** conservation of key species, establishment of testing and evaluation plantations, establishment of provincial conservation centers
III) Sub breeding region	74	Development of conservation strategy for sub breeding regions, establishment of research bases which conducts both conservation of FGR and tree breeding, conservation and utilization of FGR
IV) Basic breeding area (at provincial level)	31	Development, coordination and implementation of conservation and deployment strategies for the basic breeding area, stratified conservation of FGR, establishment of regional and provincial breeding center and production bases, establishment of information management system and connection with the national network.

Genetic resources identified for conservation

The first batch of 478 tree species for conservation has been identified. Based on the present situation and specific property of main afforestation species, non-timber tree species, species for water and soil conservation, exotic species and rare and endangered species, the 478 species were divided into 4 groups. The Group 1 includes 87 species such as Masson pine etc. that are used for timber production and ecological protection. The second group includes 38 species such as seabuckthorn etc., which are used for non-timber products, water and soil conservation. The third group includes 43 exotic species, which are used as main afforestation species, such as Black locust etc. The fourth group includes 310 species registered as class I, II and III of rare and endangered species.

The species in groups I, II and III are important species for forest products and ecological protection. The species in the group IV are species under risk of distinct threat and must be conserved.

Stratified conservation plan

The 478 species identified for conservation are divided into 3 classes based on their importance and level of threat they face.

Class 1 consists of 73 species that are in urgent need of conservation, including 40 species of the first group, 11 of the second, 15 of the third and 7 of the fourth group (class I of the rare and endangered species). These species are very important for forest products and ecological protection. They are in imminent danger or gradually endangered, and need to be urgently conserved, or they belong to the class I of the rare and endangered species.

Class 2 includes 173 species that are little less important than the species listed in the class I and some of them belong to the class II of the rare and endangered species. These species include 20 species of the first group, 11 of the second group, 14 of the third and 128 of the fourth group.

Class 3 consists of 232 species that are of significance to forest products or to environment protection and renewable resources or they belong to the class III of the rare and endangered species. These species include 27 species of the first group, 16 species of the second group, 14 species of the third and 175 of the fourth group.

Table 2 gave a matrix of numbers of species under these different types and categories

Table 2. Stratified conservation plan, integrating different types of species based on threat and importance

		Group 1		Group 2		Group 3		Group 4	
Class 1	***73***	Species	40	Species	11	Species	15	Species	7
Class 2	***173***	Species	20	Species	11	Species	14	Species	128
Class 3	***232***	Species	27	Species	16	Species	14	Species	175

Sampling strategy, conservation pattern and related technologies

Optimum sample size for conservation

The optimum sample size adopted for different conservation models is determined on the basis of the genetic composition and biological characteristics of various germplasm materials. Many measures of sample sizes, such as sample size of megagametophyte population (NG), number of monomorphic loci within family (NF1), number of polymorphic loci within family (NF2), half-sib family size estimated by quantitative characteristics (NF3), population size estimated by gene frequencies (NG) and by quantitative traits (NP), progeny size (Nm=M*N) and the number of populations within species (Nps) etc., are suitable measures for ***in situ***, ***ex situ*** (field genebank or ***ex situ*** stands) and conservation of seed or ***in vitro***. They are also applicable to the combined conservation ***in situ*** and ***ex situ***. In addition, the land area needed for ***in situ*** conservation and the quantity of plant material and conservation equipment for ***ex situ*** conservation can be estimated according to the optimum sample size.

According to the results of real calculation and analogue calculation, the main types of sample sizes are listed below:

1. Number of populations within a species to be conserved (Nps)
   a) Nps = 3-4, for species under rescue conservation or in priority conservation areas.
   b) Nps = 5-10, for species with medium genetic variation and distribution and for range wide conservation.
   c) Nps = 11-16, for species with large genetic variation and wide distribution and for range wide conservation.
2. Number of individuals within a population, the individuals are unrelated (Nip = 30-50).
3. Number individuals within a family (Nif = 30-40).

Different patterns for conservation of FGR

Ten conservation patterns were developed according to the features of FGR, in consideration of the theories of ecogenetics and experimental genetics, the technologies of field experiment of forest tree breeding. These conservation patterns reflect the combination of conservation, evaluation and utilization (Gu ***et al***. 1998).

1. Species conservation pattern (3434: 3 populations, 4 samples/population, 3 planting locations, 4 afforestation designs), combining conservation, evaluation and utilization (PTF).
2. Population conservation pattern (312: 3 populations, 1 sample, 2 afforestation designs), combining conservation, evaluation and utilization (PTO).
3. Population/family conservation pattern, combining conservation, evaluation and utilization (PF).
4. Minimum population conservation pattern, combining conservation and evaluation (Pmin).
5. Family/breeding population conservation pattern, combining conservation, evaluation and utilization (FBP).
6. FM pattern, combining family testing, conservation and utilization (FM).
7. Family/reproduction conservation, combining conservation, evaluation and utilization (FPP).

8. Plus-tree, clonal conservation, combining conservation, evaluation and utilization (PC).
9. In situ conservation (IS).
10. Conservation by assembling the rare and endangered species together with the narrowly distributed species (EDS).

Technologies related to conservation and evaluation

1. Documentation. Collection and maintenance of original registration forms, recording forms of propagation, and the layout of conservation stands (***in situ*** and ***ex situ***).
2. An Establishment and management technology of conservation stands, including experiment design, silviculture of ***in situ*** and ***ex situ*** conservation stands.
3. Technologies for conservation of seed or ***in vitro***, including seed collecting, seed testing and viability tests and multi-generation conservation.
4. Technologies for measuring conservation stand, including population size, traits of interest, precision, standard, information cards and forms for different germplasm and the duties of research staffs.
5. Technologies for measuring phenotypic diversity, including growth, adaptability, resistance, wood properties etc. at species ad individual levels.
6. Technologies for measuring genetic diversity, including isozyme and RAPD markers which have been applied to Pines, Fir, Larch, Poplar and Oak etc.
7. Technologies for database and information management. For instance, the FGR information system version 1 has been finished in 1995 and now is being upgraded to version 2.

Achievements in conservation and utilization of FGR

A great deal of FGR are conserved in nature reserves and forest parks. A total of 333 state and local nature reserves have been established during 1956 to 1986 (a total of 8.6 million ha) and by June 1996, a total number of 799 nature reserves with total area of 71.85 million ha have been established, covering 7.19% of the total land area of the country (Gu 1995). More than 100 large botanical gardens, 255 domestication bases for wild plants have been set up. Up to 1998, a total number of 926 nature reserves have been established in China with a total area of 76.98 million ha, covering 7.64% of the total land area of the country. The established nature reserves and forest parks are distributed over all 5 climatic zones, covering all the 8 floristic regions and 24 sub-regions defined by “China flora zoning (1979)”. It was established that 50-70% of the total 9000 species of arbor, shrub and vine was conserved at species level and along with 20-50% of the main afforestation species at population level. A total of 354 important species, including more than 200 of the class I and II of the rare and endangered species, was partly conserved. For example, in Shannxi province where nature reserves were established earlier, 12 nature reserves and 10-nature protection sites have been built. The area amounted to 0.32 million ha which covers 1.56% of the total land area of the province. The famous Taibai mountain reserve in Qinling mountain range which was build since 1965, has now conserved 40 species with a total area of 54 000 ha in the subtropics, temperate and boreal climate zones. Now it has been included in the IUCN list of nature reserve sites.

Another example is in Guangxi Autonomous Region where 64 nature reserves and forest parks were established during the 80s and the 90s. The total area of these reserves and parks is 18 886 ha, covering 7.53% of the land area of the province. Of these, 40 are tropical and subtropical reserves including 8 nature reserves, 20 water conservation stands 3 mangrove conservation stands and 3 reserves of rare species. All these reserves and parks together, to a large extent, have helped to conserve the forest ecosystem, biological component and varieties of tropical monsoon rainforest and monsoon evergreen forest.

The research programme on conservation of FGR of important coniferous and broad-leaved species for industrial timber production has been listed in the National Key

Technology Research Program since 1991. The programme was implemented throughout the country and preliminary results have been obtained. Ten conservation centres located respectively in the north temperate zone, the temperate zone, the subtropics, the south subtropics and the tropics have been built by the end of 1998 (Table 3).

Table 3. The conserved species and germplasms' number in 10 conservation centers (banks) in China

Name of banks	*Number of species*	*Number of germplasm*	*Conserved species*
Fenyi county, Jiangxi province	11	2 910	Bitter Evergreenchinkapin, Camphortree, Sweetgum, Common Sassafras, Longpeduncled Alder, Chinese Tuliptree, Chinese Fir, Masson Pine, Loblolly Pine, Slash Pine, Flous Taiwania
Qionglai county, Sichuan province	11	1 720	Oriental Oak, Longpetiole Beech, Camphortree, Long peduncled Alder, Chinese Tuliptree, Chinese Fir, Masson Pine, Chinese Weeping Cypress, Peacock Fir, Japanese Cedar, Flous Taiwania
Mengxian county, Henan province	16	1 855	Ailanthus, Black locust, Kiri paulownia, Chinese white Poplar, American Black Poplar, Siberian Elm, Manchurian Catalpa, Chinese Toona, Oriental Oak, Chinaberry-tree, Japanese Pagoda tree, Hairy Chestnut, Chinese Spruce, Fortune keteleeria, Fortune paulownia, Japanese Larch
Linkou county, Helongjiang province	13	2 840	Korean Pine, Scotch Pine, Dahuruan Larch, Japanese Larch, Olgae hay Larch, Korean Spruce, Chinese Aspen, Asian white Birch, Manchurian Walnut, ***Pheudodendron amurence,*** Manchurian Ash, Mongolian Oak, Maple
Pingxiang county, Guangxi autonomous region	8	760	Chinese Fir, Masson Pine, Michelia, Machilus, Rangoon, Hainan Homalium, Alder Birch, Truestar Anise tree
Nanning municipality, Guangxi autonomous region	13	1 305	Chinese Fir, Masson Pine, Fortune keteleeria, Loblolly Pine, Slash Pine, Cariben Pine, Gum, Acacia, Longan
Taibai mountain, Shaanxi province	9	410	Dragon Spruce, Poppy tree peony, Oriental Oak, Japanese Larch, Northern-China Larch, Spruce, Chinese Pine, White Birch, Lacebark Pine
Zhangji county, Jiangsu province	7	1 280	American Black Poplar, Black locust, Chinese white Poplar, Chinaberry-tree, Ginkgo, Willow, European Black Poplar
Changping county, Beijing	24	1 380	Lacebark Pine, Chinese Pine, Spruce, Chinese Juniper, Chinese Honey locust, Chinese Arborvitae, Chinese Tuliptree, Chinese white Poplar, European Black Poplar, Ailanthus, Japanese Pagodatree, Willow,Chinese Date, Chinese Ash, Ginkgo, False sour Cherry, Common Smoke tree, Chinese Box, Rose Bay, Scotch Pine, Olgae hay Larch, Mongolian Oak, White Birch, Chinese Toona
Jingshan county, Hubei province	8	560	Faber Fir, Masson Pine, Oriental Oak, Chinese Ash , Hairy Chestnut, Alder, Chinese Tulip tree, Japanese Larch

Among the 10 conservation centres, six are national centres and joint (State Forestry Administration and province) production bases for breeding and mass production of improve planting materials, three are research bases and one is national nature reserve. These conservation centres will be used for long-term conservation and research.

We have in total conserved 15 000 large populations, provenances, families, plus trees and clones of 74 main tree species with 270 ha of ***ex situ*** conservation stands and 276 ha of 13 ***in situ*** conservation stands.

All the genetic resources collected and conserved at the 10 conservation centres have their own features (Gu ***et al***. 1998). (Tables 3 and 4).

Table 4. Species conserved in the 10 conservation centres

No.	*Number of locations*	*Species (English)*	*Species (Latin)*
1	2	Flous Taiwania	***Taiwania flousiana*** Gaussen
2	3	Chinese Spruce	***Picea asoerata*** Mast.
3	1	Korean Spruce	***Picea koraiensis*** Nakai
4	1	Dragon Spruce	***Picea asoerata***
5	1	Faber Fir	***Abies fabri(***Mast.)Graib
6	4	Chinese Fir	***Cunninghamia lanceolata*** Hook
7	1	Fortune keteleeria	***Keteleeria fortunei***
8	1	Chinese Weeping Cypress	***Cupressus funebris*** Endl.
9	2	Lacebark Pine,Bunge Pine	***Pinus bungeana*** Zucc. ex. Endl.
10	1	Korean Pine	***Pinus koraiensis***
11	5	Masson Pine	***Pinus massoniana*** Land.
12	2	Scotch Pine	***Pinus sylvestris*** var.***mongolica*** Litv.
13	3	Chinese Pine	***Pinus tabulaeformis*** Carr**.**
14	1	Peacock Fir	***Cryptomeria fortunei*** Hooibrenk ex Otto et Dietr
15	1	Japanese Cedar	***Cryptomeria japonica***
16	1	Northern-China Larch	***Mayr.***
17	2	Olgae hay Larch	***Larix olgensis*** Henry
18	1	Dahuruan Larch	***Larixgmelini*** (Rupr.) Rupr**.**
19	1	Chinese (Oriental) Arborvitae	***Platyoladus orientalis*** (L.)France
20	1	Chinese Juniper	***Sabina chinensis***
21	2	Ginkgo	***Ginkgo biloba*** Linn.
22	2	Japanese Pagoda tree	***Sophora japonica***
23	2	Hairy Chestnut	***Castanea mollisima*** Blume
24	1	Manchurian Walnut	***Juglans mandshurica*** Maxim.
25	1	Bitter Evergreen chinkapin	***Castanopsis sclerophylla***
26	2	Mongolian Oak	***Quercus mongolica***
27	4	Oriental Oak	***Quercus variabilis*** Bl.
28	1	Long petiole Beech	***Fagus longipatiolata***
29	1	Michelia	***Michelia maoclurei*** Dandy
30	1	Spiny bract Evergreen chinkapin	***Castanopsis hystrix***
31	1	Machilus	***Machilus zuihoensis***
32	2	Camphor tree	***Cinnamomum camphora*** (L.) Presl.
33	1	Common Sassafras	***Sassafras tsumu***
34	1	Manchurian Catalpa	***Catalpa bungei*** C.A. Mey.
35	1	Amur or cork tree	***Pheudodendron amurence***
36	1	Manchurian Ash	***Fraxinus mandshurica***
37	2	Chinese Ash	***Fraxinus chinensis***
38	2	Chinaberry-tree	***Melia azedarach***
39	4	Chinese Tulip tree	***Liriodendron chinense***
40	3	Long peduncled Alder	***Alnus cremastogyne*** Burk.
41	1	Maple	***Acer***
42	3	Asian white Birch	***Betula platyphylla***
43	1	Alder Birch	***Betula alnoides***

Table 4. (continued)

No.	*Number of locations*	*Species (English)*	*Species (Latin)*
44	1	Sweet gum	***Liquidambar formosana***
45	1	Siberian Elm	***Ulmus pumila*** L.
46	2	Ailanthus	***Ailanthus altissima*** Swingle
47	1	Chinese Toona	***Toona sinensis*** (A. Juss.) Roem.
48	1	Chinese Honey locust	***Gleditsia sinensis***
49	1	Chinese Box	***Buxus sinica***
50	1	Common Smoke tree	***Cotinus coggygria***
51	1	Truestar Anise tree	***Illioium verum*** Hook.
52	1	Longan	***Dimocarpus longan***
53	1	Falsesour Cherry	***Prunus pseudocerasus***
54	1	Rose Bay	***Rhododendron***
55	1	Chinese Date, Jujube	***Ziziphus jujuba***
56	1	Hainan Homalium	***Homalium hainanense***
57	2	Willow	***Salix***
58	3	Chinese white Poplar	***Populus tomentosa*** Carr.
59	1	Chinese Aspen	***Populus davidiana***
60	2	Black Poplar	***Populus nigra***
61	1	Kiri	***Paulownia tomentosa***(Thunb.) Steudel
62	1	Fortune paulownia	***Paulownia fortunei*** (Seem.) Hemsl.
63	1	Poppy tree peony	***Paeonia suffruticosa*** Andr var. ***Papaveracea***
64	1	Rangoon	***Tectona grandis***
65	2	Loblolly Pine	***Pinus taeda***
66	2	Slash Pine	***Pinus elliotii***
67	1	Caribbean Pine	***Pinus caribea***
68	4	Japanese Larch	***Lanix kaempferi***
69	2	Black Locust	***Robinia pseudoacacia***
70	2	Black Poplar	***Populus deltoides***
71	1	Eucalyptus, Gum	***Eucalyptus uraphylla***
72	1	Gum	***Eucalyptus***
73	1	Flooded Gum	***Eucalyptus tereticornis***
74	1	Auriculate Acacia	***Acacia auriculiformis***
75	1	Coiledfruit Acacia	***Acacia*** sp.
76	1	Acacia	***Acacia*** sp.

From these tables it can be noted that

1. The conserved species cover almost all the major forest areas for timber and ecology in central and eastern China, accounting for 96% of the species used in the National Afforestation Program (NAP). All the species for industrial timber production were used in The Eighth National Key Technology Program (NKT) and about 80% of the species used in the Ecological and Forestry Engineering Program (EFEP).
2. There are many rare and endangered species among the 74 species that have been conserved, such as ***Abies***, ***Taiwania flousiana***, ***Pinus koraiensis***, ***Castanopsis hystrix***, ***Pseudodendron amurence***, ***Fraxinus mandchurica***, ***Liridendron chinense*** etc. Thus these efforts combine rescue conservation and with conservation for economic utilization.
3. Trials established at each of the conservation centres were conducted by collecting, multiplying and conserving the plant materials at several levels, such as species/ population, population/family, population/individual etc., according to the importance of the species and status of genetic improvement. Meanwhile, activities were carried out starting with the easy ones and progressively moving on to more difficult and from specific to general.

4. The purpose of the research was explicit. All research procedures of ***ex situ*** and ***in situ***, including investigation, collecting, propagation and design of FGR conservation were carried out under the principle of combination of conservation, evaluation and utilization.
5. Every conservation centre has its regional feature and features of the species group. Species are of high value for demonstration and extension.
6. Technologies employed at the 10 conservation centres should represent the technological system of conservation of FGR in China.

Conservation of FGR in the production bases

Breeding materials conserved at the breeding bases

Some genetic resources and original breeding materials were conserved by institutions of tree breeding and the administrative departments of seed and planting stocks through establishing small stands of collection of genetic resources or genebanks. At present, superior provenances and their origins of 23 main afforestation species such as ***Cunninghamia lanceolata***, ***Pinus massoniana***, ***P. tabulaeformis*** and ***Larix*** spp. were conserved using the Pmin pattern. Provenances and stands were also conserved of other 18 species with minimum population size. The area of the conservation plantation is 34 000 ha. In total, 446 000 plus trees of more than 30 species (such as pines, firs, poplars, ulmus, oilteas, metasequoia, larch) were selected. A total of 470 ha genebanks and 3670 ha experiment stands were established. Abut 6000 or more pieces of superior hybrids, individual and clones of broad-leaved species such as poplars, willows, ***Eucalyptus*** and ***Robinia*** have been conserved. Nearly 10 000 pieces in total of provenances, varieties, cultivars and clones of successfully adapted exotic species such as ***Eucalyptus***, ***Populus nigra***, ***P. deltoides***, ***Pinus taeda***, ***P. elliottii***, ***Larix Kaempferi***, ***Robinia pseudoacacia***, ***Tectona grandis***, ***Casuarina*** spp etc. have greatly enriched the FGR in China and have become important sources for genetic improvement.

Significant achievements have been made in utilization and conservation of genetic resources in production bases of improved planting materials. Establishing of production bases of improved planting material is an effective way of combining conservation and utilization of FGR. Conservation and utilization of FGR at both population and individual levels is the main component of the Chinese conservation programme.

Genetic resources are categorized as provenances, seed stands, seed orchards, cutting orchards based on genetic composition of the resources. By early 1996, 327 seed production bases were established for 18 main afforestation species with a total area of 1.217 million ha. The annual seed production is 4 million kg. Another 626 production bases for more than 40 major species with a total area of 72 880 ha has been established, including 11 541 ha seed orchards, 49 648 ha of seed stands, 898 ha of cutting orchards, 581 ha of clonally propagated orchards and 10 217 ha of experimental and demonstration plantations. Total seed production was 700 000 kg, including more than 200 000 kg produced by seed orchards. The annual production of the cutting orchards is 150 million scions. The seed stands and the seed collection bases were thinned natural forests, secondary natural forests and plantations. These stands have high genetic diversity, hence important gene resources for conservation.

Conservation of the rare and endangered species

Chinese government always attached great importance to the protection of rare and endangered species and has developed a comprehensive plan of conservation, evaluation and utilization since the foundation of the new China. China joined in the international organization of nature conservation and species protection in 1979 and published relevant laws, regulations and standards. The first list of protected rare and endangered plant species in China was published in 1987. The national standard of forest germplasm conservation principles and methods was published in 1993. The regulation of wild plant protection in China was published in 1996. In the first list of protected rare and endangered species, 354 species in total (including 1 subspecies and 21 varieties) were included. There are 9 pteridophyte species (fern), 68 gymnosperm species and 277 angiosperms species. Of these, 8 species are in class I protected rare and endangered species, 143 in class II and 203 in class III.

Rescue conservation of species in the list belonging to genera with only single species has already been started. These species are ***Ginkgo biloba***, ***Cathaya argrophylla***, ***Metasequoia glyptostroboides***, ***Glyptostrobus pensilis***, ***Pseudolarix kaemferi***, ***Fokienia hodginsii***, etc. Many of these species are 'living fossils' or famous ornamental plants or garden species. At present, 4002 types of nature reserves, forest parks, ***in situ*** habitat conservation sites of wild rare and endangered species have been established in different geographic regions and the reproductive and inhabiting sites of rare and endangered plants. Now there are 752 forest parks at various levels in China with a total area of more than 6.8 million ha, of which 266 are national forest parks approved by the State Forestry Administration with an area of 2.8 million ha. In these forest parks more than 100 rare and endangered plants are conserved. Significant progress has been made in studies on population distribution, reproduction, genetic diversity and conservation strategy for 24 key rare and endangered species such as ***Cathaya argyrophylla***, ***Taiwania fluosiana***, etc.

Problems and recommendations

1. Overall coordination of conservation programmes. The conservation of FGR, nature reserves and forest tree breeding need to be coordinated and links among them should be recognized. An integrated plan for their management is necessary in order to avoid overlapping and duplication of efforts.
2. Limited understanding of the concept of genetic resources. Genetic resources are the resources providing us the genetic diversity. Conservation of as much genetic diversity (gene and allele frequencies) within species as possible should be emphasized. The rare and unique genes can be lost easily because they exist only in a few populations, or in one population, hence the population size must be large enough to conserve the genetic diversity.
3. Better understanding of the relation between genetic diversity and ecosystem diversity. Ecosystem diversity ensures species differentiation and stability. It is necessary to develop a comprehensive ecogenetic strategy, an optimal deployment of population/ family/genotype with in the environment, to carry out multi-site conservation for the same species.
4. Conservation of FGR is to conserve genetic diversity in forest plant species, not just the superior germplasm. At present, the material in the existing provenance trials can not fully represent the population genetic diversity. The families/genotypes conserved are mainly the superior materials (improved materials). This should be changed to conserve genetic diversity, by conserving different types of material.

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Conservation and utilization of the genetic resources of medicinal plants in China

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General situation

The natural resources of medicinal plants in China are abundant with about 11 146 medicinal plant species in the country, according to results of a nationwide investigation. The distribution of the species is as Table 1, which includes 1000-1200 species of traditional Chinese drugs, 4000-5000 species ethnopharmacological drugs and 5000-6000 species of folk drugs (Zhang 1995).

Table 1. Distribution of medicinal plants in China

Items	*No. of families*	*No. of genera*	*No. of species*
Algae	42	56	115
Fungi	40	117	292
Lichens	9	15	52
Bryophytes	21	33	43
Pteridophytes	49	116	456
Gymnosperms	10	27	124
Dicotyledons	179	1 597	8 632
Monocotyledons	33	348	1432
Total	383	2 309	11 146

Characteristics

Abundant medicinal plant species are widely distributed and have complex biological features. Chinese herbal medicines could be classified into 7 types according to the parts used for medicines as presented in Table 2.

Table 2. Types of Chinese herbal medicines based on plant part

Type	*No. of species*	*Representative species*
Root and rhizome	200-250	***Panax ginseng***
Fruits and seeds	180-230	***Macrocarpium officinale***
Whole plants	160-180	***Pogostemon cablin***
Flowers	60-70	***Trollius chinensis***
Barks	30-40	***Cinnamomum cassia***
Leaves	50-60	***Aloe vera*** L.
Liana	40-50	***Santalum album*** L.
Total	720-880	

Based on period of harvest, the medicinal plants fall into three categories:

1. Annual: ***Isatis indigotica; Rehmannia glutinosa*** Libosch***; Salvia miltiorrhiza*** Bge
2. Biennial: ***Platycodon grandiflorum*** (Jacq.) DC ***Scutellaria baicalensis*** Georgi
3. Perennial: ***Panax ginseng*** C.A.May***, Belamcanda chinensis*** L.

On the basis of habits and characteristics many of the medicinal plants could be placed in several different groups, such as:

1. Shade-loving plants: ***Coptis chinensis*** Franch.
2. Parasitic plants: ***Cuscuta chinensis*** Lam.

3. Symbiotic plants: ***Cistanche deserticola*** Y.C.Ma

The formal research on most of these species is in initial stage, though investigation and utilization of traditional Chinese medicines have been going on for several thousand years, Health care in China has been dependent on herbal medicines and a whole set of theoretical systems has been developed. At present, traditional Chinese medicines play in an equally important role in the public health service along with the western medicines. Some progress has been made in studies on chemical ingredients and pharmacological activities of medicinal plants but the work on agronomic features, such as output, quality etc., is relatively recent. Genetic basis of the agronomic characteristics still remains untouched.

Research on genetic resources of Chinese medicinal plants

With the increasing use of medicinal plants, about 200-250 species of medicinal plants have been brought under cultivation and these cover about 500 000 hectares. Several new varieties have been developed, for example:

- Varieties developed through systemic breeding : “Guizhou No.1” (***Fagopyrum dibotrys*** Hara); “Xinling No.1”(***Fritillaria thunbergii*** Miq.)”; “Dayei Yuanhu”(***Corydalis turtschaninovii*** Bess) and “Yellow fruit ginseng”
- Hybrid varieties: “Beijing 1”, “Beijing 2” (***Rehmannia glutinosa*** Libosch); “Ningqi 1”(***Lycium barbarum*** L.); “Haixiang 1”(***Mentha haplocalyx*** Briq.).
- Tetraploid varieties of ***Salvia miltiorrhiza*** Bge and ***Isatis indigotica*** Fort.(IMPLA 1991)

Conservation

Professional botanical gardens of medicinal plants have been established in Beijing and Guangxi and about 2000-2500 species were introduced for conservation and study. In addition, studies on collecting, identification and utilization of more than 10 species of cultivated medicinal plants have been conducted in recent years such as the selection and breeding of new varieties.

Developing trend

China is in a dominant position to develop traditional Chinese medicines. Great attention to the work on genetic resources of medicinal plants needs to be paid. The State Government has taken the research and development of traditional Chinese medicines as one of the focus for scientific research. It is important to develop an independent conservation structure and system, which aims of protect the genetic resources of Chinese medicinal plants and improving the current cultivated medicinal plants genetically and finally serving the medicinal and health resources of the whole world.

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The management of genebank in China

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Introduction

With the extension of storage time and increase in crop germplasm amount, the safety of germplasm stored in the national long-term and all medium-term genebanks becomes the most important problem for the genebank managers (Dong 1999). As mentioned in earlier presentations, nearly 320 000 and 500 000 accessions are currently stored in the national genebank and in the medium-term genebanks, respectively. By now, the majority of accessions conserved in different types of genebanks has already exceeded 15 years and seed viability monitoring has become a main task for the genebank workers (Lu 1995). In 1991, the national genebank (NGB) began to selectively monitor the viability of stored seeds, to study the viability monitoring methods and early-warning indices. The main results of these studies are discussed in this paper.

Viability monitoring

Results of seed viability monitoring of 15 200 accessions of 14 crops stored in the NGB (at –18°C) for more than 10 years are shown in Table 1. About 95% of the accessions had similar or even higher germination ability as compared to the initial viability, whereas the germination of 80 accessions (0.53%) declined significantly from 80% or higher to 70% or lower. The results also showed that priority for seed viability monitoring should be given to some short-lived crop species, such as carrot and lettuce.

As it was shown that the seed viability of some accessions significantly declined when stored at low temperature, it is very important to study the losing characteristics of seed viability and early-ageing physiological index for seed viability monitoring. In order to simulate conditions for seed viability decline, to determine an index to give early warning, and to provide a model for seed viability monitoring to help in the management of low temperature genebank a study on 64 varieties rice seeds stored at 45°C constant temperature was carried out. Viability of these accessions was tested every three months. The results showed that seed viability survival curves appeared to be contra-sigmoid for each variety. There was a rapid viability-declining phase during the seed ageing. For 34 ***japonica*** rice varieties, the mean germination percentages of three critical survival levels were 90.06% at the first declining point, 73.74% at the second low point and 46.03% at the third low point. But for 30 ***indica*** rice varieties, they were 85.45%, 74.51% and 58.59%, respectively. The results indicated that the germination percentages of 73.74% for ***japonica*** rice and 74.51% for ***indica*** rice should be taken as important reference points of regeneration threshold. Variation analysis showed that the seed germination potential, dry weight of roots and shoots, germination index and vigour index declined significantly before the germination percentage did. Moreover, the seed germination was prolonged and the seedling was significantly weakened before the coming of the rapid declining phase of seed viability. The rate of compatibility of tests (RCT) and coefficient of variation (CV) could be used as early warning indices to indicate overall quality of mass accessions. These early warning indices could also be used in monitoring the viability of seeds stored in the NGB (Lu 1999).

According to the results of viability monitoring of seeds in genebank and model test of 64 accessions stored at 45°C, we have proposed the following viability monitoring plan for rice seed stored in the NGB.

- Monitoring interval: The first monitoring should be conducted when seeds have been stored for 15 years.
- Monitoring pattern: Seed viability monitoring should be done for all the seed lots.
- Evaluation of the qualitative change of stored seeds and early warning index: While monitoring the seed viability, not only seed germination potential and germination percentage, but also vigour index should be tested. The RCT and CV could be used as early warning indices.
- Calculation of safe longevity for stored seed: The seed safety storage longevity of each accession could be predicted according to the survival curve drawn by all viability monitoring results and vigour indices.
- Regeneration standard: The germination percentage of 75% should be taken as a reference of regeneration threshold.

Suggestions

Although our endeavours have resulted in remarkable achievements in the viability monitoring, some problems still exist and it is necessary to strengthen the following work.

- With the increase of the amount of germplasm preserved and the extension of storage time, safety of material stored in the genebank is a challenge. In addition to periodical monitoring of seed viability to ensure the safety and prolonged-preservation of germplasm, NGB should increase its efforts to strengthen the studies on prolonged-storage techniques, for instance, seed viability monitoring method and regeneration standards.
- Establish the National Crop Germplasm Resources Committee, tighten up the coordination work of national germplasm collection management, and formulate germplasm distribution and utilization policy, so as to enhance the contribution of germplasm resources to social development.
- Establish comprehensive testing stations having a wide scope of seed propagation, germplasm introduction and adaptability trial, quarantine and regeneration, so as to enhance the distribution and utilization of elite germplasm.
- Set up for a national germplasm information management network, based at ICGR.
- Set up Crop Expert Consultative Committee to provide expert advice for effective management and full utilization of germplasm collections.
- The government should enlarge funds to guarantee germplasm conservation and management working smoothly, and to prevent the losing of germplasm collected.

Table 1. Viability change after the seeds were stored for more than 10 years

Crop	*Initial viability Standard (%)*	*Number of accessions tested*	*Accessions with viability of*			
			initial standard		*70%*	
			No.	*%*	*No.*	*%*
Rice	90.00	2 995	2 939	98.13	3	0.10
Sorghum	85.00	2 786	2 514	90.24	12	0.43
Maize	90.00	1 368	1 343	98.17	0	0.00
Wheat	85.00	2 989	2 894	96.89	7	0.23
Millet	85.00	1 079	1 034	95.83	5	0.46
Barley	85.00	2 010	2 009	99.95	0	0.00
Soybean	85.00	1 020	1 018	99.80	0	0.00
Cotton	90.00	200	130	65.00	4	2.00
Sunflower	90.00	100	90	90.00	1	1.00
Peanut	85.00	200	200	100.0	0	0.00
Carrot	80.00	100	60	60.00	23	23.00
Lettuce	80.00	100	80	80.00	14	14.00
Allium	80.00	100	89	89.00	7	7.00
Castor-oil plant	90.00	200	159	79.50	224	2.00
Total		15 247	14 549	95.42	80	0.53

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In vitro maintenance of sweetpotato genetic resources

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Introduction

Sweetpotato is an asexually propagated crop with relatively high light use efficiency. It is also high yielding, nutritious, highly tolerant to environmental stresses. Both the underground and aboveground parts can be utilized. Use of sweetpotato as vegetable, medicine and source of natural pigments are also being exploited, which requires development and utilization of sweetpotato germplasm and thus effective conservation of its germplasm has become important.

Evaluation of sweetpotato germplasm maintenance

Characteristics of sweetpotato

Sweetpotato is asexually propagated. Organs that can be used for propagation include the storage roots, shoot tips, and inter-nodes (for stem cuttings). In temperate areas, storage root is the main plant part used, which contains 65-85% water, making it difficult to store and to transport. As hexaploid heterozygote, F_1 hybrid of sweetpotato can segregate so much that it is virtually impossible to produce genotypes identical to parents without screening a large number of progenies. Self-incompatibility in sweetpotato also presents problem to generate homozygotes. In addition, incompatibility groups (IGs) within the species effectively reduce hybridization among varieties within the same sexually incompatible group (no seeds produced upon crossing). To date, there are 13 IGs identified. IGs may encourage crossing between different genotypes to prevent the loss of hybrid vigour but also limit the development of homozygotes. The latter poses a major problem for sweetpotato true seed production that could be used in agricultural production and germplasm maintenance.

Current methods for germplasm maintenance

The combination of field and ***in vitro*** maintenance provides a safe, long-term and low-cost method, facilitating exchange, evaluation and utilization of the maintained materials.

Field maintenance: In temperate region, sweetpotato is regarded as an annual crop with seed bedding in nursery, transplanting, harvest, and storage. In tropical areas, however, it is perennial since it can grow in the field year-round. In this case, the germplasm is continuously re-planted for several years. Thus a field genebank can be sustained in one site for a long term.

Field maintenance is easy to handle and does not require complicated procedures, equipment or techniques. Besides, field-grown plants can be used for evaluation in the maintenance nursery and for plant breeding (Huang ***et al***. 1991). But it has the following disadvantages when compared to ***in vitro*** conservation method.

1. Space limitation. For example, to grow 12 plants for each accession, 2.55 × 2.25 meters are needed. For 1000 accessions, this is 0.6 ha.
2. Labour-intensive and time consuming. From seed-bedding, transplanting, harvest to storage, every step required lot of labour, and all activities growing season. If extreme care is not exercised, mislabelling and mixing can lead to loss of some accessions.

3. Disease and virus infection. Disease build-up especially of virus, and subsequent decline of plant vigour, frequently resulting in loss of the materials.
4. Poor adaptation to genebank site. Poor ecological adaptation of certain accessions to the maintenance site often results in loss material due to drought, water logging (rotting) or inappropriate storage conditions. Poor adaptation to edaphic or climatic conditions may also lead to plants not forming storage roots.
5. Sheet bulk of the material. All materials (roots or stem cuttings) used for propagation are bulky and inconvenient to transport.
6. Germplasm exchange. International exchange of germplasm from field maintenance is also subjected to stricter quarantine measures.

In vitro ***genebank***: Because of above disadvantages for field maintenance, ***in vitro*** maintenance methods have been developed. There are three different ***in vitro*** methods: 1) Tissue cultured plants. This is the most common method; 2) Maintenance of artificial seeds developed in recent years; 3) cryopreservation for long-term maintenance. All these methods require tissue culture on which we will focus our discussion.

There are several advantages in maintaining sweetpotato germplasm ***in vitro***. It is independent of growing seasons and once established ***in vitro***, plants can be increased rapidly. ***In vitro*** cultured plants are grown in controlled environment and can be made free from pathogens, by producing virus-free plants by meristem-tip culture. ***In vitro*** conservation needs much less space compared to field maintenance for the same number of accessions and demands less labour. Special materials such as progenies from wide hybridization, somaclonal hybrids (Xia ***et al***. 1987) and materials that do not form storage roots can be maintained ***in vitro*** successfully. ***In vitro*** materials are also easier to transport because of small size. ***In vitro*** culture being mostly pathogen-free faces less restrictive quarantine measures for international germplasm exchange (Engelmann 1991).

However, it has certain disadvantages. For instance, ***in vitro*** maintained plants can not be directly used for field evaluation and it takes time to prepare the ***in vitro*** plants for field evaluation. This will make maintenance and evaluation into two different processes. Costs, such as equipment maintenance, electricity etc., are usually high. Unstable supply of electricity can lead to temperature fluctuation in tissue culture room and destroy the cultures. Tissue culture also needs aseptic working conditions, which make the process more complicated and contaminated cultures can be lost. Moreover, tissue-cultured material is prone to the occurrence of somatic variation, which remains hidden, whereas most asexual variants can eliminated in field-grown material where they manifest themselves as changes in colour or shape (Engelmann 1991). This is especially the case for plantlets induced from callus.

Cryopreservation of genetic resources has been explored in recent years in the context of long-term conservation. Cryopreservation of meristem-tips has been achieved in potato and cassava. This long-term storage/maintenance can be combined with ***in vitro*** maintenance (short/medium term) for the benefit of maintenance and utilization (Figure 1). In Fig. 1, base collection is conserved under long-term conditions, which, without considering application, emphasizes on gaining the highest safety factor in order to avoid loss of the materials, while active collection is used for germplasm evaluation and distribution, and gives more attention to application and emphasis is placed on how to utilize materials in the collection (Jarret ***et al.*** 1990).

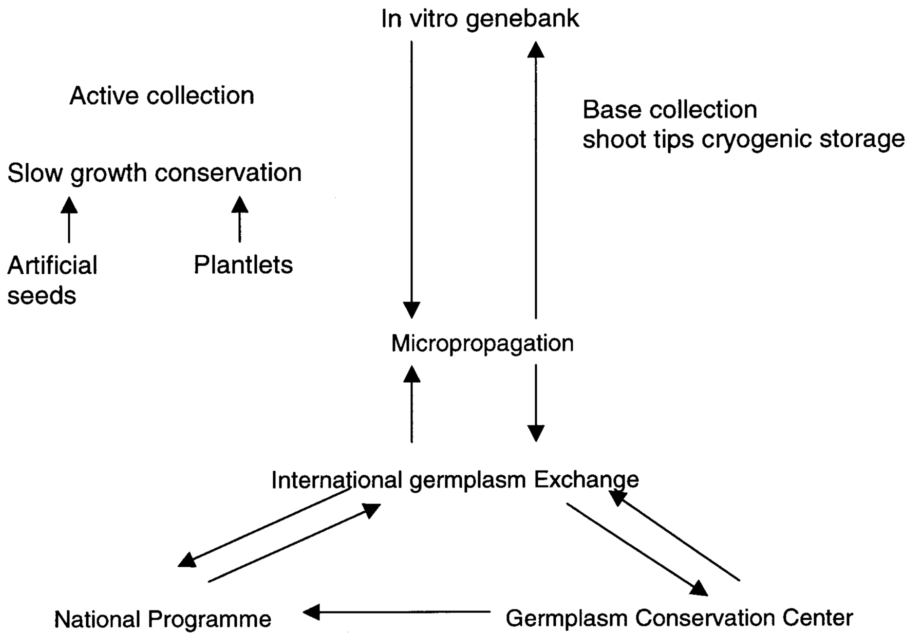

Fig. 1. In vitro conservation, exchange and utilization of sweetpotato germplasm

Botanical seed (true seed): In the Asian Network of Sweetpotato Genetic Resources (ANSWER) meeting in 1996, the possibility of using true seed to maintain germplasm was discussed. Although the seeds may be stored for decades easily, the nature of hexaploid and random segregation in the plant makes it impossible as germplasm maintenance choice. This has been the main reason that China never used it for germplasm conservation (Guo ***et al***. 1996). However, if the conservation of genes instead of genotypes is considered in the future, the botanical seeds spontaneously produced or obtained through artificial hybridization could be a suitable method for long-term conservation.

In vitro Methods

Tissue culture

Test tube cultured plants can be manipulated for slow or minimal growth by changing physical conditions, such as temperature, light, etc. These physical factors include:

Low temperature: The optimum temperature for sweetpotato tissue cultured plant growth is 26-28°C and lowering it about 15-18°C inhibits the growth. Jarret (1991) reported that when culture temperature decreased from 21.1°C to 15.6°C, growth was reduced by 50%. Lowering the temperature is the most common method for inhibiting ***in vitro*** plant growth (Angel ***et al***. 1996; Bertrand-Desbrunais ***et al***. 1992; Huang 1991; Lin ***et al***. 1989; Van den Howe, 1995; Xin, 1985). Tolerance of plant to low temperature is related to its origin. Sweetpotato, originating from the tropical areas, is sensitive to low temperature, which in turn can be used to inhibit its growth in controlled environment.

Light: ***in vitro*** plant requires 14-16 hrs day light of 3000-4000 lx for optimal growth. When light is reduced to 8-10 hrs and 1000 lx, respectively, photosynthesis is reduced and plant growth decreases. With a light period of 4 hrs, plants can still grow with slight yellowing leaves (Jarret ***et al***. 1991). When broccoli ***in vitro*** plants were subjected to different types of light, it was shown that white was better than red or blue for growth (Kubota ***et al***. 1996). There has been no published report of effect of light effect on the growth of ***in vitro*** sweetpotato.

Gases: Reducing oxygen supply can also slow down cell metabolism and growth (Xia ***et al***. 1987). But these require sophisticated instruments and thus are not yet practical.

Chemicals: Chemical treatments can effectively reduce plant growth. Many ***in vitro*** plant maintenance methods were developed by adding different chemicals to MS medium.

1. Phytohormones: Supplementing high concentration of ABA (abscisic acid) and KT (kinetin) inhibit ***in vitro*** plant growth. When using 1-10 mg l^{-1} ABA, growth of axillary buds is completely stopped. But this can be resumed when transferred to MS medium without ABA (Xin, 1987; Xin 1989a). On the other hand, on MS supplemented with 10 mg l^{-1} KT, 71.3% plants survive after one-year culture (Xin 1989a,b). High ABA concentration in the medium reduces survival rate after certain period of time (Lin ***et al***. 1989).
2. Growth regulators: Adding growth regulators to the medium can also inhibit plant growth. This has been effectively demonstrated in potato and yam (Lin ***et al***. 1989; Song ***et al***. 1991). Growth regulators used in sweetpotato culture include glyphosate at 1 mg l^{-1}, CCC (cycocel) at 100-500 mg l^{-1} (Xin, 1989a), methyl succinic acid at 50-70 mg l^{-1} (Zhou, 1987), and paclobutrzol or PP333 at 3-5 mg l^{-1} (unpublished data). In potato ***in vitro*** culture, B9 (dimethyamino succinamic acid) and MH (maleic hydrazide) are also used at 10-30 mg l^{-1} (Zhou, 1989) and 10 mg l^{-1} (Xia ***et al***. 1987), respectively.
3. Osmoregulators: This group of chemicals includes sucrose, mannitol and sorbitol. They increase osmotic pressure in the medium and reduce nutrient and water uptake by cultured plant from medium hence inhibiting growth. Many ***in vitro*** culture systems for clonally propagated crops employ mannitol. In sweetpotato, optimum concentration for mannitol has been shown at between 1-1.5% (Xin 1989a; Jarret 1991). Higher concentration of mannitol damages cells (Huang ***et al***. 1991). It was also shown that autoclaved mannitol in the medium can increase the pH (Liang, 1987). These factors should be taken into consideration when mannitol is used for ***in vitro*** culture (Lo ***et al***. 1993).
4. Varying carbon concentration. Reducing sucrose concentration results in stunted growth (Bertrand-Desbrunais ***et al***. 1992). Normal concentration of sucrose in the medium is 30 g l^{-1}. Significant growth inhibition can be observed when sucrose is decreased to 15-20 g l^{-1} (Jarret 1991). Reduced growth, stem elongation and low dry matter can occur at higher or lower concentrations (Lo ***et al***. 1993). Sucrose serves as both carbon source and osmoregulator. Substituting sucrose with other carbon source affects the ***in vitro*** plant growth. For example, when sucrose is substituted by 3% glucose, growth rate/biomass is decreased. Other monosaccharides such as lactose, maltose, mannitose, galactose and arabinose can not be readily used by in vitro plants since plant will die after culture for short period of time (Lo ***et al***. 1993).

Artificial seed

The technique of artificial seed was originally developed for use in sweetpotato production (Bapat ***et al***. 1990; Ganapathi; 1993). Tang ***et al.*** (1994) showed the use of making artificial seeds with axillary buds. Currently, work is under way to study the possibility using it for germplasm maintenance (Guo ***et al***. 1997). The production of artificial seed involves the following steps: stem segments with axillary buds (about 3 mm long) from plantlets ***in vitro*** are encapsulated by 4-5% sodium alginate in MS culture medium, resulting beads are packed in petri dish or test tube for storage. The artificial seeds can be transplanted from tissue culture on to horticultural substrates thus ensuring good genetic stability

Coated axillary bud maintains its genetic stability since it generates seedlings from the bud. Germplasm maintenance using artificial seed has following advantages:

1. Space saving. A petri dish with a diameter of 6 cm or a test tube of 2 × 18 cm can hold 50 seeds, compared to 15 test tubes of cultured plants for ***in vitro*** maintenance.
2. Energy saving. Energy can be saved artificial seeds in sealed containers are kept in incubators with light source.
3. Longer storage period. When grown on storage medium, artificial seeds produce shoot and root in about a month. However, it takes 2-3 months to produce shoot and root when kept at 18-20°C.
4. Stronger regeneration capacity. Artificial seeds can produce seedlings whether grown on culture medium or in a mixture of sand, vermiculite and perlite (unpublished data).

Our next goal is to store artificial seeds at 20°C with light to study the possibility of using them for germplasm storage.

Cryopreservation

Cryopreservation can help greatly to reduce the space needed for conservation of germplasm and germplasm can be maintained free from pathogen attacks. With new developments in technology, storage procedure can be simplified and efficiency can be increased at the same time. In the liquid nitrogen, cellular metabolism is basically arrested, avoiding subculturing that is normally required for ***in vitro*** conservation, which can be source of somaclonal variation. This ensures the integrity of the stored materials. This has been successfully used in potato and cassava germplasm maintenance. In both species, acceptable survival rates and genetic stability were reported on material stored for 4 years (Bajaj 1985). This demonstrates the feasibility of storing asexual plants under ultra-low temperature and it has just been started in sweetpotato germplasm storage. Experiments using sweetpotato meristem-tip and embryonic tissue for cryopreservation have shown that while the latter is easy to maintain with higher survival rate the former is genetically more stable (Blakesley ***et al***. 1997; Towill ***et al***. 1992). Towill ***et al***. (1992) reported the first successful vitrification of meristem-tips being stored in liquid nitrogen and reported survival rate of about 83% of two sweetpotato genotypes studied. Vitrification presents no technical problems, since no programmed cooling machine is needed. The components of vitrification solution were 30% glycerol + 15% ethanediol + 15% dimethyl sulfoxide (DMSO). After storage in liquid nitrogen, part of shoot tips treated by vitrified solution produces plantlets in recovery medium (Towill ***et al***. 1992). Further research is needed to refine the technology for making it suitable for routine use.

Genetic stability of *in vitro* maintenance plants

Evaluation method

Genetic stability if material conserved in ***in vitro*** is of prime importance and hence there should not be any differences in the phenotype when of plants regenerated ***in vitro*** material. Thus morphological characterization is crucial. Further confirmation could be carried out by analyzing soluble proteins and isozyme patterns (Dodds 1988). Molecular techniques such as Randomly amplified polymorphic DNA (RAPD) analysis could be used for further confirmation of genetic stability.

Length of storage

Our research using isoenzyme and RAPD data indicates (unpublished) that after 8-10 years conservation of sweetpotato plantlets ***in vitro*** in a medium containing 1% mannitol, no genetic changes occurred. However, it is not clear if the genetic changes that occur are directly related to the length of time for which the material has been conserved. There is also a need to further study the differences in rates of genetic change among different genotypes conserved ***in vitro***. It is suggested that ***in vitro*** conservation and field maintenance should be undertaken in a complementary mode, which will enhance the safety of the conserved germplasm.

Factors associated with genetic instability

Asexually propagated crops are known to have higher rate of somaclonal mutation variation and it appears that some external factors might play an important role. It has been shown that tissue culture can cause chromosome aberrations (Shang 1984). For example high concentration chemicals induced variation in some characteristics of sweetpotato ***in vitro*** plant (Xin 1989b) (Table 1). However, variations caused by addition of mannitol are transient and reversed after field cultivation. Those caused by KT and CCC treatments are inheritable (Wang ***et al***. 1989). In potato, restricted fragment length polymorphism (RFLP) using rDNA as probe was used to study the effect of mannitol and cryopreservation on genetic stability. Different RFLP patterns were found between mannitol-treated and control plants while plants regenerated from cryopreserved material did not show any differences (Harding 1991). DNA analysis also indicates that plantlets regenerated from meristem-tips or nodal buds are genetically stable while those from callus displayed somaclonal variations (Muller ***et al***. 1990; Potter, 1991). Therefore, once ***in vitro*** method is chosen, one needs to balance the size of meristem-tips used with its effect on virus elimination to ensure minimal callus formation and virus-free regenerated plants.

Table 1. The effects of three chemicals and their concentration on plants in vitro of sweet potato variety Yiwohong (Xin Shuying, 1989b)

Treatment	*Concentration (mg l^{-1})*	*Yield per plant (g)*	*Stem colour*
Kinetin	5	420	purple
	10	450	green
	15 000	410	purple
Mannitol	30 000	100	green
	0.5	230	purple
ABA	1.0	175	purple
	10.0	75	green
CK	0	389	purple

Conclusions

Currently sweetpotato ***in vitro*** maintenance relies on tissue cultured plants. Once the technique of using artificial seed improved, it would provide an alternative to conventional tissue culture method. Cryopreservation of sweetpotato can be achieved through encapsulation and dehydration technique. ***In vitro*** maintenance of sweetpotato can be improved using slow growth method with the addition of mannitol or reduced sucrose or glucose and using nodes as explants maintained at 18-20°C with daily light period 8-10 hrs and light intensity 1000-2000 lx.

A combination of morphological characterization and molecular analysis should be used for determining the genetic stability of material conserved using ***in vitro*** and cryopreservation methods.

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Promote conservation and use of underutilized crops

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Introduction

Plant genetic resources (PGR) are the raw material for sustainable development through agriculture and forestry and basis for production of food, fibre and other basic needs of humans. PGR are important for world food and agriculture, particularly for food security of present and future generations. They contribute to development by helping to increase food production, eradicate poverty and protect the environment. Humans depend on a very limited number of crops to meet the food and other needs. Although people consume approximately 7000 plant species, only 150 species are commercially important, and about 103 species account for 90 percent of the world's food crops. Just three crops, rice, wheat and maize, accounting for about 60% of calories and 56% of protein that people derive from plants. However, many of underutilized crops are very important for food production in low income, food deficit countries.

Underutilized crops are locally adapted and require relatively low inputs so they are important in sustainable agricultural development and play vital role in farming systems. They are adapted to a wide range of growing conditions and contribute to food security, especially under the stress conditions. Many underutilized crops contribute to rural income and therefore, they have great value to small farmers, especially in marginal areas. In recent decades, international efforts have been made for promoting use of underutilized crops and development of underutilized species. The major international promoters for development of underutilized crops are the Food and Agriculture Organization of the United Nations (FAO), the International Centre of Underutilized Crops (ICUC), and the International Plant Genetic Resources Institute (IPGRI). It is one of the priorities in the Global Plan of Action (GPA) of FAO (FAO 1996), which was adopted by the 150 member states in 1996. The GPA emphasizes the importance of underutilized crops and indicated that "promoting development and commercialization of underutilized crops and species" is very important in promoting the use of plant genetic resources. While a small number of species provides a large promotion of global food needs, hundreds of other species are utilized at a local level, either trough cultivation or harvesting from the wild (FAO 1996) and contribute substantially to household food and livelihood security. They are often managed or harvested by women. Knowledge concerning the uses and management of these species is likewise often localized and specialized. Many underutilized plants have potential for more widespread use, and their promotion could contribute to food security, agricultural diversification and income generation, particularly in areas where the cultivation of major crops is economically marginal.

In 1991, IPGRI (the then IBPGR) convened a workshop on less utilized crop genetic resources of East Asia in Beijing. In 1992, Improving conservation and use of underutilized crops was identified as a priority project in Asia, Pacific and Oceania. Buckwheat, sesame, safflower, lathyrus and taro were target crops for the project. In 1993, IPGRI Europe Office started project on conservation and use of plant genetic resource of underutilized Mediterranean species. In 1999, CGIAR convened a workshop to examine priority issues in the conservation and use of underutilized species and the potential contribution for the CGIAR in this field. IPGRI's attention on neglected and underutilized crops is consistent with a clear recognition by the world community the role of those species particularly in the area of food security.

Neglected and under-utilized crops

Neglected crops are traditionally grown in or near their centre of origin or centres of diversity. Occasionally they become important underutilized crops far removed from centres of diversity or origin. There may be distributed widely in a country but tend to occupy special niches in the local ecology and in production and consumption. They are very important for the subsystems of local community. They continue to be maintained because of various socio-cultural needs, for example, minor millets and some leafy vegetables are continued to be maintained by local communities.

Underutilized crops mean different things to different people. For the purpose of this presentation, underutilized crops are those which were once more widely grown such as buckwheat, sesame, safflower, but now are falling into disuse due to various agronomic, genetic, economic and cultural factors. Farmers are losing these crops because they are less competitive compared to improved major crop species. Those crops are particularly subject to genetic erosion. Therefore, neglected and underutilized crops are of local importance and have potential value. Not much genetic improvement work has been done on them as they have largely been neglected by research and development community. Almost all the neglected and underutilized crop species are essential to local people as food and or as a source of income. Many of these species are also adapted to marginal or unfavourable conditions, such as zones with saline soils, arid conditions, or degraded or hilly areas. Based on these factors the criteria for selecting such crops are:

- The importance of the crop for the purposes of eradicating poverty, by contributing to employment and income-generation among resource-poor producers and processors.
- The regional or international importance of the crop, in terms of both area grown and economic value
- A clear demand from partners for IPGRI to work on the crop
- The potential of the crop to sustain production systems or otherwise protect the environment
- The threat of genetic erosion to the crop

Asia is rich in underutilized crops. According to Dr. R.K. Arora, who has reviewed the genetic resources of lesser-known cultivated food plants in different parts of the world, the maximum diversity of lesser-known cultivated food plants occurs in the Chinese-Japanese, Indo-Chinese, Indonesian, South American gene centres (Arora 1985;). Arora divided 900 lesser-known food plants into several use-based categories viz. tuberous types, vegetables, fruits and root types, 135 kinds of vegetables, 30 types of fruits and 33 kinds of seeds/nuts plus 57 other miscellaneous lesser-known food plants in Asia (Arora 1985). Some of the neglected and under-utilized species in APO region are listed in Table 1.

Table 1. Neglected/under-utilised species in APO region

Types	***Crops***
Cereals and Pseudo-Cereals	Finger millet (***Eleusine coracana***)
	Foxtail millet (***Setaria italica)***
	Buckwheat ***(Fagopyrum*** spp.)
Legumes	***Lathyrus*** spp. (different species)
	Adzuki Bean (***Phaseolus angularis*** Wight)
	Macroptyloma uniflorum
	Winged bean (***Psophocarpus tetragonolobus***)
Forages	Panicum (***Panicum*** spp.)
	Leucaena (***Leucaena leucocephala***)
Fruits/nuts/palms	***Artocarpus*** spp.
	Rambutan (***Nephelium lappaceum)***

Table 1. (continued)

Types	*Crops*
Fruits/nuts/palms	Durian (***Durio zibethinus***)
	Mangosteen (***Garcinia mangostana***)
	Litchi (***Litchi chinensis)***
	Sago palm (***Metroxylon sagu*** Rottb.)
	Tamarind (***Tamarindus indica***)
	Chinese date/Indian Jujube (***Ziziphus mauritiana***)
	Indian gooseberry (***Phyllanthus*** sp.)
Oil Crops	Safflower (***Carthamus tinctorius)***
	Sesame (***Sesamum indicum***)
	Niger (***Guizotia abyssinica***)
Root and tubers	Asian Yams (***Dioscorea alata*** and ***D. esculenta***)
	Taro (***Colocasia esculenta)***
Spices	Coriander (***Coriandrum sativum***)
	Ginger (***Zingiber officinale***)
Vegetables	Cucurbit (***Cucurbita moschata)***
	Chayote (***Sechium edule***)
	Egg plant (***Solanum melongena***)
	Okra (***Abelmoschus esculentus***)
Medicinal/Industrial	Yam (***Dioscorea zingiberensis*** C.H. Wright)
	Vetiver grass

IPGRI commitment on underutilized crops in APO region

In 1992, IPGRI initiated a project on promoting conservation and use of underutilized crops in APO region. The objective of the neglected and underutilized crop strategy of IPGRI to drives an approach, which will achieve the aim of Diversity for Development Strategy (IPGRI 1999a), through

- Promoting the conservation and increased use of diversity of neglected and underutilized crops.
- Identifying and overcoming the socio-economic and technical constraints to the conservation and use of diversity in neglected and underutilized species.
- Focusing on the local value and uses of the crops, in order to link and promote cooperation between actors.

Buckwheat, safflower, sesame, ***Lathyrus*** and taro were identified as target crops. Up to now, progress has been made in assessing genetic diversity, studying conservation strategy, promoting regional collaboration through workshops and networking and promoting use of such crops.

Below is a brief description of IPGRI's work on the underutilized crops is given, focusing on work in China.

Buckwheat

Genetic diversity study of buckwheat in China was conducted in Shanxi Academy of Agricultural Sciences in 1993 – 1994. The results generated from these studies that give information to better understand the extent and distribution of buckwheat genetic diversity in China have been published (Zhou ***et al.*** 1995; Hao ***et al.*** 1995; Zhou ***et al,*** 1995; Lin ***et al.*** 1996). Consultants' reports on buckwheat genetic resources in China, India and Nepal provided comprehensive information on buckwheat genetic resources in East Asia and South Asia (IPGRI 1999b). Publications of Buckwheat Bibliography and Directory of Germplasm Collections in Buckwheat provided useful information to germplasm workers and researchers in this field. Feasibility studies on on-farm conservation in China and Nepal were initiated in 1996. The genetic diversity of buckwheat was assessed and the factors affecting conservation on farm were analyzed. The results showed that there was a possibility to conserve tartary buckwheat ***in situ*** on-farm (Zhou ***et al***. 1998; Zhao ***et al***. 1998; Zhao ***et al***. 2000). IPGRI closely collaborated with the International Buckwheat Research Association in organizing and participated in the International Symposium on Buckwheat.

Safflower

Safflower (***Carthamus tinctorius)*** is a multi-purpose crop with great potential for development. The activity in safflower aims to develop a low-level network in cooperation with International Safflower Germplasm Advisory Committee (ISGAC) to promote conservation and use of safflower germplasm. IPGRI-APO assisted the organization of the Third International Safflower Conference in Beijing, China on 14-18 June 1993. An electronic catalogue of 2000 accessions of world safflower germplasm was put together in 1995-1997. A joint safflower ecotype study in China and India was carried out during 1996-1998 and collecting safflower germplasm in India to fill existing gaps in collections was carried out in 1997. IPGRI continues to collaborate with the ISGAC in safe conservation and better use of safflower genetic resources.

Sesame

Sesame ***(Sesamum indicum)*** is one of the oldest oilseed crops and has been under cultivation in Asia from ancient times. Rich diversity occurs in India, China, Myanmar, Bangladesh and several other countries in Asia. Like other underutilized crops, the research and development of sesame has not received adequate attention and there is tremendous scope for crop improvement through exchange of information of existing germplasm collections across Asia for selective use in national sesame breeding programmes. Realizing this potential, IPGRI-APO organized a workshop on Sesame Evaluation and Improvement jointly with ICAR/NBPGR at Nagpur and Akola, India from 28-30 September 1993. Eleven countries participated in the Workshop. Besides country participants, IPGRI professional staff from the region and Headquarters also participated. A special feature of this workshop was that each participating country had provided seed of 20-30 cultivars and landraces, which were planted at Akola along with over 4000 accessions from Indian collection, all which were available for the participants to observe and make selections. Selected accessions were provided to partners by NBPGR, India. Proceedings of this workshop were published (Arora ***et al***. 1993).

Core collections of sesame in China and India have been established based on the results from a project on sesame core collection establishment in China and India respectively published (Zhang ***et al.*** 2000). Multiplication and characterization of sesame world collection were carried out in RDA genebank, Republic of Korea. A core collection study is underway in Republic of Korea.

Lathyrus

Lathyrus is a promising underutilized grain-cum-fodder legume suited to marginal areas and important in parts of South Asia and west Asia and North Africa. As neurotoxin-free cultivars are now becoming available through crop improvement efforts, more emphasis on this crop genetic resources is required. Studies were undertaken with emphasis on conservation and use during 1993-1995. The major activity has been to interact with the national institutes in India, Bangladesh and Nepal, plus international organizations such as International Centre for Agricultural Research in Dry Areas (ICARDA), Centre for Legumes in Mediterranean Agricultural (CLIMA) and International Development and Research Centre (IDRC). This resulted in organizing a Regional Workshop on Genetic Resources of ***Lathyrus*** in Asia in December 1995 at the Indira Gandhi Agricultural University, Raipur, proceedings of which were published (Arora ***et al***. 1996) and widely distributed. Based on the recommendations of the above workshop, work was initiated on the preparation of a Directory and ***Lathyrus*** descriptors and an electronic catalogue of ***Lathyrus*** germplasm collection. Formation of a

Regional Network was recommended at the above workshop and IPGRI-APO further discussed with partners from South Asia (Nepal, India and Bangladesh), ICARDA, IPGRI-WANA (IPGRI Regional Office for West Asia and North Africa) and CLIMA, Australia, during a Working Group meeting form 8-10 December 1997, organized by IPGRI. The proceedings of this workshop have been published and widely distributed (Mathur ***et al.*** 1998).

Taro

Taro is an important food crop in many parts of the tropics. Some types have special significance for use in difficult lands as they can produce large yields under flooded or swampy conditions. APO initiated a project with aims at improving the conservation and utilization of taro (Ramanatha Rao 1996). Information on taro and yam genetic resources from published and other sources is being collated and catalogued on a continues basis. The information gathered from different countries has also been computerized, analyzed. Consultants' reports on PGR activities in taro in India, Philippines and Sri Lanka distributed to interested partners. These efforts have helped to better understand the status of taro genetic resources and to improve planning of PGR activities. IPGRI has been providing technical backstopping given to Taro Genetic Resources Project (TaroGen) and Taro Network for Southeast Asia and Oceania (TANSAO). Ethnobotany and genetic diversity study on taro was conducted in China to better understand the scope and distribution of taro in Yunnan province and effective of human factors on the formation of taro genetic resources in that region. Based on this study strategy on safe conservation of taro genetic resources was discussed and developed.

Concluding remarks

In summary, through working on selected species, IPGRI will continue to collaborate with national programmes to broaden their focus to include a wider range of species that can contribute to national development and goals. IPGRI will provide information and advice to support national decision-making on the choice of target species, based on assessment of their role in poverty eradication, and food security and the feasibility of conservation efforts.

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Plant genetic resources information management and indigenous knowledge documentation

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Introduction

Documentation is one of important activities for conservation and use of plant genetic resources (PGR). It is closely associated with all other activities such as germplasm collecting, characterisation, conservation, regeneration and use. An effecient information system for PGR will greatly promote the capability of national programmes to implement the conservation strategies. In the Global Plan of Action (GPA) of the Food and Agriculture Organization (FAO), promotion of documentation system is identified as the major component in the activities of capacity building in national programme (FAO 1996). Many national programmes have developed comprehensive documentation systems for managing their genetic resources data, providing basic information for decision making and identifying useful materials for research and variety development.

Documentation of PGR is promoted along with the rapid development of various media for data recording, exchanging, analysis and use. The traditional manual documentation system has been replaced by computerised database. Many genebanks have employed documentation staff responsible for data management and information service in genebanks. For promoting cooperation, many information networks have been or being developed for crop, regional or global networks.

IPGRI-APO considers that it is very important to promote documentation activities in the region. A number of activities have also been carried out on strengthening the national programme capacity for data management, developing methodologies for data exchange and reuse and promoting information networks for crop and regional networks. IPGRI-APO also initiated research on the tools for monitoring genebank health and analysis of economics. Documentation training has been conducted to build the capacity of national programmes in operating and managing genebank management systems. In the area of ***in situ*** conservation, a model for documenting indigenous knowledge for conservation and use of PGR has been developed.

Promotion of information exchange and network development

As noted earlier, many genebanks in the APO region have established computerized documentation systems. Due to differences in platform, languages and formats for data recording, method of exchanging with others is a major problem, particularly in network activities. Such an effort, due to the uniqueness of each genebank documentation system, will involve tedious work of data re-entry. A common, computerized documentation system for all genebanks is the best solution but it is not really acceptable due to reasons such as cost, language, etc (IPGRI-APO 1999).

With computer technologies, it is possible to promote the data exchange electronically between genebanks, central or crop databases for network activities, and developing information network. This can be achieved with the development of a common format as the basis of data and information exchange. At the same time, the local system of information management adopted in the various genetic resources centres could be maintained (Quek 1999).

Data exchange

IPGRI-APO, in cooperation with the national genebanks in China and Japan, has developed the Data Interchange Protocol (DIP), which enables national programmes to exchange data in a format so that the exchanged data can be reused by the recipient without re-entering into the computer. DIP is independent of any underlying means of data transmission. National programmes need only to develop the import and export functions in their systems to DIP format, which will enable genebanks to deliver data exchanged in a standard or common format that is accessible by all. Thus the receivers of data can manage and use the exchanged data without the tedious work of re-entering and validating the data.

DIP is a vertical text format composed of three sections: head, data and trailer. Head section provides the description of the data, which serves as help information for users. The data section provides the listing of the data by accession. One character within one accession occupies one line. A blank line is placed between two accessions (IPGRI-APO 1999).

For Taro Genetic Resources Network (TaroGen), curators from various Pacific Island countries agreed to exchange data with DIP format. As the format is simple, the data exchange can be performed using word processing software, a spreadsheet or database software. For managing the exchanged data with DIP format, IPGRI and Institute of Crop Germplasm Resources (ICGR) have developed software called DIPVIEW to enable data to be transferred from plain text file to spreadsheet and databases.

Information network

Establishment of central or crop databases is major activity of national, regional or international networks, crop networks and cooperative programmes related to conservation and use of PGR and is considered as a mechanism to promote cooperation within and among countries (Zhang 1998). The information network usually involves data exchange and sharing among member countries. According to the size and scale of the network activities, three kinds of information networks can be developed: crop-based information network, subject-based information network and region-based information network.

IPGRI-APO is promoting various information networks in the region. PGR conservation networks in the region include EA-PGR, SANPGR, RECSEA-PGR and Pacific (the last one is yet to be developed). For crop network, it includes buckwheat, safflower, sesame, taro and ***Lathyrus***.

InfoBase

InfoBase is being developed to integrate different kinds of PGR information from national programmes in APO. InfoBase aims to assist in strengthening PGR programmes through networking and information dissemination. It will provide links to various sources of information on PGR in different national programmes in Asia as well as in other countries in the world. It will be placed on IPGRI server and make it accessible through Internet.

Develop methodologies for information management and use

The methodologies for genebank documentation are needed by most of the national programmes. Some strong national programmes have developed their own documentation systems with computers. However, most of national programmes are facing problems due to 1) lack of sufficient resources and 2) lack of knowledge in developing efficient systems for genebanks. IPGRI has paid much attention to this area and developed some systems in cooperation with national programmes.

Genebank Management System (GMS)

IPGRI developed a PGR documentation system called Genebank Management System (GMS). It aims to help the curators of national genebanks to manage their PGR data and conservation processes. Since its development in 1992, it is well accepted by many national programmes and extensively used for training purposes in different national programmes. Now several improvements have been made and the version 1.2 has been released. In APO region, several countries, e.g. Mongolia, Nepal, Bhutan, etc. have chosen GMS as a national PGR documentation system. To promote the use of GMS, IPGRI-APO has organised several national and regional training courses.

There are two parts in GMS: descriptor definition and data management. Before one can add any data to the system, one must define first the descriptor list. In descriptor definition part, descriptor list can be defined for each crop. The data management has two models: document (passport, regeneration and characterisation) and management (inventory, accession and movement). Two models are controlled by accession registration. If a registration record is added in management mode, it does not need to be added in document mode. This design is logical for most genebank operations and ensures that there is at least one record type present for each accession.

Genebank monitor

Usually, genebank curators rely on their experiences for genebank management including accession regeneration work. Because of the large number of samples and the transfer of staff in the genebanks, the experiences gained by genebank curators would be lost or may not be transferred to new staff properly. Thus there is a need for a system to hold the experiences and provide the information for decision making for new staff members. IPGRI, in cooperation with the national programme in China, is developing the Regeneration Expert System (RES), which will build the knowledge base on the seed viability of different crops in the system and predict the seed longevity according to the viability monitoring data. The System will help genebank curators to identify and determine the accessions to be regenerated and resources needed for regenerating germplasm conserved in the genebanks.

Statistical analysis

Data analysis provides basic information for the diversity scope, distribution, improvement and use of PGR. As PGR data are characterised by a large number of variables and entities, which contain considerable variation caused by uncontrolled conditions, the analysis of these data becomes so complicated and difficult due to lack of the suitable means to interpret the results. IPGRI is now investigating the possible software available for genetic diversity analysis. Also, there is a need to identify different approaches such as GIS, graphic programmes for better presenting results and to make people better understand the characteristics of germplasm collections.

Human resources development

Training on documentation and information management is one of the priority activities in APO region, which aims to build / strengthen national programme capacity in documentation activities and promoting the use of available software. IPGRI-APO has provided two kinds of training opportunities, i.e. regional courses and in-country courses. The regional courses focus on developing methodologies and addressing some common issues interesting to all countries in the region while national training provides practical-orientated lectures on basic technologies for information management and computer facilities. GMS is usually used as a training tool to make participants fully understand the information generation and management procedures at the genebank.

IK documentation

Documenting indigenous knowledge (IK) is essential for ***in situ*** conservation. The IK is the result of long-term interaction between human activities for selection, conservation and use of various plant species for food, medicine and other purposes. It is closely associated with the on-farm management of PGR by farmers and related to the environment that the people live in. It is a living knowledge that will change over time as crops adopt to their changing environment (Quek and Zhang 1998). The close interactions between plant, the environment and the farmers generate the basic sources of IK in the community in terms of PGR conservation.

The introduction of modern methods and crop varieties which result in the erosion of genetic material will also cause the lost of the IK that is used with the traditional crop varieties. The documentation of IK is important to ensure that the younger generations can learn and build on the knowledge made available to them by the older generation (Dai ***et al.*** 1998).

For documenting IK, a concept of "IK Journal" was tested on the Journal of Yunnan Agricultural Science and Technology by Yunnan Academy of Agricultural Sciences (YAAS) in cooperation with Yunnan Farmers' Speciality Technical Association (YFSTA). In 1998, four issues were published. All sources of articles were the farmers who provided the information through story telling and recorded on audio tapes. When such information was published in a journal, the farmer was the main author (first author) and scientists helped in further refining the article and help to conserve the original audio tapes. The IK journal has been translated into English and the concept will be used in other regions. Any scientist accessing to these articles or tapes can cite the source in their publication, thus giving full credit for the IK to the farmer or farmers. The original audio tapes will be kept in the community's library and can be easily accessed. This way, the holders of the knowledge are empowered and their contributions are well recognised.

Conclusion

Information management is critical to the successful implementation of national strategy for conservation and utilization of PGR in a country. Capacity Building for developing national documentation system needs to be strengthened with application of available documentation technologies. The national documentation systems could be linked together through commonly accepted protocols, such as DIP developed by IPGRI-APO, so the information can easily exchanged for mutual benefit. The information networks should be developed to backup the operation of various cooperative activities such as crop network, regional network, etc. The information section / division of a genebank should also play a role in disseminating information for public awareness and provide useful information for policy makers in decision making. The public awareness also should be focused on school children and general citizens, particularly farmers who directly involved in managing plant diversity in natural conditions. Farmers' knowledge in managing plant diversity is equally important as scientific knowledge and will play important role in sustainable development of agriculture in a country.

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Chinese crop germplasm resources information system

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Introduction

The germplasm collecting began in 1950s in China. From 1979 to 1995, large-scale expeditions were made in Yunnan, Guangdong, Guangxi, Jiangxi, Hubei, Hainan, Xizang and Guizhou, collecting a number of germplasm samples which were on the brink of extinction, including landraces, rare species, wild species and weed species. A total of 350 000 accessions have been collected and conserved so far. These are the basis for multiplication, entering into storage, characterization, evaluation and setting up germplasm resources database that had once been dispersed in various provinces.

From 1986 to 1999, 310 000 accessions of germplasm have been entered into the National Crop Gene Bank (NCGB). At the same time, 350 000 accessions of 180 crops were identified for agronomic and morphological characters, in which 200 000 accessions were evaluated for different traits such as quality, stress tolerance, disease and pest resistances. All the data of evaluation were provided to the Chinese Crop Germplasm Resources Information System (CGRIS).

Data acquisition of crop germplasm resources

The experts on crops determined all the evaluation items of germplasm. The data acquisition of crop germplasm resources was made on the basis of uniform evaluation techniques and methods. A network of data acquisition for crop germplasm resources, consisting of 2600 scientists and technical personnel from over 400 agricultural institutions all over the country has been set up.

Data on agronomic and morphological characters

The agronomic and morphological characterization data are the observational results of 2 to 3 years in original or adapted ecological regions. A total of 6 200 000 data items were recorded by professional staff of the research institutes or laboratories for germplasm resources of agricultural academies in various provinces.

Quality analysis data

The items of quality analysis are mainly the basic nutritional composition of various crops, for example, protein content, crude fat content, starch content and lysine content of rice, wheat, corn, sorghum, millet, soybean, grain legumes etc. Eighteen kinds of amino acids were also analyzed for some accessions. Besides, there are 72 items for some specific crops, for instance, gelatinization temperature and gel consistency for rice, hardiness and sedimentation index for wheat, melt extract and saccharifying capacity for barley. About 750 000 data items were provided by the centres that carried physiological and biochemical tests on different crop germplasm in various provinces. To ensure that the evaluation data were uniform and comparable, standard methods were adopted in quality analysis.

Data for stress tolerance

Stress tolerance, including tolerance to cold, drought, water logging, acidity, salinity / alkalinity, flooding, poor soil and lodging, were identified by researchers in various provinces. These total 227 000 data items, including 30 000 items of resistance to cold in wheat, corn and sorghum and 90 000 items of resistance to salt and poor soil on soybean, sorghum, barley and grain legumes. The methods used for identifying of stress resistance are different for various crops.

Data for resistance to pests and diseases

Pests and diseases, including blast, white-backed planthopper, brown planthopper and bacterial leaf blight of rice, yellow rust, leaf rust, stem rust, powdery mildew, scab, yellow dwarf virus and root rot of wheat, northern leaf blight, southern leaf blight and mosaic of corn etc., were appraised with different inoculating methods. At present, there are 45 kinds of pests and diseases with 1 040 000 data items identified by the researchers of plant protection.

Data standardization of crop germplasm resources

Before setting up the database, we attempted to standardize of crop germplasm resources information processing in China, on the basis of research for recording as per the standards laid down by experts on crops. In order to do a comprehensive job, of analyzing hundred and thousands of evaluation data, we consulted the crop descriptor lists developed up by International Plant Genetic Resources Institute (IBPGR/IPGRI). This standard stipulates field name of descriptor, descriptor states and file formats of various crops (Zhang 1990a).

Crop germplasm resources information system

Database of crop germplasm resources

CGRIS is a central repository for all kinds of PGR information. It mainly consists of six databases:

1. The management database of the National Crop Gene Bank (NCGB).
2. The management database of the National Duplicate Gene Bank in Qinghai.
3. The management database of National Germplasm Resources Nursery.
4. Crop characterization and evaluation database.
5. The database for germplasm exchange at home and abroad.
6. The management database of the medium-term storage in Beijing.

At present, there are over 2000 megabytes data on 180 kinds of crops (including food crops, fibre plants, oil crops, vegetable, fruit tree, tea, mulberry, tobacco, sugar, pasture and green manure crops, tropical crops etc.) on 350 000 accessions of germplasm stored in CGRIS (Zhang and Cao 1991).

Management database of NCGB

This database mainly stores the information of passport (accession number, variety name, origin, seed source, number in original preservation unit), seed multiplication unit, harvest date, storage date, condition of vigour, the weight of seeds and location number of the sample in NCGB. At present, it has stored 310 000 records (one record has 15 fields) on 141 crops (not including fruits and tropical crops).

Management database of the national duplicate gene bank in Qinghai

This database is mainly for the management of the long-term storage facility in Qinghai Province. The data includes accession number, condition of vigour, the weight of seeds and location number of the sample etc. At present, 310 000 records on 131 crops have been stored in the database.

Management database of national germplasm resources nurseries

At present, there are 32 nurseries of germplasm resources (field genebanks) (including 17 nurseries of fruit germplasm resources, 2 wild rice, 1 tea, 1 mulberry, 1 sugarcane, 1 wild cotton, 1 water vegetable, 1 ramie, 1 peanut, 1 tropical crops, 1 wheat, 1 forage, 1 potato and 2 sweet potato). Aquatic vegetables include water chestnut, lotus, water dropwort, water rice and water spinach etc. The data on 19 978 accessions of germplasm have been stored in the database.

Characterization and evaluation database
This database mainly stores the characterization and evaluation information on agronomic characters, quality, stress tolerance, disease and pest resistance etc. The record in this database corresponds to an accession in NCGB or to germplasm resources nursery of fruits, tea, mulberry, hemp and tropical crops etc. It means each accession stored in the genebank has a valuable datum. Now 350 000 records (the average fields for one record is 45) on 180 crops have been stored in this database.

Database for germplasm exchange at home and abroad
This database was set up on the basis of the germplasm exchange at home and abroad during 1980-1998. At the same time, we have stored the catalogues of the first, the second and the third categories of germplasm, namely, not permitted, not permitted at present and exchange permitted with foreign countries, in computer. The database has 120 000 records.

Management database of the medium-term storage in Beijing
The database has 124 280 records on 52 crops (including rice, wheat, soybean, wild rice, wild soybean and wild relatives of barley etc.). At present, there are 9617 accessions of germplasm and average weight of sample is more than 250 g.

Database management system

CGRIS for PC
The CGRIS for PC can run on compatible IBM PC. The programming languages are Visual Foxpro and Visual C. Chinese-character menus drive the system. The CGRIS for PC has the function of graphical analysis and pedigree tracing. In addition, input, maintenance, retrieval, generating reports, printing, classification, and linking data with statistical analysis software can also be the functions.

CGRIS for Internet
The CGRIS for Internet was developed under Microsoft Windows NT 4.0 and SQL 6.5 in a Server/Browser mode. The URL is http://icgr.caas.net.cn/. The homepage of CGRIS linked with crop germplasm resources database using Active Server Page (ASP). The CGRIS for Internet has the function of metadata query, data query, FTP, classification, basic statistical analysis, random graphical display and map browsing etc. User can access the database of crop germplasm resources by Internet.

Application software on crop germplasm resources

Electronic map system of crop germplasm resources in China
Using development software of Microstation set up the electronic map system of crop germplasm resources in China. At present, 272 maps of germplasm resources of 84 crops have been drawn. When drawing a map, firstly the data stored in CGRIS are classified according to origin and longitude and latitude of the origin places is examined and then the sum of accessions of crop germplasm resources in each 1 latitude x 1 longitude grid is calculated. Finally, we project the degree of longitude and latitude on the coordinates of map using the Albers conic equal-area projection. The complete distribution of crop germplasm resources is shown by geographical distribution and density distribution (Cao 1995). The maps on characterization of crop germplasm resources are being drawn.

Crop chromosome and isozyme bands image analysis system

On the basis of pre-processing and segmentation of images, the parameters of chromosome and isozyme bands can be obtained by recognizing and then matching of chromosome and isozyme bands. The parameters include length, relative length, arm percentage and body of chromosome and migration ratio and type of isozyme band. The system can automatically get these parameters from chromosome and isozyme photographs and draw the karyogram and ideogram (Chen and Cao 1997, Zhang 1990b). The “fingerprint” recognizing system is being developed.

Statistical analysis software for germplasm resources

A statistical software package for crop research has been developed in China (Zhang 1990b). The package can be run on compatible IBM PC. The programming languages are Basic and C. This package includes 88 programmes and covers the most commonly used statistical procedures for data analysis in agricultural research. These include variance analysis, covariance analysis, regression and correlation analysis, chi-square test, principal components analysis and cluster analysis etc.

This software can be used to analyze different kinds of information in the database by agricultural scientists and technicians in order to study the relationships and associations of various characters of a certain crop. For example, 1) cluster analysis to differentiate germplasm within one subspecies. 2) Use biodiversity index to decide the geographical type of biodiversity, etc.

Pedigree tracing system of crop germplasm

This system can help breeder find the characters of parents of improved varieties and matching rate of each parent in various improved varieties , analyze pedigree structure, draw family tree, etc. This provides an important means for choosing the parents correctly and rationally.

Information service of crop germplasm resources

The CGRIS was established in 1988 and there are 42 service stations have been set up in 25 provinces. The WEB server has been set up in ICGR. CGRIS can rapidly provide needed information to genebank managers, breeders and biotechnologists. During 1988 - 1999 , about 24 millions data items have been provided to agricultural scientists all over the country. The information on germplasm also can be provided by publishing germplasm catalogues, floppy diskettes, CD-ROM, File Transfer Protocol (FTP), E-mail and letters etc.

Serving for management of NCGB

CGRIS can compile information and generate reports in Chinese and English about storage conditions for various crops every year, as well as reports about the quality of a storage for a certain crop a particular multiplication unit, etc.

Serving for the germplasm exchange at home and abroad

CGRIS can help the administrators to be kept informed about various introductions and germplasm exchange and other developments that are taking place in the area of PGR conservation and use. This would avoid introducing materials blindly, and also repeated introduction or provision of germplasm to foreign countries. It can also provide useful genetic information with definite aims for breeding and biotechnology, for searching for suitable parents with good characters according to the breeding goals and for tracing varietal pedigree which could effectively avoid repeated matching and raise breeding efficiency.

Prospects

1. Establishing the management databases of the medium-term storage in every province and institutes of CAAS and record all exchanges of seed.
2. Setting up the Chinese Crop Germplasm Resources Information Network. The network should link long-term storage, medium-term storage, introduction stations, germplasm resources nurseries, protection centres of crop diversity, agricultural institutes of CAAS and provinces etc. User could access the information and order the seeds by Internet.
3. Developing a germplasm monitoring information and early warning system in the National Genebank / Nursery of China.
4. Setting up the fingerprint database of main crop germplasm resources in China.
5. Exchange data with the database in other countries. CGRIS should be able to provide information both in Chinese and English, and also should be able to accept standardized information on germplasm.

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Collecting crop germplasm resources in China

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Under the leadership of the Ministry of Agriculture and different government levels, a movement of collecting crop genetic resources in the whole county began since the early 1950s. The Ministry of Agriculture delivered notice concerning collecting the original varieties of main crops from the whole country twice. The notice required that the different crops were to be collected comprehensively and fully and organized at the county level. Total of 200 000 accessions of 53 field crops and 17 000 accessions of 88 vegetables (including some duplications) were collected in 4 years. During the "Cultural Revolution', the collecting work was stopped, and there was also some loss of conserved resources. In order to further rescue genetic resources, three collecting patterns, i.e., supplementary collecting, exploring main crops and main regions, was adopted since 1978. A total of 110 000 accessions were collected in the supplementary collecting during 1979-1984, and the explorations for the wild rice, wild soybean, maize and vegetables were carried out at the same period, which resulted in collecting of 15 000 new accessions. These included 9000 accessions of wild soybean (specimens and seeds, including seed of 5000 accessions) from 1020 counties of the 29 of provinces, cities and autonomous regions.. This work also resulted in the extension of the limits of distribution of wild soybean to an altitude of 2620 meters. The distribution of wild rice was investigated in 139 counties of 7 provinces (regions), i.e., Guangdong, Guangxi, Hainan, Yunnan, Jiangxi, Sichuan and Fujian, and wild rice was found to be distributed in all these provinces. Meanwhile, the about 38 accessions of wild rice (seeds or plants) were collected. Additionally, the distribution and habitat of three kinds of wild rices, ***Oryza rufipogon***, ***O. meyeriana*** and ***Oryza Officinals*** were investigated thoroughly.

Investigation and collection of genetic resources in main regions

From 1981 to present, the exploration and collecting of genetic resources as a State Key Project have been carried out in Tibet, Shennong mountain, Hainan Island, Daba Hill, the mountainous areas of the southwest of Sichuan, south of Guizhou and west of Guangxi, the reservoir regions of the Three Gorges, and the mountainous areas of the south of Guangxi and north of Guangdong. During 1981-1984, the crop variety resources of Tibet were explored and more than 30 different crop specimens and seeds and 14 787 herbarium specimens and seed samples were collected for more than 30 crops. This included 7700 seed samples.. Wild soybean, wild millet, grain goosefoot and wild Job's tears were discovered for the first time in Tibet. Among the collected semi-wild barley, there were 169 new varieties. A total of 143 varieties of wheat were collected in Tibet, of which 24 were semi-wild. In addition, rich genetic resources in fruits, vegetables, Job's tears, mulberries, fibre crops etc., were collected. During 1986-1990, crop germplasm resources of Shennong Mountain and Hainan Island were explored and 14 448 accessions were collected. A total of 9526 accessions were collected in Shennong Mountain and 4922 in Hainan Island. During 1991-1995, investigations in four provinces, Sichuan, Shaanxi, Guizhou and Guangxi were conducted and 14 689 accessions of different crops and their wild relatives were collected, of which 6613 were cereals, 1062 oil crops, 1765 fruits, 1189 industrial crops, and 380 green manure crops, fodder crops, nectar sources and others.

During the Ninth-Five-Year Plan, the field investigation work in the reservoir regions of the Three Gorges, the sections along the Beijing-Kowloon Railway, and the regions of the south of Jiangxi and north of Guangdong were carried out. A total of 8082 accessions of cereal crops, oil crops, cotton crops, fibre crops, tea, tobacco and their wild relatives were collected from these regions. Moreover, the batch of precious and rare germplasm resources were also discovered, including rice, maize, rape, vegetables, fibre crops, fruits and other local varieties that had disease resistance, cold resistance, strong adaptability and good quality. Six sites with wild rice were discovered recently. Among the collected ramie resources, three accessions, i.e., wedge-end ramie, cauline-flower ramie and spicate ramie are the newly recorded species in Chongqing Municipality, of which the wedge-end ramie was discovered for the first time which has research and utilization values. A lot of precious and excellent resources are being identified in material that has been recently collected and planted in experimental fields.

By the end of 1998, genetic resources of different crops (plants) numbering 70 000 accessions in all were collected in China. Thus, collecting genetic resources in main crops were basically completed in the investigated region. Meanwhile, their extent of distribution, ecological environment and botanical characters of genetic resources collected were also determined. Additionally, some new and wild communities, species, subspecies and mutations (types) were discovered, which not only enriched the genebank of crop genetic resources, but also provided materials for breeding, biological engineering, taxonomy and origin and other researches.

Future tasks in collecting crop genetic resources

There are rich and interesting genetic resources in the mountainous areas in the central and southwest China, the lowlands adjacent to it, and the temperate zones and subtropical regions in the east and south parts of China. These regions included Yunnan-Guizhou Plateau, southern and southwest Qinghai-Tibet Plateau and along eastern part of Qinghai-Tibet Plateau, Qinling Mountains, Nanling Mountains and Wuling Hill, Dabie Mountains and southern An'hui, Fujian, Zhejiang and Jiangxi's hills, Changbai Mountain, Taihang Mountain, Funiu Mountain, etc. The above-mentioned mountainous areas are rich in crop germplasm because they did not undergo the changes during the Quaternary Period, and by having complex topography and hydrothermal conditions suited for the multiplication and evolution of many types of plants. Moreover, the local varieties have not been replaced with improved varieties completely and thus genetic erosion has been at low level. Therefore, these mountainous areas may still harbour primitive landraces and wild relatives of many different crops and other genetic resources that evolved in China. In addition, these areas could also be a major centre of secondary diversity of crops that were introduced into China long time ago.

Since the establishment of new China, the exploration and collecting work began to pay attention to the staple crops, but much less attention was paid to minor crops. The efforts were also focused on the developed regions of agriculture, but the marginal mountainous areas that were difficult to travel to, were generally ignored. In addition, the minor crops and wild types were not collected in time. Therefore, though large scale collecting work was completed, the genetic resources that have been produced originally in China and Chinese special genetic resources were not covered fully and these should be rescued.

So, special attention should be paid to:

1. The wild species and wild relatives of crops should be explored and collected, especially rice, soybean, Italian millet, buckwheat, different fruits and vegetables, which originated from China. Attention should also be paid to crops that were introduced into China long time ago and for which China is the secondary centre of diversity (including wheat, maize, barley, rape, green gram, Chinese sorghum, oriental sesame and others).
2. Special crops should be investigated and collected, including aquatic crops, root and

tuber crops and the special germplasm that possess resistance to adverse environments, resistance to pests and diseases, early maturity, dwarf stem, high quality and other characters.

3. The new crops and new types, that have potential value for development and utilization, should be investigated and collected actively, including grain amaranth, ragi millet, asparagus pea, chickpea, guar, edible canna and others.

Based on the on the above criteria of crops, the following three main regions were investigated recently and it was concluded that:

1. In the Three Gorges areas, supplemental collecting should be carried out in 30 counties. A medium term storage facility is needed for this area.
2. Supplemental collecting should be carried out in 20 counties in Qinling Mountains and Southern part of Yunnan. The emphasis should be on cereals, oil crops, vegetables, fruits and other valuable industrial crops, as well as wild relatives.
3. Collecting should be done in Changbai Mountain regions. The Changbai Mountain is the highest mountain in Northeast China, where there are vast and lush forests. Due to the diverse climates, clear ecological gradation, complex topography, Changbai Mountain are is rich in plant genetic resources. Although some measures were taken for the protection of Changbai Mountain ecosystem, and some exploration and germplasm collecting was carried out, most of the work was still needs to be done. In recent years, the forest has been destroyed by people to plant ginseng, and mining industry, agriculture, tourist industry and others; the natural ecological environment in Changbai Mountain region has been damaged significantly and the process of destruction still goes on. Moreover, the Changbai Mountain is active volcano. If the volcano erupted, it would cause extinction of plant resources. Therefore, it is very urgent to explore this region systematically and thoroughly. The Changbai Mountain and its rest mountain ranges, which include Jilin province’s Yanbianzhou, Tonghua city, Huanjiang city, and the partial counties of Jilin and Liaoyuan cities, Mudanjiang city of Heilongjiang province, Benxi and Dandong cities of Liaoning province etc. need thorough exploration. Cereal crops, oil crops, vegetables, fruits, fibre crops, fodder crops, flowers, Chinese medicinal herbs, etc., should be collected from the above regions. In addition, it is necessary to build a nursery for conservation of some special plant genetic resources that can not stored in seed genebank.

In order to ensure that the exploration and rescue collecting of plant genetic resources would be carried out steadily, three suggestions are given below:

1. Strengthening and improving management system and collecting activities should be integrated, coordinated and organized by the state. It is also necessary to strengthen linkage between collecting and evaluation as well as utilization.
2. Strengthening human resources to establish a stable team for collecting activities.
3. Establishing ecological experimental station for characterization, evaluation and use of collected materials. Collecting some special germplasm should be linked with poverty alleviation in poor areas so that the collected materials could be used locally.

Collecting, storage, studies and utilization of special genetic materials

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Special genetic resources (genetic stocks) include polyploids, aneuploids (monosomics, nullisomics, trisomics, tetrasomics, telosomics), substitution lines, translocation lines, addition lines, sterile lines and nuclear-cytoplasmic substitution lines.

Research progress

In China, special wheat genetic resources have been identified and catalogued. These are regenerated and stored in Chinese National Genebank since 1985. A total of 735 accessions have been catalogued and stored in National Genebank. Moreover, 901 accessions have been distributed to 104 researchers (Lin ***et al***. 2000).

Evaluation and utilization for special wheat genetic resources

Response of 400 materials to salt stress was studied during germination and seedling stage. Some lines showed high tolerance to salt stress, including wheat cultivars (***Triticum aestivum***) such as Hongmazha, Keyi 26, Hope; the hybrids between wheat and ***Secale cereal***: 98-46,98-113 (additional line No. 1), 98-131; the hybrids between wheat and ***Leymus*** (98-160, 98-161,98-163). The lines showed remarkable tolerance to salt stress are 98-160, 98-113. Through cytogenetic analysis, ***in situ*** hybridization and gliadin finger-printing analysis, it was proved that 98-113 and 98-131 were stable 1R addition line of triticale and 1B/1R translocation line of triticale (Ma ***et al***. 1985), respectively.

The genetic integrity for special wheat genetic resources during storage

Using artificial and natural ageing methods, the genetic integrity for special wheat genetic resources during storage was found to be different from that of normal wheat germplasm resources. The abnormal chromosome (fragment) rate for aged seeds of triticale translocation lines was high, up to 40.84% (Lu ***et al***. 1989).

Suggestions

1. The collection for special genetic resources should be expanded to other crops.
2. The special genetic resources should be safely stored in national genebank. Meanwhile the new storage methods such as cryopreservation and ***in vitro*** conservation should be developed for the special genetic materials that do not seem to store well in cold storage.
3. Only a few excellent germplasm resources have been found, so we should use the new scientific methods and promote multidisciplinary efforts to evaluate, identify and utilize new special genetic resources.

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RFLP map-based genetic diversity on twenty–one chromosomes of wheat

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Genetic diversity of fifteen wheat (***Triticum aestivum*** L. AABBDD, 2n=42) varieties and lines from 11 different countries was determined by 472 RFLP markers on twenty-one chromosomes. The results showed that:

1. Clusters based on genetic similarity (GS) estimates on each chromosome were different. Based on genetic diversity data at 472 loci on twenty-one chromosomes, four clusters were produced: “Synthetic”, “Hope” and “Timgaien” which carried "exotic" chromosome(s) or chromosomal fragment(s) clustered in different groups, the other twelve accessions without "exotic" chromosome/fragment clustered as one group. Genetic distance between different accessions related closely to the amount of introgressed "exotic" chromosomes carried by them.
2. Though the varieties originated from different countries, levels of polymorphism were very low. Overall levels of genetic similarity were around 0.8 and few polymorphic alleles were found at most loci in common wheat. About one half of the 472 loci were monomorphic.
3. High genetic diversity was observed in the accessions derived from tetraploid wheat (AABB) and ***Ae. squarrosa***. L. (DD). About 49% of the allelic variation was not found in cultivars tested in our current study, indicating that the wild species are an important resource for enriching the genetic diversity in modern wheat cultivars.
4. Introgressed chromosomes or chromosomal segments from wild relatives into cultivars could be detected from their specific allelic profiles. These segments could be identified precisely by the current RFLP maps.
5. Genetic diversity of B genome was the highest among A, B and D genomes, while it was lowest in D genome material, especially on chromosome 1D; genetic diversity of A genome was moderate.
6. Genetic differences between Chinese landrace “Chinese Spring” and foreign cultivars were found on chromosome 1B, 3B and 5B. Twelve variety-specific alleles were identified in “Chinese Spring”. Poor genetic diversity in modern cultivars is a bottleneck in wheat improvement.

The current status and tentative plans for conservation of crop germplasm resources in Liaoning

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The vast Liaoning Province is located in south Northeast of China, facing the Bohai Sea and the Yellow Sea with Changbaishan Mountains behind. It has an are of 1 475 000 km^2 of which 59.8% is upland, 33.4% plains and 6.8% making up the water area and others. There are rich germplasm resources in the province. There are about 20 000 accessions of germplasm of 20 different crops at the Liaoning genebank, equipped with modern medium-term conservation facilities for safety conservation. It has space for 50 000 accessions. Since 1998, 6669 accessions of germplasm for three kinds of minor crops (food grains other than wheat and rice and corn), minor edible legumes and minor oil plants etc., have been collected and conserved. A collection network has been established with the cooperation of the Liaoning Gene Bank. Tentative plans for next 5-10 years are: collecting of more than 20 000 accessions of germplasm resources of Liaoning province and setting up of the Liaoning Crop Germplasm Information System. In this paper, the current status and the tentative plans of crop germplasm resources in Liaoning province are briefly reviewed.

Strengthening the protection and the use of the crop germplasm resources in Guangxi, China

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Guangxi is one of the provinces that conserve the most amounts of crop germplasm resources. There are more than 50 000 crop strains or resources in Academy of Agriculture. There are 13 000 accessions of rice, making up 1/6 of all accessions in the country. A total of 4300 wild rice resources are conserved, which is about half of all accessions in the country. These resources make a large contribution to agriculture development of China.

The danger of genetic erosion is more serious in Guangxi than in most other places. We have investigated the wild resources in Nanning and Baise, which are near the Nanning-Kunming Railway. In recent years, we found that, compared with the results of investigation carried during 1979-1981, 70% of the sites where wild rice used to grow originally has been destroyed and the wild rice resources have been lost. Maliutang Guigang was one of the rich location for wild rice diversity in the world at that time, and in 1979 it covered 27.96 ha. But only after 16 years (1995), it has been destroyed completely. This is a serious loss and can not be ignored. Major reasons for genetic erosion are

1. Old strains are lost as they are replaced during the process of spread of new strains;
2. Environmental pollution damages ecology and results in crop germplasm resources being eroded;
3. Opening up virgin soil and over grazing makes the original environment to be destroyed, leading to genetic erosion;
4. Diseases, harmful insects, weeds, and mice destroy the crop resources.

In order to reduce genetic erosion in crop genetic resources, we must identify such resources that are seriously in danger of loss and protect the available resources using all possible ways. We need to develop comprehensive conservation strategies and promote research on plant genetic resources conservation and use.

We propose that measures should be taken for strengthening the protection and the use of the crop germplasm resources. We must raise the awareness and knowledge about the crop germplasm resources by government by producing documents, papers, and programmes on radio and television, and let people all over the country know the importance conservation and use of plant genetic resources in economic development of the country. Such efforts will improve awareness of public and policy makers on protection and use of the crop germplasm resources.

We must develop conservation strategies quickly; formulate the policy and laws, which will help in conservation and use of the crop germplasm resources more effectively.

Guangxi Academy of Agriculture has the largest collection of wild genetic resources of rice in our country. It also has the wild peanut nursery and the other storage facilities, which keep more than 50 000 accessions. So it should do well in the conserving work with support from the government. We should protect the natural vegetation to keep the ecological balance and try to obtain the most benefit by least cost.

The crop genetic resources are rich but use of them in breeding is rather limited. The main reason for this is lack of in depth research and evaluation of crop genetic resources to be able to meet the demands for germplasm for breeding programmes. There is a need for increased government support for characterization and evaluation, so that work on different subjects and disciplines in a coordinated manner could be undertaken. This should also include development of molecular biology and biotechnology in order to develop and enhance research capacity so as to improve the use the available genetic resources in plant breeding and crop improvement.

There is enormous genetic diversity in the country with respect to crop germplasm resources. It has great potential to strengthen the development and the use of improved crop cultivars. For example, developing an improved variety of pigeonpea through international collaboration is a good way to improve the ecological environment in Guangxi Karst area, by which 1500-2250 kg ha^{-1} of beans per year and 22500-26250 kg ha^{-1} of green feed could be produced. In addition, it helps to conserve water and soil and to restore and beautify the environment. Rational development and using the crop germplasm resources is the key to the continued agricultural development and environmental health.

It is essential that the international cooperation in the crop germplasm resources activities is strengthened. Through cooperation, we can promote friendship and understanding. We can better understand international research and development actions, promote our work and development and improve research capacity. Such cooperation and germplasm exchange not only can satisfy the needs of the research and development of our country but also can bring in the full play of research results in country’s development.

Studies on genetic stability of sweetpotato germplasm maintained in *in vitro* genebank

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In this paper, three marker systems, namely morphological characters, enzyme electrophoresis and leaf soluble protein fingerprinting were used to analyse genetic stability of sweetpotato germplasm maintained ***in vitro*** for 10 years at the National Genebank.

The results showed that most agronomic characters, POD, MDH and soluble protein banding pattern of sweet potato germplasm stored ***in vitro*** for 10 years were basically the same as the original varieties. The difference was only detected in EST and α-amylase isozyme zymograms in a few plants of some varieties. This means that long term ***in vitro*** storage affects the genetic stability of sweetpotato germplasm. Thus, it is considered that POD, MDH and soluble protein electrophoresis could not be used as markers for assessing genetic stability of sweet potato germplasm maintained ***in vitro***, but EST and a-amylase could be. It also underlines the importance of using more markers while studying the genetic stability of conserved material.

The results of the biochemical analysis of the plants in the field and stored ***in vitro*** showed that there were no genetic differences between them. The results also showed that differences can be detected, but isozyme zymograms could be different in two different growing conditions.

Information of vegetable resources

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Introduction

Vegetable research centre began gathering germplasm resources from 1970s and total number is more than 13 000 accessions belonging to more than 140 species, coming from more than 70 countries and from all provinces and cities of the country. There are four databases constitute the documentation system; conservation database, stock status database, a database with evaluation data and information on analysis of specific characteristics and a database on nutrition and quality traits. This is in accordance with the actual situation of our resources storage. All the four sections are linked by accession number as the keyword.

Information management system of vegetable resources

This system adopts SUN SPACE station 10 as hardware and UNIX as operation system which is essentially different from DOS. This system adopts INFORMIX-SQL, 4GL as database language. "SQL" is structure query language and is extensively used in large database systems and possess data safety ability. SQL consists of DDL (data definition language) and DML (data manipulation).

The passport database includes the most basic and important information on accessions necessary and it is very important for data query.

The management database has location data, seed data and entry of seed into genebank and distribution information, germination data, etc. This database provides information on seed storage, seed vigour and seed longevity etc., required for day to day management of the genebank. Botanical and biological properties of vegetable resources are the most important information for breeding work and helps in breeding and selecting improved varieties.

It is relatively complicated to set up the database for evaluation of vegetable specific properties. There are more than 140 species stored, classified according to biological properties and edible organs.

Setting up the database for nutrition and quality provides dependable basis for study and product development and developing high quality vegetables. It can help in developing a better diet structure and improve health condition for people.

Database for analysis and evaluation

Data on all evaluations for specific properties are comprehensively stored in this database. At present, evaluation and analysis germplasm resources for specific traits are carried out separately according to species. An important feature of this database is that data query function can be used select more than one trait at a time and synthesize the information from different evaluations.

The standards for resources evaluation are defined through consultation between resources office and different breeding offices. There are more than 200 varieties for which quality characteristics and all other properties are databased. This database facilitates in selection and breeding of vegetable crops and at the same time, it can assist making better use of resources stored.

Germplasm enhancement with biotechnology

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Breakthroughs by germplasm enhancement are now possible because of the developments in biotechnology and genetic engineering. Somaclonal variation in combination with radiation and chemically induced mutation and the molecular marker techniques for particular germplasm combined with conventional cross breeding methods are very important for inducing variation and developing novel germplasm. Meanwhile, various donor genes and DNA and a series of transformation techniques should be used in the process of developing germplasm. Moreover, the germplasm management system for conservation, exchange and utilization of novel genetic resources also should be established in order to accelerate the germplasm enhancement and development of biotechnology.

Field crops

Origin and evolution of biodiversity and the taxonomy of *Oryza sativa*

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Biodiversity

Biodiversity is referred include all kinds of organisms (plants, animals and microorganisms), their genes and ecosystems which they inhabit and evolve in. Biodiversity includes gene (genetic) diversity, species diversity and ecological diversity.

Origin and evolution of biodiversity

The present biodiversity has formed through a long evolutionary process for 4 billion years since the primary life originated on the Earth (Figure 1) (Zhang 1998). The Earth is a special celestial body in our Solar System; it is composed of the biosphere of different kinds of life forms, lithosphere, atmosphere and hydrosphere. Organisms such as blue algae, vascular plants and humans are the key factors during the formation and the long evolutionary process.

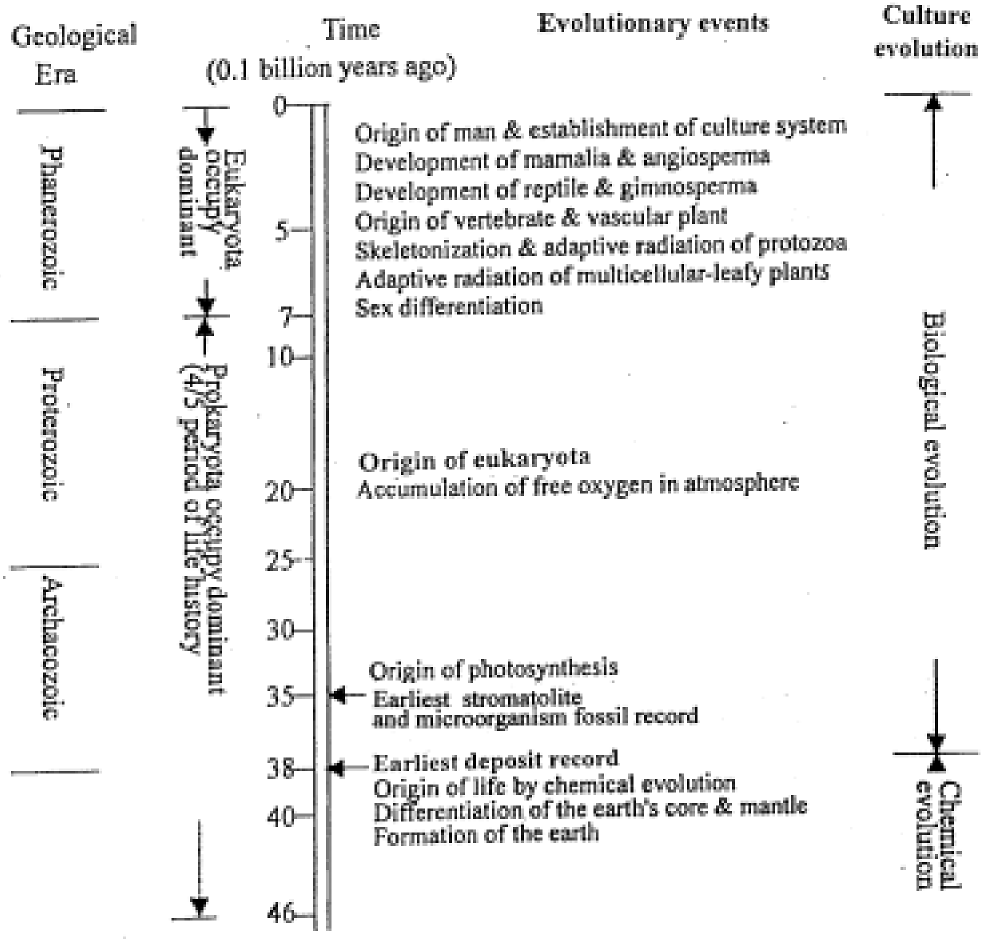

Fig. 1. Geological era and biological evolution (Zhang 1998)

Blue alga is also called blue green alga or blue alga. It was the first kind of cyanobacterial life form.

The vascular system of plants that transport of water and nutrients was the basis for the development of upland ecological systems of high productivity. Vascular plants became highly adapted to different kinds of upland environments and created every kind of environment for upland animals, which in turn determined their niches and provided the sources of energy.

Humans and human activities decide the development and fate of the biosphere on the Earth both in present and in future. For their own livelihood and development, humans have already domesticated plants, animals and microorganisms from wild species. These activities accelerated and enriched biodiversity and ecological diversity. Within last one hundred years, since the industrial revolution of human society, the environment of the Earth has changed dramatically. The nature of the biosphere has also been changing.

Enlargement of the ecosystems in the biosphere

Origin of life was the primary phase during the formation process of biosphere. The second phase was the enlargement of the earth's ecosystems and they enlarged four times during this phase.

Three billion and fifty million years ago, respectively, ecological system developed from the deep Ocean, bottom to the shallow Ocean bottom, photosynthetic prokaryotic organisms such as blue algae and other photosynthetic microorganisms appeared. The ecological system composed of photosynthetic microorganisms was established in the shallow Ocean bottom.

About 2 billion years ago, ecosystems developed from the shallow Ocean bottom to the lucid sphere of the Ocean and Ocean and loch (intertidal zone) The blue alga that could produce oxygen began to thrive and atmosphere was formed and expanded, at last ozonosphere was formed. As a result, the ultraviolet radiation decreased and gradually organisms appeared in the plankton system and the loch in the upper layer of the Sea. Eukaryotic organisms appeared.

The third stage of development of ecological system occurred about 60 to 70 million years ago. Increase in biodiversity and the complexity of the ecosystems were the main characteristics of this period. Because of the photosynthesis by blue algae and eukaryotic plankton, the oxygen production in atmosphere increased and C02 decreased. The temperature on the Earth decreased. Thus, glacial climate occurred, the sea level decreased, large area of shallow sea beach appeared. All these factors created several mini-environments. Moreover, the evolution of organisms themselves such as sex differentiation, multicellular, increased size and complexity of organisms made biodiversity to explode. Animals andplants (mainly algae) lived on the surface and single cellular organisms lived in many different environments.

The surface ecosystem developed from the Ocean to the Earth (0.4 billion years ago) and gradually the vascular plants could adapt to upland environments and created many different mini-environments that provided dwelling places and energy for animals. The evolution and diversity of animals increased; at last the main area on the Earth was covered by organisms and real biosphere formed.

Genetic diversity and taxonomy of *Oryza sativa*

The ancestral species of ***O. sativa is O. rufipogon*** Griff. It appeared about 60 to 70 million years ago at the beginning of Gramineae differentiation during Tertiary period. Through a long evolutionary process in Tertiary and Quaternary periods, it originated in China and India about 10 thousand years ago and then spread to countries in Asia and all over the world. During the long evolutionary process and under the high selection pressure by human and natural factors such as light, temperature and water, ***O. sativa*** systematically and genetically changed to what it is now. For example, its distribution extended from south to north in latitude, from east to west in longitude from lower to upper reaches in altitude and from spring to autumn and winter in seasons. Finally it divided into subspecies and huge diversity of varieties.

Our ancestors began to classify these variations in ***O. sativa*** into two groups of "Xian" and "Jing" equal to modern ***japonica*** and ***indica*** subspecies. Kato ***et al***. (1928) classified it into ***japonica and indica*** as subspecies using scientific methods. These two terms had been used for 70 years and then Tarao ***et al***. (1939), Ding (1941), Matsuo (1952), Oka (1958), Morinaga (1968), Chang (1976) and Cheng ***et al***. (1984) advanced new taxonomic systems and new terms equal to the subspecies.

Kato (1928) and Ding (1949) classified ***O. sativa*** into only two subspecies, ***indica*** and ***japonica***, because they only used materials from China and Japan. Obviously varieties in the two subspecies available in China and Japan were different. Thus their proposed taxonomic system could not include all the diversity available in ***O. sativa***. Tarao ***et al***. (1939), Matsuo (1952), Oka (1958), Chang (1976) and Cheng ***et al***. (1984) used materials including the so-called ***Javanica***, Nuda and Australian rice, which were not included in earlier studies. They found that ***Javanica***, Nuda and Aus rice were different from typical ***indica*** and ***japonica*** rice and there were many more types including some intermediates between the two. In addition, different scholars used different materials, methods and criteria for rice taxonomy; therefore there was some material that would not fit the original ***indica*** and ***japonica*** subspecies.

Based on all the taxonomic studies to date and a comprehensive analysis, Cheng ***et al***. (1984, 1988), Wang (1993) and Wang ***et al.*** (1998) classified the disputed ***javanica*** and Aus rice into two ecogroups under ***japonica*** and ***indica*** subspecies. This method basically solved the controversy about subspecies classification of ***O. sativa***. Wang ***et al***. (1998) added deep-water rice as an ecogroup under ***indica*** subspecies and classified the two subspecies into 7 ecogroups and then into following ecotypes forming one of more perfect taxonomic system for ***Oryza sativa*** in the present plant kingdom (Figure 2).

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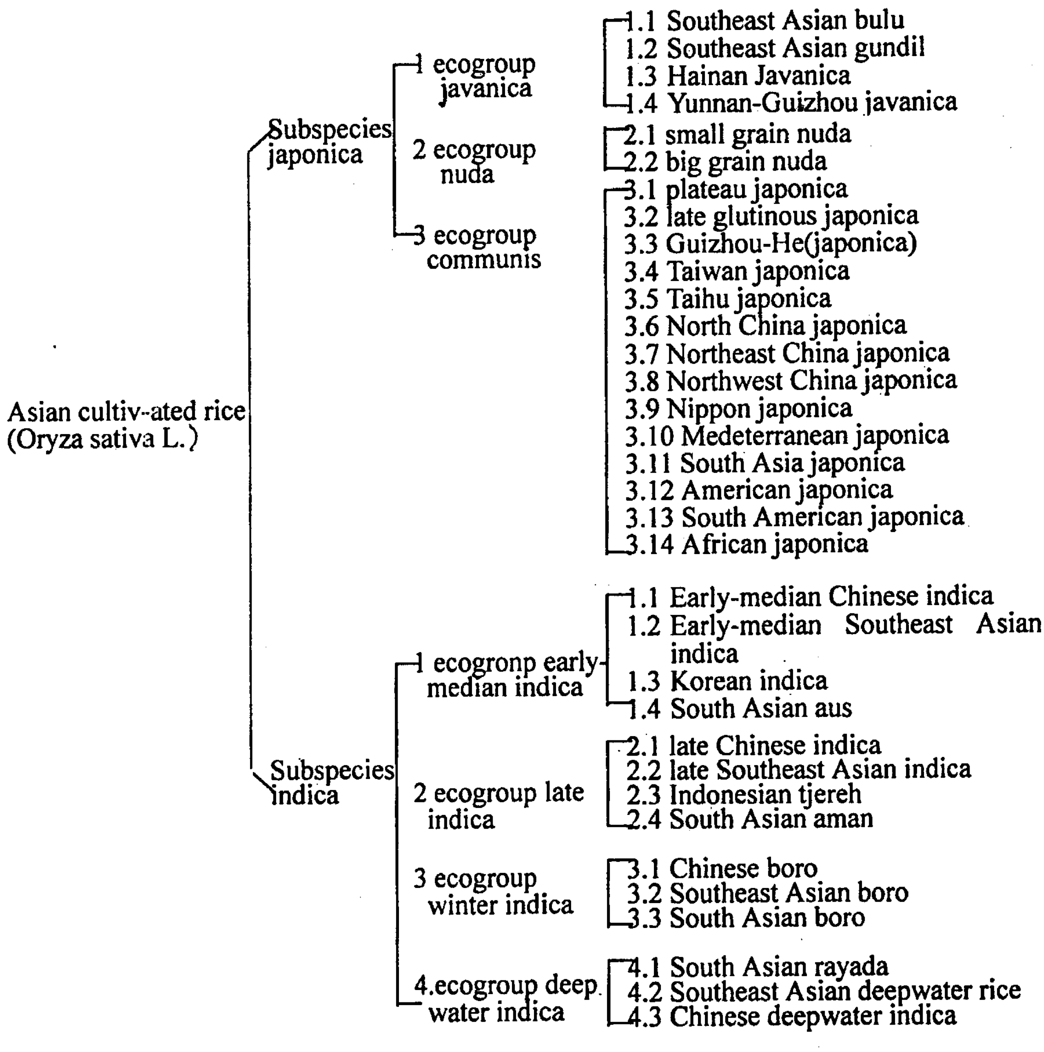

Fig. 2. Taxonomic system of subspecies, ecogroup and ecotype of Asian cultivated rice

Collecting, conservation, utilization and development strategies of rice genetic resources in China

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China is one of the centres of origin of rice. Rice has been cultivated in China for about 7000 years and is widely distributed in the country. Rice germplasm resources are not only very abundant in quantity but also in their types. Through exploration, collecting, evaluation and characterization, more than 60 000 accessions of rice have already been conserved in the National Genebank. These resources include ancient landraces, improved varieties, resources of 'Three-line' materials (sterile lines, sterility maintaining lines and restorers), foreign varieties, wild rice, mutants and testers etc. The utilization of rice germplasm in China began in 1920s. Studies have confirmed that all significant breakthroughs of rice breeding and production were dependent on the utilization of new germplasm. For instance, the discovery and use of dwarf genes and cytoplasmic sterility genes played important role in improving Chinese rice production. This paper provides some suggestions for research strategies on rice germplasm resources.

The general strategy is that our research on rice germplasm should consider the conserved resources and exploit new genes in developing improved varieties and combinations that have wide genetic background. The strategy includes: 1) development of rice core collection in order enhance access to superior germplasm for genetic studies and breeding; 2) evaluation of conserved rice germplasm to exploit beneficial new genes; 3) research on special genes of wild rice to be used through distant hybrdization; 4) selection of varieties or breeding parents to suit current breeding objectives.

The crisis status of wild rice resources in Yunnan province of China

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In order to investigate the status of wild rice resources in Yunnan Province of China, we carried out an exploration programme to collect wild rice resources in the western region of Yunnan Province in 1998.

The status of resources of *Oryza sativa* f. spontanea

According to the available records, the Laboratory of Rice Ecology in Chinese Academy of Agricultural Sciences (CAAS) carried out a exploration and collecting mission in Yunnan Province and discovered 24 locations for wild rice in Jinghong City in 1964-1965. However, when we investigated during 1979-82, only 3 locations with wild rice could be found. These three locations are: in the field around the Agricultural Institute of Xishuangbanna; ponds beside Gaxi Street in Jinghong Town and Ponds in Manjinghan village. According to the development plan of Gaxi Street, this area would be used to build a road in the future and thus this population will be lost.

In 1982, Yuanjiang County was also found to have distributions of ***O. sativa f.*** spontanea. The environment was thought to be special because wild rice distributed in four ponds on the top of a hill (650 m). Ponds were fed by rain in summer and there was no water in winter and were not linked by any canals and were about 400 to 1000 m apart. In 1998, several clumps of wild rice could be found only in one of the ponds. The other wild rice populations had been damaged by grazing, cutting and fishing. The villagers had already planned to widen and deepen the four ponds to maintain more rainwater to irrigate their fields. Thus, if there were no strategy for protection, wild rice in Yuanjiang County would disappear in a short time.

Resources of *Oryza officinalis*

In 1965, we discovered 5 locations in Jinghong City and Gengma County in Yunnan Province where ***O. officinalis*** was distributed. Between 1979 and 1982, we found another 7 locations in Gengma, Rongde, Jinghong and Puer counties. In 1998, we visited all the 12 locations and did not find ***O. officinalis*** in any of the locations and the habitat was changed significantly. For example, in 1980s ***O. officinalis*** was found distributed over 800 m along a hill in Zhedian village. In 1998, this hill had been developed to crop fields.

Resources of *Oryza meyeriana*

O. meyeriana was widely distributed in Yunnan Province according to the investigations in 1965 and 1981. Eighteen counties in seven prefectures were found to have ***O. meyeriana*** in 66 locations in Yunnan Province in 1981. In 1998, we visited the previously reported locations first and then tried to find new locations. The situation for ***O. meyeriana*** appeared to be much better than the two wild rice species mentioned above. The ecosystems where ***O. meyeriana*** occurred were maintained in good condition, but some populations were damaged. For instance, on a hill in Jinghong City, about 10 ha of ***O. meyeriana*** were found in 1981 and were growing very well. However, this area was planted with rubber in recent years and most of wild rice populations had been damaged.

During the 1998 exploration, five new locations for ***O. meyeriana*** were found. 1) In a bamboo forest in Galu village (Gengma County), about 1.5 ha at an altitude between 520 and 550 m. 2) More than 0.3 ha in a bamboo forest in Palian village (Gengma County) at an altitude of 750 to 800 m. Plants were found to be growing very well and density was high. 3)

About 0.8 ha on Dabao Mountain in Huohai district, on half of the mountain. 4) About 0.7 ha in shrubs along a ditch in Galu Mountain. From this exploration activity, we concluded that, though wild rice resources of ***O. meyeriana*** in Yunnan Province faced a crisis, the situation was optimistic and that they would not be damaged entirely in immediate future. However, it important to have conservation programme in place, so that they will not be damaged like the other two species.

Suggestions

There is a rich diversity of biological and ecological resources in Yunnan Province. Rice resources are also very abundant. More importantly, it has some special types of rice resources. In order to conserve rice resources including wild rice species, we suggest that:

1. Promoting public awareness of the importance of biodiversity: We have to make people to realize the importance of biodiversity and to increase awareness among them the consequences of its loss. We need to highlight the fact that the loss valuable genes that are lost can not be created and that this would adversely affect agricultural development of our country at present and in the future.
2. We should identify a few locations for each wild rice species and conserve them ***in situ***. The funds for maintaining them should allocated by the central government while agricultural scientists and local governments will contribute to the management of the conservation sites. The selected locations have to be separated from other buildings or farms. It should be made illegal to use the conservation sites for any other purpose.

Abundant genetic resources of rice and its wild relatives in China: significance, genetic erosion and management

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China has abundant in genetic resources of rice and its wild relatives, which are useful for genetic improvement of rice for the present and in the future. Unfortunately, the combination of new conditions, including rapid population growth, new agricultural technologies and swift economic and cultural changes, are changing the environment, and most of the wild populations have disappeared and others are nearing extinction. In addition, the widespread adoption of high-yielding rice varieties (HYVs) have led to biological poverty of rice germplasm, as local rice varieties are abandoned for modern varieties. These processes, collectively known as "genetic erosion". This paper reviews the genetic erosion in rice and its wild relatives in China and stresses the possible impact of these processes. Finally, the proposals for enhancing efforts to conserve rice genetic resources, including investigations on genetic erosion, studies on genetic diversity, identification of conservation priorities, conservation management and monitoring of ***in situ*** conservation localities, are given.

The study and utilization of good quality rice germplasm in Jilin

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Rice is the main grain crop in Jilin. With the development of new multi-pest resistant and high yielding varieties and the development of modern cultivating techniques, the rice production has increased very fast. By the end of 1998, rice planting area reached 750 000 ha and occupied 16.7% of the total area that is planted with grain crops. Total yield increased from 2 million tons in 1980s to 4.5 million tons in 1998. Rice plays a very important role in promoting economic development of rural Jilin. With increased living standards due country's development, the pattern of food consumption has changed; citizens need more good quality rice. So breeding for good quality of rice and other crops is in demand. Due to this change in consumption pattern and due to increased total rice grain production, there is a surplus of ordinary rice, which is difficult to sell. So it is important to improve the quality traits of current rice cultivars through breeding using genetic resources with desirable quality traits and developing production systems for quality rice.

Summary of good quality rice breeding in Jilin

The peasants and consumers urged for changing the situation with regard to qulaity of rice varieties. The research agency began its efforts on developing rice cultivars with better quality during late 1980s. Good quality germplasm was introduced and collected from within the country or abroad, such as Quitanxiaoding, Xiabe1, Satean, Quiguang, Tengxi 127, Zhengfu 10 etc. The quality of Tianxiaoding is very good and was widely planted in Jilin as a good quality rice variety, and was even exported back to Japan. Xiabe, Satean, Quiguang, Tengxi 127 were used as main parents in breeding programme. Since the strengthening of good quality rice research and study, rice quality breeding and production entered a new stage in Jilin.

Breeding of good quality rice variety

Since the shift in breed for developing good quality varieties in late 1980s, than 90% of total rice arean in Jilin is planted to improved quality rice cultivars. The quality of cultivated rice has improved to a great extent. Many varieties or lines were chosen as good quality rice varieties during the first rice quality evaluation meeting in 1995 and 1998, which greatly stimulated the good quality rice breeding and production in Jilin. The main good qualities of rice variety are:

Xuelfeng (JIK911):

Xuelfeng was bred in 1986 using Xiabei as female and Jigeng 60 as the male parent. It was licensed in 1998 and was evaluated as good quality rice variety in the same year. It was liked by many famous rice breeders in China and abroad. It can match with the most famous good quality rice variety for Japan, "Yueguang".

Jlgeng73 (JI96-16)

Jlgeng 73 was selected from F9 generation of (Leng11-2 / Satean) after radiation treatment with Co60. It was licensed by Jilin Agricultural Variety Committee and was evaluated as good quality rice in 1998. It is a late maturing variety and has beautiful milled rice appearance, good taste and high yield. It was welcomed by both peasants and consumers.

Jigeng66 (JI91-2605)

Jigeng 66 was bred by using JI 88-30 (Quiguang/Tengx127) as the female parent, and Jiyen 86-11 as the male, licensed in 1998 and was identified as good quality rice in the same year. It is high yielding and multi-pest resistant. Its milled rice is strongly competitive in the market.

Chaochan2

Chaochan2 is a new line developed through backcross breeding. Its appearance, taste and yield are all very good and has a good market in China. The price of milled rice of this line is double that of ordinary rice. It was evaluated as good quality rice line in 1995, but it does not have resistance to rice blast and fungicide must be applied in its large-scale production.

Use and development of good quality germplasm

Introducing and selecting good quality rice germplasm from abroad and from within the country is an important way for developing new good quality rice varieties. The four varieties mentioned above have been used as parents by some other breeders in their programmes on breeding for quality. It is very important to identify rice quality at early generation after crossing.

By breeding and using of good quality rice varieties, rice production has increased very fast in Jilin. They strengthen the competitive ability in the national market, Xue Feng was sent to an exhibition held in Japan in 1995. Jigeng 73, which is a high yielding and multiple pest-resistant variety, is widely planted by farmers, has been used as a parent by other breeders also. In order to match with the needs of grain market, we have strengthened research on quality rice breeding and studies on cultivating techniques for quality rice. Some advanced quality analysis equipment has also been acquired. All of these efforts are expected to improve further the work on good quality rice breeding in Jilin.

Study on the variation in quality character of M_2 generation of Chinese common wild rice

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In recent years, much progress has been made in the research on the origin and evolution of cultivated rice in China. The discovery of "Jiahu ancient rice" and "Peng-tou-shan ancient rice" with the longest history (more than 8000 years) in the world has confirmed that the common cultivated rice (***Oryza sativa*** L.) originated in the mid plains of Yangtze River and the upper reaches of Huai River (Wang 1996). Hisen-cline, Keng-cline and Wild-cline characteristics can be found in the ancient grain and rice samples. The same segregation of characters between Hsien (indica) rice and Keng (japonica) rice has also been found in common wild rice (***O. rufipogon***) (Chen 1994). On the other hand, DNA analysis and isozyme analysis (Wang 1996) indicated the existence of Hsien and Keng gene sites. All the above have provided direct scientific evidence for the origin of Hsien rice and Keng rices from ***O. rufipogon***.

We used irradiation (Cobalt 60 as the source) dry seeds of the common wild rice pure line to induce variation and study the evolutionary process. We studied the variation that was generated in quantitative characters in M_1, M_2 generations and in quality characters in M_1 generation. A study of 38 M_2 lines of Chinese common wild rice showed much higher random variation in quality characters in M_2 generation than those observed in M_1. Many characters were similar to that of the common cultivated rice, which provides an extensive selection base for using wild rice in rice breeding programme.

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The historical mission: from collecting and conservation to evaluation and enhancement of rice germplasm resources

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Rice is the main food for more than half world's population. It is also the one of the most important crops in China. It was predicted that the rice production should be increased from 559 million tons at present to about 758 million tons in 2020 to meet the needs of human beings. Furthermore, the improvement of rice grain quality has become more and more important. To achieve these objectives, generally increasing yield per unit area and enlarging cultivation area are considered. However, it is very difficult to enlarge any more rice growing area in China. The only effective way is to increase the yield per unit through scientific methods. Among different factors related to increasing yield per unit area, varietal improvement is the most important one and rice germplasm is the basis for such varietal improvement. The demand for elite rice germplasm is increasing to meet the needs of rice improvement. This paper briefly introduces the status on rice germplasm resources collecting and conservation. In the light of the main problems in rice breeding and production, topics such as screening for useful traits, germplasm enhancement and continued utilization are also discussed.

History and status of rice germplasm resources collecting and conservation.

Rice is grown widely in the world and in a number of production areas in Asia. The activities of collecting rice germplasm in a few of Asian countries began in the early 20^{th} century and most of the countries were growing rice by the end of the Second World War. The most of collected accessions were commercial varieties and traditional varieties. The special ecotypes in remote areas and related wild species were less well collected. The early collections were conserved with very simple facilities. In order to maintain seed viability, the accessions needed be planted frequently which resulted in mixtures and loss of accessions. Since 1970s, the rice germplasm collecting and conservation activities have been carried out more systematically in the world, which resulted in their safe and effective ***ex situ*** conservation.

Rice germplasm collecting

By 1996, according FAO statistics, rice germplasm conserved in genebanks totalled 430 000 accessions, stored in six national and international research institutes: International Rice Research Institute (IRRI, 19%), China (13%), India (12%), USA (8%), Japan (5%) and West Africa Rice Department Association (WARDA, 4%) (FAO 1996). A total of 7970 rice accessions were characterized and catalogued in China. Also, a total of 64 186 rice accessions and 8632 wild rice accessions were conserved in the national genebank and wild rice nursery, respectively.

Establishment of conservation systems

With the establishment of modem genebanks, represented by the International Rice Research Institute (IRRI) Gene Bank, were set up and are running well. In China, in addition to the national genebank, genebanks in a few provinces have also been established. A number of papers have been published regarding the conservation methodology, seed physiology and seed vigour. Much of the information on rice genetic resources is available on databases in IRRI, China, USA, Japan etc.

The status and problems of rice variety improvement

The world rice production has more than doubled in the past three decades. This increase has largely been due to the great achievements in genetic improvement of rice worldwide. Looking back at the history of the rice improvement, two breakthroughs that have significantly raised yield of rice resulted largely from identification and utilization of two naturally occurring genetic resources- sd-1 in 1960s and the wild abortive cytoplasmic male sterility in 1970s.

Though the yield levels of both inbred and hybrid rices are still far from the theoretical limit, they have apparently reached respective plateau in recent years. Breaking the yield ceiling and realizing the yield potential of rice in diverse environments is a major challenge and this could be achieved only through genetic improvement. It is clear that the current slow down in progress in breeding is not due to exhaustion of genetic variation available to rice breeders. There is sufficient evidence for the existence of rich genetic diversity for almost all traits within the primary gene pool of rice. For example, the major QTLs that increase yield by 17% higher than hybrid rice were found in low yielding wild species ***O. rufipogon***. Thus there is the need for enhanced use of available genetic diversity in modern breeding programmes.

However, we should not belittle the past work. In the past, numerous studies on rice germplasm resources were carried out using traditional methods, including characterization, grain quality analysis, evaluation for pest and disease resistance. The results of these researches not only provided many accessions to rice improvement programmes but also formed an important basis for further research. It has been very helpful to improve single traits such as resistance to a disease. However, selecting parents based only on the phenotype usually results in using same germplasm repeatedly, leading to genetic uniformity of the cultivars. The important characters such as yield and yield components are affected by quantitative genes and these are difficult to be identified in wild and landraces using traditional methods. BThus, all most all the conventional breeding programmes have used only very small portion of variation that exists in rice gene pool. To a large extent, the most important variation that can be used to increase yield, namely the exotic germplasm (i.e. traditional varieties, subspecies, and wild rices) was left unexploited.

The limited use of exotic germplasm in conventional breeding programmes is due to three reasons. Firstly, the frequency of “desirable” genes/QTLs or multi-locus alleles in exotic germplasm is low. Secondly, there always the negative effects of introgression, resulting in genetic drag due to tight linkage with undesirable genes, and/or due to negative pleiotropic/epistatic effects of these genes. Thirdly, the gene flow between the improved lines and unrelated germplasm is restricted by different degrees of hybrid sterility and hybrid breakdown.

Another reason for the sluggish advances in breeding is the fact that traditional breeding has largely been based on the experiences of plant breeders. However, information on genetics of traits generated during the process of breeding is very limited or none. This rises some new questions for germplasm researchers to answer: How to go a step further to screen and evaluate diverse germplasm? How to enhance and use the rice germplasm resources more effectively?

The new strategies on rice germplasm identification, enhancement and use

Advances in modem biotechnology, especially the DNA marker technology during the last 10 years, provides powerful tools to make more detailed research on rice germplasm resources and genetic improvement as well as genomics. The most successful use of this technology is the development of molecular genetic linkage maps in many organisms, which, in turn, provide the foundation and tools for gene/QTL mapping, marker assisted breeding, physical mapping, and map-based cloning of genes, etc. Another important application of molecular linkage map is to allow "molecular dissection" of complex traits through design, execution, and analysis of QTL mapping experiments.

Rice is the one of main food crop as well as the model crop for genomic research. In 1988, the first version of molecular linkage map was published by S. R. McCouch and others (McCouch ***et al***. 1988). In 1994, high-density rice molecular linkage maps were established in USA and Japan (Causse ***et al***. 1994). Some maps also have been constructed in China (Xu ***et al.*** 1993). Since then, DNA markers and molecular linkage maps have been used to map many important rice genes to their corresponding genomic locations. These include a number of genes for grain yield and yield components, grain quality characters and resistances to blast, brown plant hopper, bacterial blight, submergence, salinity, etc. DNA markers have also been successfully used in pyramiding of 4 bacterial blight resistance genes into an elite rice line in IRRI (Huang ***et al***. 1997). All these efforts would help to make better use of available genetic resources to increase rice yield with high degree of success and achieve the breakthrough in rice improvement using wild relatives and traditional varieties. It should be noted that some mature technology, used in rice germplasm enhancement successfully such as genetic engineering are expected to be more widely used in rice germplasm research in the future.

China National Rice Research Institute (CNRRI) has initiated a new programme named as "Rice molecular breeding program in China". This programme is based on a new strategy that will introduce different elite germplasm resources worldwide and make systematic efforts to combine the traditional and molecular methods. This strategy will consists of

1. To enforce massive gene flow through maximum introduction of diversity from the primary rice gene pool into elite genetic backgrounds.
2. To accurately trace and characterize the gene flow between elite rice germplasm with target character, under both genotypic and phenotypic selection.
3. To identify, map, and transfer large numbers of desirable QTLs for yield and stability, simultaneously.
4. To dissect various types of genetic drag associated with use of exotic germplasm using molecular techniques.
5. To generate large number of near isogenic lines for elite rice germplasm with target character.
6. To establish molecular and phenotypic database for above mentioned germplasm and finally.
7. To achieve breakthrough rice germplasm enhancement.

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Comments on utilization and development of crop resources in Yunnan province

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Yunnan government determined that bio-resources industry would be supported as a new major industry for the future in Yunnan province and corresponding policy has been developed. Comments on the question as how to use and tap crop resources in Yunnan province are given below.

Outline for using and tapping crop genetic resources in Yunnan province

Tapping special resources for industry

Now it is the time to adjust structure of agriculture industry and to pay increased attention to quality of products. The special resources, which can meet the current and future demands, should be identified and used. Besides the new and useful characteristics of available resources should be evaluated and identified. The high protein corn resources suitable for making forage, healthy drink soft rice resources and flame pear resources, which are particular to Yunnan, should be used for industrial development on a priority basis.

Cloning and using functional genes

Eighteen sequences related to important functional genes have been cloned from crop resources in Yunnan province, such as purple pigment of flower, agglutinin gene from ***Oryza rufipogon***, cold tolerant genes from pumpkin and rice. Identifying and cloning Xa-22 for resistance to bacterial blight is almost complete. Efforts should be made to identify and clone new genes from the available resources so that a rich genebank could be developed in the future. Studies on the cloned genes and modifying genes should be undertaken so that intellectual property rights (IPR) could be sought for them and genes with our own IPR could be industrialised.

Promote seed industry through full use of crop resources

Most crop genetic resources can be used as gene donating parents in breeding. Yunnan Academy of Agricultural Sciences (YAAS) has developed 88 varieties of food and cash crops, which contributed greatly to yield increases in different crops in the province. For example, improved varieties of oil crops were planted over 70% the total area in the province. For example, improved Japonica rice varieties “Hexi” were grown in more than half of area the area suitable for their production in the province. Use of modern technology for breeding other crops should be enhanced, and improvement should be brought about in resources-based on market-oriented strategies. The newly bred varieties can meet better the demand of market and this should be done as soon as possible.

Facilities for conservation and research of crop resources

Construction and improvement of facilities

About 24 000 different crop resources have been collected in the province and of 9740 have been stored in the national seed bank in Beijing. There is one low temperature genebank and three national nurseries/field genebanks for crop resources as well as other material in the province. The conditions for conservation should be improved in the future. Through participatory approaches, rare and endangered crop resources should preferentially be collected, conserved and managed in the future, particularly the forage and underutilized crop resources.

Use of new technologies for assessing crop resources

Evaluation for different agronomic characteristics of crop resources and documentation of information thus generated has been more or less completed. However, there is a need for carrying out more systematic and genetic evaluation of the resources in the future, particularly the evaluation for specific characteristics and molecular characterization. New technologies for assessing crop resources or key laboratory for crop resources should be established in Yunnan province.

Comparison of parameters for testing the rice core collection in phenotype

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This paper presents results of a study comparing different parameters for testing the genetic diversity and utility of core collection is discussed. The material studied consisted of 5026 Chinese rice landraces registered in national genebank. Information on 26 characters that had been databased was used for this study. The results showed that parameters Index of Diversity (I), Variance of Phenotypic Frequency (VPF), Variance of Phenotypic Value (VPV) and Coefficient of Variation (CV) were more effective in selecting accessions for core collection and testing the representation of genetic diversity. However, Ratio of Phenotype Retained (RPR) was found to be an indispensable parameter for testing the utility of core collection while the other three parameters Dave, Dmax and Dmin were more random, and only can be used as a reference.

Genetic diversity and genetic erosion of Triticeae species in China

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China is one of the major areas of distribution of Triticeae, including many unique species. Through collecting expeditions over the past 16 years, a number of sizeable collections have been established. This paper gives an overview of the major progress made in the assessment of Triticeae diversity in China.

Diversity of distribution areas and growth environments

Triticeae species are distributed throughout China, but mostly found in the northern part of the country. The diverse topographical features and climate of China influence the diversity of the Triticeae. There are lowlands, basins such as the Tuloufan Basin at 150 m below sea level in Xinjiang, plains, deserts, mountains and plateau such as 4000 m above sea level in Qinghai-Xizang. The climate is generally temperate monsoonal but due to the geographic location and the diverse topography, there are regions with unique local climatic conditions. The mean annual temperatures vary form -5.8°C to 26.4°C; average annual precipitation ranges from 3.9 mm to 3000 mm. There are about 40 soil types, mainly black, brown, yellow and red soils (Xi 1998). In addition to ***Triticum*** species, 161 species (including 11 introduced species) and varieties involving 10 genera were described in Flora of China (Guo 1987).

Collection status

A team of Chinese scientists conducted Triticeae expeditions throughout Xinjiang in 1982-1983. Additional expeditions in 12 provinces of northern China have been carried out since 1986 with support from the International Board for Plant Genetic Resources, IBPGR (now IPGRI), National Natural Science Foundation of China (NNSFC) and the National Five-Year Plan of China. So far, a total 2704 accessions belonging to 225 species have been collected (Table 1)

Table 1. Collection status of Triticeae in China

	No. of species			*No. of accessions*		
Genus	*Total*	*China*	*Introductions*	*Total*	*China*	*Introductions*
Aegilops	28	1	27	1 030	10	1 020
Secale	9	2	7	147	131	16
Eremopyrum	4	4	0	21	11	10
Hordeum	21	6	15	106	59	47
Agropyron	6	6	0	199	132	67
Roegneria	45	44	1	303	294	9
Elymus	60	11	42	467	360	107
Elytrigia	22	1	21	140	29	111
Leymus	22	13	9	229	187	42
Psathyrostachys	4	4	2	56	33	23
Dasypyrum	1		1	4		4
Austalopyrum	1		1	2		2
Total	225	92	126	2 704	1 246	1 458

During the expeditions, 4 species that were not recorded by Flora of China (Guo 1987) were collected. These are ***Leymus aleinolinensis, L. arenarius L. karelinii*** and L. ***salinus.*** The natural populations of ***Agropyron fragile***, which has been recorded as an introduction by Flora of China and hexaploid ***A. cristatum*** were found in Mulei County of Xinjiang in 1997. It was considered that hexaploid ***A. cristatum*** was only distributed in a narrow range in Iran bounded with Turkey (Dewey and Asay 1975). Discovery of a new hexaploid ***A. cristatum*** is a significant event because of the rarity of hexaploid taxa.

Evaluation for resistance to wheat diseases

A total of 737 accessions involving 102 species and 11 genera were screened for resistance to powdery mildew. The results are given in Table 2.

Table 2. Screening of Triticeae for resistance to powdery mildew

Genus	*No. species screened*	*No. accession screened*		
		Total	*Immune*	*%*
Aegilops	14	118	63	53.4
Secale	2	38	38	100.0
Eremopyrum	4	14	10	71.4
Hordeum	15	33	19	57.6
Agropyron	4	32	4	12.5
Roegneria	21	161	47	29.2
Elymus	20	233	50	21.4
Elytrigia	2	8	4	50.0
Leymus	7	83	14	16.7
Psathyrostachys	2	6	1	16.7
Thinopyrum	6	6	5	83.3
Pseudoroegneria	5	5	4	80.0
Total	102	737	259	35.1

Barley yellow dwarf virus (BYDV): To date, no accession, including all species of Triticum, has been found to be resistant to BYDV, and only a few have shown moderate tolerance to the disease. Resistance and immunity to BYDV were found to be widely distributed in Triticeae (Table 3) (Dong ***et al***. 1992; Xu ***et al***. 1994).

Table 3. Screening of Triticeae for resistance to barley yellow dwarf virus

Genus	*No. species screened*	*No. accession screened*		
		Total	*Immune*	*%*
Hordeum	3	24	11	45.8
Agropyron	5	33	5	15.2
Roegneria	15	100	13	13.0
Elymus	10	170	61	35.9
Elytrigia	2	6	3	50.0
Leymus	7	71	29	40.8
Psathyrostachys	2	5	1	20.0
Total	44	409	123	30.1

Genetic erosion

Genetic erosion in Triticeae appears to be very serious in China. Genetic erosion can be divided into three types, due natural conditions, due to genebank problems and artificial factors.

Genetic erosion under natural conditions: Triticeae species are wild and usually grow in mountain areas, natural grasslands, river valleys and desert. In most such areas climatic conditions such as temperature and precipitation have changed greatly over the years. It is possible that changes of climatic conditions would have affected diversity of Triticeae species, as seen from a comparison of the numbers of species collected and distributed (Table 4).

Table 4. Genetic erosion of Triticeae species in China

Genus	*No. of species*			*No. of accessions**	
	Recorded	*Collected*	*No. of not collected*	*Collected*	*No. of lost in genebank*
Aegilops	1	1		1 030	200
Secale	2	2		147	11
Eremopyrum	4	2	2	22	1
Hordeum	14	6	8	106	48
Agropyron	10	6	4	199	61
Roegneria	91	44	47	303	95
Elymus	12	11	1	467	207
Elytrigia	1	1	0	140	62
Leymus	9	13	0	229	75
Psathyrostachys	6	4	2	56	11
Hytrix	2	0	2	0	0
Dasypyrum				4	3
Austalopyrum				2	1
Total	152	90	64	2704	775

*The number of accessions includes introductions

Genetic erosion due to artificial factors: China has a very large population and food supply is not keeping pace with population growth. Triticeae are mainly distributed in the northern part of China, which is relatively poor. Thus, over-grazing by animals and bringing natural grasslands and barren hills under cultivation are common in such areas, which directly leads to loss of some species. According to the Flora of China (Guo 1987), about 152 native species were distributed in China. But 64 species have not been found yet in original areas of distribution of Triticeae, which have been affected by natural and artificial factors.

Genetic erosion under genebank conditions: As described earlier, numerous accessions of Triticeae have been collected and conserved in the genebanks. However, genetic diversity is always threatened in ***ex situ*** collections. Firstly, obtaining enough samples of each population is not easy during the expeditions because of many limiting factors such as time, optimum time for collecting etc. Thus only a sample of available diversity in nature is collected. Secondly, loss of genetic diversity can occur in genebanks before it reaches researchers and breeders because only very small samples could be obtained from the genebank. Thirdly, genetic diversity could be lost during seed regeneration and multiplication. Although a total of 2704 accessions of Triticeae were collected in China, about 775 accessions have been lost so far. The reasons for this reduction in number include non-germination of original seeds, inviable or weak seedlings, non-flowering under ***ex situ*** conditions or changed conditions, sterility due to genetic and physiological (late flowering) causes and low seed productivity. In addition, as only a small sample would be used while regenerating germplasm seed, genetic drift could contribute to genetic erosion of material conserved in the genebank.

Genetic erosion in Triticeae can make cereal crop improvement, especially in forage breeding, difficult as this reduces the genetic diversity available to crop improvement scientists. Comparatively little breeding has been done to develop improved cultivars of perennial Triticeae grasses in the world. In North America, for example, much of the planting in the intermountain zone were done with unimproved introductions or cultivars developed for the Northern Great Plains (Asay 1993). In addition, many cultivars were derived from a single accession. Thus, expanded plant exploration activities and improved breeding procedures have to be undertaken. Development of promising germplasm through interspecific hybridization, as well as more conventional means is expected to have positive impact on a range of improvement programmes.

Using Triticeae for wheat improvement

In China, Li and Hao (1992) reviewed the work of transferring desirable genes from Triticeae. Recently, the desirable genes such as resistance to powdery mildew and stripe rust, tolerance to drought, higher protein content and black grain in colour from ***A. cristatum*** have been transferred into common wheat (Li ***et al***. 1998).

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The utilization outline of wheat germplasm resources in China

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Wheat has been cultivated in China for more than 4000 years. It occupies an important place in Chinese agriculture and it is distributed widely in the country. Wheat germplasm resources in China are plentiful and have many different types, including landraces, improved varieties, special genetic materials and related wild species. Most of the wheat genetic resources were collected within China, only a small part of them were introduced from overseas. Through several years of research, especially by national cooperative studies during the recent 15 years, important achievements have been made. This paper summarizes the utilization status of wheat germplasm resources in China from 1984 to 1998.

Number and types of wheat germplasm resources conserved in China

At present, there are 45 500 accessions of wheat germplasm in China, which belong to 15 genera, 237 species (including 10 subspecies)(Qian ***et al.*** 1989; Pu ***et al***. 1980; Zheng 1995, 1996; Liu and Song 1999). A brief description of the available genetic resources is given below.

Triticum is the largest genus among the 15 genera of Triticeae in China. There are 39 629 accessions of bread wheat (***Triticum aestivum***), 25 319 of which were collected within China (including 13 930 landraces and 11 389 improved varieties) and 14 310 accessions were introduced from more than 80 countries and regions. There are 951 special genetic materials of wheat (210 accessions were from overseas) conserved in China. They are mainly synthetic polyploids, aneuploid alien addition lines, substitution lines, translocation lines, ph gene line, nucleoplasmic replacement lines, and dominant nuclear-sterile lines etc.

There are 2434 accessions (919 from China and 1515 from abroad) in 23 rare species conserved in the National Gene Bank, of which more than half are durum wheat (1302 accessions). We have also conserved 2505 accessions of wheat related wild plants belonging to 213 species (containing 10 subspecies) in 14 genera. Roegneria, Elymus, and Aegilops are the main ones with 595, 543 and 425 accessions respectively

From above analysis, it can be concluded that Chinese wheat germplasm resources are not only numerous (about 40% of the total number in the world), but also very diverse. They are absolutely material basis for contributing to lasting development of wheat production and breeding in China and the whole world.

Outline of seed provision

During 1984 to 1998, the Laboratory of Wheat and Barley, Institute of Crop Germplasm Resources, CAAS alone provided 22 996 samples to 1297 researchers within China. We also provided 476 accessions to 16 countries (Australia, Canada, Czech, Ethiopia, France, Germany, India, Japan, Korea, Mexico, Pakistan, Sweden, Thailand, USA, UK, and previous USSR). Germplasm that was supplied included bread wheat (landraces, improved varieties and advanced breeding lines), rare wheat species and wild relatives. Most of the materials provided were improved varieties of bread wheat, about 78.5% of the total accessions supplied. Generally, the improved varieties were provided to breeding units while local cultivars, rare species and related wild species to basic research units. Very few varieties were provided to production units. According to statistical data, scientists of wheat germplasm resources provided about 3534 accessions to breeding or other institutes annually on an average.

Utilization status of germplasm supplied

The resources provided to breeding units were mainly used as parents for breeding. The varieties provided to basic research units were used for genetic research, comparative research (eg. varietal differences over time) and evaluation for absorption of trace elements in soil. The resources provided to production units were used for yield testing, varietal selection or commercial production directly. However, because of the problems in research and management systems, the utilization results could not be fed back in time, we got little information about the utilization status.

It generally takes about 10 years to select a new wheat variety, according to the report of new wheat varieties, which passed through national or provincial variety tests between 1984 and 1995. During this period, 267 wheat new varieties successfully passed through the strict variety tests. Among them, 101 varieties were improved between 1991 and 1995 (Jin ***et al***. 1997; Zhuang ***et al***. 1996; Li ***et al***. 1996). In order to improve these varieties, 213 samples were provided by National Genebank and 61 (28.6%) were used as parents, among which Lovrin series (e.g. Lovrin 10, Lovrin 13, Avrora and Kavkaz) were the most frequently used parents. All of them belong to 1B/1R germplasm. Forty-two new varieties were improved from these parents, they account for 15.7% of the total improved varieties. Mexican wheat varieties such as Penjamo T62, Yecora F70, Saric F70 etc., occupy the second position for using as parents, from which 28 new varieties were developed, accounting for 10.5% of total improved varieties. Taigu nucleo-sterile wheat, Mianyang 11, Punong 3665, Bainong 3217, Sumai 3, Aimengniu, Fu 660, Fan 6 etc., were also used as parents frequently. Based on source of these parents, these can be divided into two groups: local and exotic/introductions. About 120 varieties were improved using exotic materials as parents, accounting for 45% of the total improved varieties. This result indicates that introduced germplasm resources are very important for Chinese wheat breeding.

Germplasm enhancement

Germplasm enhancement is generally undertaken by crossing between varieties, recurrent selection, mutagenesis by physical or chemical factors, distant hybridization between species or genera (Zhaung ***et al***. 1996). Only distant hybridization is discussed here.

- Using hybridization between ***Haynaldia villosa*** and ***T. aestivum***, new germplasm with resistance to powdery mildew was developed. For example, 92G151 and 92G157 were selected from TH 3/Yuan 7107//Ji 5418/3/Shaan 7859. They are 6V/6D substitution lines. Another example is 92R137, which was improved from Yangmai 5/Sub. 6V. It belongs to 6VS/6AL-translocation line.
- Chinese spring (CS) is an important bread wheat variety. It was used to hybridize with ***Leymus racemosus*** and ***Roegneria kamoji*** with resistance to scab disease. Add.Lr-2, 820290, and Add.Rk-13 are the representative examples. Add.Lr-2 was from CS/***Leymus racemosus***//CSx2 while 820290 while Add.Pk-13 were from CS/***Roegneria kamoji***//CSx2.
- Using hybridization between ***Agropyron cristatum*** and wheat variety of Fukuho, a series of new germplasm which have characteristics of high protein content, resistance to rusts, powdery mildew, drought have been obtained.

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Discussion on breeding objectives on main characteristics of new wheat germplasm

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Importance of use and germplasm enhancement

Selection of parents, hybrid combinations and selection in subsequent generations must rely on the breeding objectives. It is an important strategy for wheat breading. Breeding a new variety with very high yields is a current objective but there is a shortage of suitable germplasm. It is necessary to enhance new germplasm and to improve some important characteristics.

New objectives for wheat germplasm enhancement

Large head with large grain: The basic factors that contribute to increased yield per unit area are the number of grain of per head and amount of heads per unit area. To realize the target objective, very high yield, we have to increase the number of grain per head and grain weight. Since it is difficult to combine many good characteristics together (higher grain weight, more grain number per a head, etc.), all these characteristics must be considered and adjusted reasonably during breeding.

Superior quality, including nutritional and processing quality: Improved nutrition quality means higher protein and essential amino acids contents. Good processing quality means that the flour must be suitable for making bread or Chinese noodles, dumplings or steam bread. Both nutrition and processing qualities must be considered during breeding new variety and germplasm.

Bushy and percentage of ear-bearing tillers: Considering present needs of production, the newly bred variety and enhanced germplasm should be nicely bushy with higher percentage of ear-bearing tillers. It should also be strong and vigorous and should have reasonable density in the field to obtain higher yield. Any germplasm resources that are used for breeding these traits (short stalk, large head with large grain, early maturity and disease resistance) should possess these characteristics.

Early maturity: There are many advantages with early maturing wheat variety with higher yield, such as escaping from germination on head or the period of disease. Because of the differences in ecological environments, there are many types of early maturity, thus the requirement for early maturity varies. The newly developed early maturity germplasm should have higher yield and different maturity periods to meet the needs in different regions.

Disease resistance: Disease severity is affected by host, pathogen and environment and their interactions. It is necessary to pay attention to combine allelomorph to breed new germplasm that has stable disease resistance.

In brief, higher yield and superior quality are the main objectives for wheat breeding, and it requires new germplasm. To release a new variety, usually requires distantly related material as parents with desirable genes, hybridization, release of genetic variation and selection.

Study on resistance to sharp eyespot *(Rizoctonia cerealis)* in wheat germplasm

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With the continuous increase in yield, there is a tendency for occurrence of severe epidemic of sharp eyespot. It is estimated that epidemic of this disease can occur in about 5.34 million ha around the country and 1.34 ha million in Jiangsu (Shi ***et al.*** 1993). Due to rotting of transportation and mechanical tissues, wheat sharp eyespot would affect transportation of nutrients, cause lodging and even cause white head in severe condition, resulting in 30-40% or more yield loss (Wang ***et al.*** 1996). Therefore, sharp eyespot has become a major problem in wheat production. In order to reduce its damage, comprehensive studies have been made on the fungus, epidemic, damage and ways to prevent it. But progress has been very slow. We tried to investigate screening techniques genetics and breeding using artificial inoculation with mixture cultures.

Resistance to sharp eyespot in introduced varieties

Among germplasm tested, some varieties showed relatively good resistance to the disease. Niavt 14, Niavt 30, AR2, NSOW35 and Minn 35-53 showed resistance in all 3 years, while Oasis, Rendezvous and Amigo showed resistance in 2 years. Their disease indices were at least 30-35% lower than the susceptible check. Other 4 varieties, Adito, Compton, GBI 63, and Niavt 5 showed moderate resistance in more than 2 years, with at least 25% lower disease indices than the susceptible check. They could be used as resistant parents in wheat breeding. Interestingly AR2, NSOW35, Oasis and Amigo are all the progenies of wheat crosses with rye. Rendezvous, the most resistant germplasm to eyespot in Europe, comes from the combination Ventricosa and Capplle Desprez (He ***et al***. 1998, Li ***et al.*** 1997).

Resistance to sharp eyespot in landraces

Disease indices in Jiangdongmen, Fuqing Heshangmai, Baichaoyu, Shuilaomai, Shuilizhan and Jiutaiwan were about 15% in an epidemic year, a little higher than those in some introduced resistant varieties, but 20-40% lower than that in the susceptible check. Therefore, these six landraces were identified as moderately resistant (He ***et al***. 1998, Li ***et al.*** 1997).

Response to sharp eyespot in improved Varieties

Among 271 improved varieties tested over 3 years, no resistant varieties were found. Only Ningzuo No.1 showed moderate resistance in 1997 and 1998. Zhe 908, Ningfen, Ningmai 9 and Shangnong 950 095 had higher disease indices (>20%) in epidemic year and seem to be moderately susceptible or moderately resistant. It should be pointed out that almost all commercial varieties in the Lower Yangtze River Valley, such as Yangmai 5, Yangmai 158, Yangmai 10, Ningmai 8 and Sumai 6, are susceptible to the disease.

Discussions

Generally, introduced cultivars showed the higher level of resistance, followed by landraces. In this study, all the improved varieties tested seemed to be highly susceptible. This could be due to narrow genetic base and genetic uniformity of the improved varieties (Liu 1999) Among introduced varieties, Rendezvous, which was reported as the resistant source to eyespot (Lupton 1987), showed not only strong and stable resistance in itself, but also in its derivatives. Therefore this could be a potential resistant parent in wheat breeding. Furthermore, some germplasm derived from wheat crosses with rye, such as Oasis, Amigo, AR2, also showed stable resistance in several years. It is worth investigating the source of resistant gene(s) in wheat-rye translocation lines in addition to using them as resistant parents as soon as possible. It should be pointed out that commercial varieties in the Lower Yangtze River Valley, such as Yangmai 158, Yangmai 5,Mingmai 8 and Sumai 6, are all highly susceptible to sharp eyespot. It could be one of the most important reasons why the disease is widely epidemic in recent years. In order to control the disease with genetic means, it is essential to widen the genetic base and use these resistant germplasm to breed resistant commercial varieties.

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Development of parents with stripe rust and powdery mildew resistance or good quality for wheat breeding and study of their molecular biology

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By means of nullisomic backcross and induction of translocation N9134, N9227, N9207 and N9209 with stripe rust and powdery mildew resistance were developed by transferring stripe rust and powdery mildew resistance genes from ***Haynaldia villosa*** and ***Triticum dicoccoides***. Two RAPD markers, $OPH\text{-}07_{340}$ and $OPQ\text{-}19_{900}$, linked to powdery mildew resistance gene of ***Triticum dicoccoides*** were obtained. By Ph gene effect, Yuanfeng 898 with stripe rust resistance and high yield was developed by transferring the stripe rust resistance from ***Secale cereale*** into common wheat. A wheat –***Thinopyrum intermedium*** addition line and a substitution line with stripe rust resistance were developed by nullisomic backcross; the results of ***in situ*** hybridization analysis indicated that St-genome chromosome of ***Th. intermedium*** was transferred into common wheat. By the improvement of wheat ***Th. intermedium*** partial amphiploids Zhong No. 4 and Zhong No. 5, new wheat variety Shaanmai 150 with bread-making quality, disease resistance and high yield was developed in 1997 and registered in 1999. Glutenin subunit 14+15 was combined with glutenin subunit 5+10 by crossing monosomic 1D of Xiaoyan No. 6 and Pavon diploid. Glutenin subunit 14+15 was isolated and purified by SDS-PAGE from ***Triticum aestivum*** Xiaoyan No. 6. The sequences of N-terminal amino acid of two subunits were analyzed after transblotting them onto polyinylidene difluoride (PVDF) membrane.

Winter wheat and establishment of sustainable production system in Ningxia of China

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Introduction of winter wheat and northward expansion production region have promoted farming system reform in the Yellow River Ningxia Valley, a pure spring wheat production area. Winter wheat was better adapted local conditions, which gave 39% higher yield than spring wheat and had good quality. Early winter wheat could mature earlier by 20 days than spring wheat and facilitated double or multiple cropping. Scientists have challenged traditional farming system and succeeded in the Valley. New planting system could utilize Ningxia natural resources, such as sunlight, heat radiation, water, land. More than 15t ha^{-1} grain yield in double cropping situation, or 7.5 t ha^{-1} winter wheat plus 15 000 Yuan (US$ 1800) per hectare income with vegetable cultivation in the Spring could be achieved. The new cropping cycle could increase net income by 41% to 80% per unit area than the traditional cycle. A number of new advanced winter wheat lines have bee developed, which came from winter wheat crossed with local spring wheat or back crosses.

Development of wheat germplasm with good quality, early maturity and scab resistance

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In most wheat planting regions to south of the Yellow River, developing wheat variety with good quality, early maturity and scab resistance is an important breeding objective. There has not been a wheat variety with these three characteristics at one time in these regions till recently. Developing such a wheat variety would have a major impact on raising wheat production level in these regions (Jin 1996). New variety Zhengzhou 9023 released recently by Henan Academy of Agricultural Sciences, China, has been developed by combining good quality, early maturity and scab resistance together. Some details on breeding methodology, characteristics and usability of this new variety are briefly described in this paper.

Objective and breeding of Zhengzhou 9023

Objective

Objective was to develop a good of bread wheat, early maturing (earlier than the current early variety), with stronger resistance to scab and yellow rust, weaker photoperiod sensitivity, plant height about 80 cm and grain yield 6000 kg ha^{1}- 7500 kg ha^{1}.

Parental combination

Parental combination of Zhengthou 9023 was [83(2)3-3 / 84(14)43 / / Xiaoyan 6 / Xinong 65]F3 /3/ Shaan 213. 83(2)3-3 was early progeny of an early variety 78(6)9-2. 84(14)43 was resistant progeny of Sumai 3 with stronger resistance to scab. Xiaoyan 6 was a source for good quality and resistance to leaf ***Septoria***. Xinong 65 and Shaan 213 were resistant sources for yellow rust with good agronomic background.

Breeding methodology

Quality, maturity and scab resistance was selected by pedigree breeding from F_2 to F_5 segregating generations. In the nursery, all plants were inoculated by litter pieces of paper containing ***Fusarium graminearum*** through florets and plants with stronger scab resistance were selected. Early maturity was selected at heading and maturity period. SDS sedimentation test (0.6g wheat flour for each plant) (Ma 1996) was used for selecting progeny with good quality. In addition, yellow rust inoculation and agronomic selection were carried out under field conditions.

Testing for yield and disease resistance was done on selected lines from F_6 to F_7. Single plant selections were made continuously. In F_8, yield tests were conducted in many sites. Based on whole flour quality test single plant selections were made from selected lines. For selected F_9 lines were tested in many locations for yield, quality and diseases resistance. In autumn 1999, selections were included in the wheat variety regional tests in Henan, Anhui, Jiangsu, Hubei, Sichuan and Chongqing province.

Characteristics of Zhengzhou 9023

Good quality

Results, which were analyzed at the Grain Quality Experimental Center of Ministry of Agriculture (Beijing) and The Agriculture Product Quality Experimental Center of Ministry of Agriculture (Zhengzhou), showed that the quality of Zhengzhou 9023 reached the standard of bread wheat and was suitable for producing flour with stronger gluten (Wan 1997). Grain samples for quality analysis were harvested in the field of the Henan Academy of Agricultural Sciences in 1998 and at 11 sites in the central and northern parts of Henan province.

Early maturity

In the central and northern parts of Henan province, wheat is generally planted on 15-25 October and Zhengzhou 9023 matured by 25 May. Growing period was about 220 days. It matured 2 days earlier than the early maturing variety Yumai 18. However, in Hefei of Anhui and Yongchuan of Chongqing it was much earlier.

Strong scab resistance

Studies by Shaanxi Academy of Agricultural Sciences, Northwestern Agricultural University and Chongqing Crop Institute proved that Zhengzhou 9023 was highly resistant to scab. Its resistance type was no-extension and its resistance to scab was as strong as Sumai 3, a famous scab resistant variety.

High yield.

The yield components of Zhengthou 9023 was about 600 spikes/m^2, 42g/1000 grains, 31 gains/spike. The yield of Zhengzhou 9023 was about 6000-7500 kg ha^{-1}, which was similar to Yumai 18 planted commercially in Henan province.

Other characteristics

Zhengzhou 9023 was weak spring variety with other characteristics such as quick growth in spring season, erect plant type, 82 cm in height, stronger resistance to lodging, highly resistant to yellow rust, moderately resistant to leaf rust, sheath blight and leaf ***Septoria*** and moderately susceptible to powdery mildew.

Use of Zhengzhou 9023

We were successful in combining good quality, early maturity and scab resistance together in Zhengzhou 9023. In addition, it had better resistance to many diseases such as yellow rust, leaf rust, sheath blight and leaf ***Septoria***, except for powdery mildew. It has also been inferred that Zhengzhou 9023 showed weaker photoperiod sensitivity and had better adaptation because it matured earlier in the central and northern parts of Henan, Hefei of Anhui, Yongchuan of Chongqing. Thus, Zhengzhou 9023 represents an effort on combining many good characteristics in one genotype. It is possible that Zhengzhou 9023 could become a good parental material for wheat breeding in the future.

The high molecular weight glutenin subunits of Zhengzhou 9023 were Null, 7+8, 2+12, so its quality could be enhanced further by combining with material containing high molecular weight glutenin subunits 5+10. Zhengzhou 9023 has good combining ability, early maturity, scab resistance and high yield and has been entered in the wheat variety regional tests in Henan, Anhui, Jiangsu, Hubei, Sichuan and Chongqing provinces. Hence, Zhengzhou 9023 could become a commercial variety.

It is necessary that the genetics of the good characteristics of Zhengzhou 9023 should be studied further because it not only has good characteristics but also has high level of transmission for these characteristics.

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Evaluation and utilization of barley germplasm resources of China

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This paper reports the results of evaluation on 16 251 accessions of barley germplasm resources that have been catalogued in China. The results included information on morphological characteristics, agronomic traits (days to maturity, plant height, 1000-kernel weight), disease resistance (to barley yellow mosaic virus, barley head blight, barley yellow dwarf virus, stripe disease of barley), tolerance (to salinity, drought, and water logging) and protein content. These results were listed and compared with those of introduced barley resources. The valuable elite germplasm were selected and their utilization was studied.

Strategy for maize germplasm enhancement in China

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Maize is the third most important crop with respect to the growing area and the second most important crop with respect to the total production in China. Therefore, it is necessary that the yield, especially in various stress environments, is continuously raised and the quality improved to promote the agricultural development and contribute to national economy. On the other hand, because hybrid maize is planted in more than 90% of the maize growing area, commercial opportunities are open to all related aspects of corn improvement and production. Particularly, strengthening maize improvement will become more important in the future. Taking the current situation of germplasm research and breeding in account, we propose that maize germplasm enhancement should be the priority in the near future.

Significance of maize germplasm enhancement

The genetic base of maize germplasm used currently in China is narrow because only four systems (Tangsi pingtou, Luda Honggu, Lancaster and Reid Yellow Dem) account for above 80% of the cultivars grown in the country. The genetic base can be broadened only through germplasm enhancement. There are few maize germplasm stored in the genebanks of China which can be directly used in breeding programmes. Germplasm enhancement can transfer desired genes from some unique materials, e.g. tropical and sub-tropical maize germplasm and wild / weedy types, to cultivated maize.

Current situation of maize germplasm enhancement in China

Nowadays China is one of the countries that hold a large number of maize accessions in genebanks. About 78% of the accessions stored in the Chinese Genebank are landraces, 12% breeding or inbred lines, 10% materials introduced from other countries (45% inbreds) and a few wild / weedy types. Since 1979, much attention has been paid to characterization and evaluation of germplasm for various traits. Almost all materials entered into the genebank were characterized for agronomic characters. A large part of the accessions were evaluated for disease / pest resistance (including maize northern leaf blight, southern leaf blight, head smut, stalk rot, maize dwarf mosaic virus, maize rough dwarf virus and Asian corn borer etc.), stress tolerance (including drought, salt, cold water logging, poor soils and lodging etc.), and quality traits (including protein, lysine, starch, fat and various amino acids). Combining ability tests were also done for some inbred lines. During 1996-2000, elite maize germplasm have been comprehensively evaluated and analyzed to make them available to breeders.

Maize germplasm enhancement in China began in the 1970s. Later, it was listed in the National Maize Breeding Sci-Tech Breakthrough Projects From 1981 to 1995 during which period significant progress was made. For example, specific populations were established and some elite inbreds were developed. Tropical and sub-tropical maize germplasm and wild germplasm were introduced into temperate maize and some inbred lines were obtained.

Objectives of maize germplasm enhancement projects in China

Objectives of maize germplasm enhancement programme in china are: to continuously make breeding materials available to all breeding and research institutions free of charge; to set up a national network of maize germplasm enhancement; to establish dynamic genebanks serving users for major traits, based on practical requirements in production; to establish a core collection and to establish a distribution system of maize germplasm.

Strategy and approaches

Firstly, suitable materials (i.e. elite inbreds) are selected and sent to one breeder. The breeder crosses the inbred with his own elite inbred. To ensure the safety of information, cooperators and their inbred lines would be coded and would not be open to the public. The combinations obtained from the crosses can be used in the analysis of specific traits, disease / pest resistance and yield evaluation. The hybrid seeds, along with data on them, are distributed to all users. Then, the hybrid seeds are sent to another breeder. The latter crosses the hybrid with his inbred. Thus, the three-way cross progenies obtained contain genetically, 25% of the original material, 25% of the first cooperator's line, and 50% of the second cooperator's line. After the yield assessment, good combinations would be selected for selfing and development of synthetics. The seeds of synthetics are sent back to the medium-term genebank for distribution.

Preliminary report on the molecular breeding technique of direct introgression of alien DNA into corn (*Zea mays* L.)

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Corn (***Zea mays*** L.) is the second important crop in Guangxi province with an acreage of 530 000 ha. The corn products are in great demand in recent years and the production is not enough to meet the demand. So 2 million tons of corn product is imported into Guangxi annually. To enhance yields and reduce imports, we initiated breeding programme using molecular methods in 1996. In the last three years, we have made some progress and some of the research results are presented here.

1. The introgression of alien DNA by the pollen tube method could generate variation in the progeny;
2. Four methods of introgression were effective in corn molecular breeding approach. As mentioned above, the pollen-tube method showed 8.87% variants in D1, the germinating seed immersion method showed 7.45%, and these two methods were better than the other two in terms of the proportion of variants observed in D1 plants. However, there was a disadvantage with microinjection and the pollen vector methods because of the ease of breaking up of pollen after it absorbed water during the manipulation. This disadvantage could be overcome by appropriate length of time of absorption of moisture. The introgression of alien DNA into corn could provide extensive variation for corn breeding;
3. The above methods were effective in crop breeding. However, because total DNA was used in breeding, random mutation was likely to have occurred. It is suggested that molecular marker assisted selection should be employed in corn breeding to get the better orientation of target character transfer.

Evaluation, utilization and study on excellent germplasm of broomcorn millet in China

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A total of 120 broomcorn millet varieties were selected from 6000 varieties based on quality analysis, disease resistance and high yield. Some of the selected varieties have good quality traits, high yielding ability and high resistance to disease. Others have one or two of these characteristics. These varieties were planted in three different ecological locations: Taiyuan Shanxi, Yulin Shanxi and Jilin. The tested varieties were grouped according to the average yield of two years in the 3rd year experiment. Based on the yield stability and adaptability, 10 high yielding varieties were identified and 3 excellent varieties were selected for production.

Results of yield tests

Among 120 varieties tested, 12 varieties yielded ≥4500 kg ha^{-1} accounting for 10% in 120 test varieties; 45 yielded 3750-4500 kg ha-[1], accounting for 37.5%; 53 yielded 3000-3749 kg ha-[1], accounting for 44.2%; 9 yielded 2250-2999 kg ha^{-1} , accounting for 7.5% and one yielded 1500-2249 kg ha-[1], accounting for 0.8%. Yield of over 90% varieties tested was over 3000 kg ha^{-1}. Ten varieties, namely Huangmizi (5283), Xiaohongmizi (2601), Baigezidan (5464), Huangmizi (5272), Heshuihongyingmi (0724), Guchenghongmizi (2620), Hanfuhongran (2621), Jizi (5159), Daqihuanggandabaishu 2 (0635), Huangyingmi (5451), yielded over 4500 kg ha^{-1}.

The stability of yield and adaptability of 10 excellent varieties

Statistical analysis on b (regression coefficient) and r^2 (decision coefficient) showed that the value of b for Huangmizi (5283) and Baigezidan (5464) was less than 1, their stability of yield and adaptability was better than that of others. The value b of Heshuihongyingmi (0724), Xiaohongmizi (2601), Huangmizi (5272) and Daqihuanggandabaishu 2 (0635) was about 1, their stability of yield was intermediate and adaptability was better. For Jizi (5159), Guchenghongmizi (2620), Hanfuhongran (2621) and Huangyingmi (5451) b was >1, they were highly sensitive to environment and they should be planted in some specific areas only.

Agronomic characters of 10 excellent varieties

Among the 10 selected test varieties, the longest growing period was 120 days and the shortest was 78 days, with a mean of 81.6 days. The tallest was 174 cm and the shortest was 124 cm (mean 151.5 cm). The longest ear length was ranged between 46.3 -30.9 cm, with a mean of 32.3 cm. The heaviest kernel weight/plant was 14.5 g and the least was 7.5g, with a mean of 9.2 g. The 1000-kernel weight ranged from 7.8 g to 6.4 g, with a mean of 7.3g. The highest, the lowest and mean value of these characters were reasonable, they reached the standards that excellent germplasm demanded.

Evaluation of 10 best high yielding varieties

Using evaluation standards, the varieties were classified in to 3 grades.

Grade I: plant height ≤180 cm, growing period ≤120 days, ear length≥30 cm, 1000-kernel weight ≥6 g, kernel weight/plant ≥7 g, nature incidence of a disease ≤5% or manual saturated inoculation incidence of a disease ≤35%, protein ≥13%, fat ≥3.0%, lysine ≥0.20%;

Grade II: Agronomic characters , high yield and disease resistance reached the standards, quality reached 2 level of standards

Grade III: agronomic characters, high yield and disease resistance reached the standards, quality reached standards 1.

On the basis of agronomic characters and yield, 10 varieties met the standards, for protein, fat, and lysine contents and incidence of smut, the 10 best varieties were evaluated as follows.

Table 1. Grading of 10 best high yielding varieties

Item No.	*Name of variety*	*Protein (%)*	*Fat (%)*	*Lysine (%)*	*Smut (%)*	*Grade*
5283	Huangmizi	11.87	3.26	0.20	9.4	2nd
2601	Xiaohongmizi	12.44	5.00	0.21	12.9	2nd
5464	Baigezidan	12.86	5.49	0.21	1.1	2nd
5272	Huangmizi	14.90	3.00	0.23	1.6	1st
0724	Heshuihongyingmi	16.11	2.24	0.16	33.3	3rd
2620	Guchenghongmizi	12.90	3.95	0.20	5.9	2nd
2621	Hanfuhongran	13.07	3.24	0.21	1.1	1st
5159	Jizi	10.63	3.36	0.19	1.4	3rd
0635	Daqihuanggandabaishu2	16.20	4.94	0.20	34.0	1st
5451	Huangyingmi	11.20	3.38	0.20	2.0	2nd

As shown in Table 1, 3 varieties belonged to first grade, 5 reached the second grade, and 3 the third grade. The 3 first grade varieties, namely Huangmizi (5272), Hanfuhongran (2621), Daqihuanggandabaishu2 (0635), will be distributed for production and breeding. They are expected to produce tremendous economy and social benefits.

Research progress and development strategy of Chinese soybean germplasm resources

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Status and problems of conservation

Present situation of collecting and conservation

The total number of Chinese soybean germplasm resources is 23 587 after several national-wide collecting missions. The provinces from which more accessions have been collected include (number accessions are given in the parenthesis): Shanxi (2282), Sichuan (2069), Guizhou (2068), Jiangsu (1782), Hubei (1679) and Liaoning (1348).

Table 1. Number of soybean germplasm resources in different provinces of China

Provinces	*Spring season*	*Summer season*	*Autumn season*	*Total*
Heilongjiang	960			960
Jilin	1 232			1 232
Liaoning	1 348			1 348
Inner Mongolia	310			310
Beijing	47	50		97
Xinjiang	42			42
Ningxia	107			107
Shanxi	2 282			2 282
Hebei	397	852		1 249
Shandong		1 134		1 134
Henan		626		626
Shaanxi	239	796		1 035
Gansu	240	110		350
Jiangsu	253	1 259		1 782
Anhui		1 084		1 084
Shanghai	7	83		90
Hubei	190	1 489		1 679
Sichuan	1 267	802		2 069
Zhejiang	150	395	382	927
Fujian	196	280	115	591
Jiangxi	102	148	172	422
Hunan	266	240	48	554
Guizhou	1 074	994		2 068
Guangdong	301	44		345
Guangxi	184	405	1	590
Yunnan			582	582
Taiwan	12			12
Tibet		5	15	20
Total				23 587

Of the total soybean germplasm resources, there are 11 206 spring-sown soybean accessions, accounting for 47.51% of the total; 11 648 summer-sown soybean accessions (49.37%); 733 autumn-sown soybeans in north and northeast areas. There are 7204 (30.54%) spring-sown accessions from the north and northeast areas; 5017 (21.27%) summer-sown accessions from Huanghuaihai areas; 11 366 (48.19%) accessions are spring-summer sown and autumn-sown soybean varieties from south (Chang et al. 1997).

Table 2. Distribution of soybean germplasm in different cultivation regions of China

Cultivation regions	Spring	Summer	Autumn	Total
North and Northeast spring Planting soybean region	7 204			7 204
Huanghuaihai summer planting Soybean Region	136	4 881		5 017
South Multiple cropping planting Soybean region	3 866	767	733	11 366
Total	11 206	11 648	733	23 587

All of the soybean germplasm accessions listed above have been included in the Chinese Soybean Germplasm Catalogue, and most of the materials have been sent to the National Genebank from the seventh five-year plan period to the ninth five-year plan period. The same materials were also conserved in the Medium-term Genebank as well. About 5000 accessions have been regenerated during the ninth five-year plan period to replace the corresponding old seeds in the Mid-term Genebank, which make it convenient for utilization.

Existing problems

About 1000 catalogued materials have been lost due to various reasons, like flood, drought, difficulty to reproduce etc. Although information about the materials is available, no seeds could be provided for utilization. Another problem is that the regeneration of seeds in the medium-term genebanks is not guaranteed because of the lack of financial support. Especially for those with insufficient quantity, this situation is more severe. When an accession is registered in the genebank, generally the quantity of the seeds less than 100g for each accession and it is difficult to replace them after they have been taken out and utilized. Although 5000 varieties were planted for regeneration during the ninth five-year plan period, there are still more than 18000 accessions that need to be regenerated. In addition, new materials collected from special investigations in Sanxia, Hainan, Jiangxi, Guangxi and Guangdong areas during the eighth and ninth five-year plan period have not been sent to the Genebank yet.

Suggestions for improvement

1. Enhanced regeneration and seed increase efforts. For making full use of the collected genetic resources, there should be enough seeds available in the medium-term genebank. Therefore it is important to enhance efforts on renewal of seeds during the tenth five-year plan period and try to replace and all of the germplasm resources. This is necessary not only to guarantee the vigour and vitality of the seeds, but also to have enough seeds for meeting the requirements of the research, breeding and biotechnology.
2. Identify, catalogue and storage the accessions collected in special investigations in the tenth five-year plan. Recently collected materials need to be catalogued and seed regenerated to have enough stocks in the medium-term genebank as well as to be sent to the long-term for conservation. Seed increase also needed for planting for their agronomic evaluation. Because most of these varieties come from the low latitude areas of the south, they need to be planted in conditions similar to their original sites. However, facilities for research those provinces are not very strong, This would require more efforts on organization and coordination for getting the job of research on these valuable germplasm resources done satisfactorily.

Improvement of evaluation and potential

Improvement of evaluation

Notable progress has been made on the following 5 aspects after evaluation in the seventh and eighth five-year plan period:

1. Evaluation for agronomic traits, including maturity date, stem termination, plant height, seed coat colour, hilum colour, cotyledon colour seed shape, seed size, flower colour, pubescence colour, leaf shape etc.
2. Analysis of nutritional quality of seed has resulted in the identification of accessions with high protein content. Protein content in the accessions that have been evaluated ranges from 45%-48% (5247 accessions), 48-50% (1059) and there are 170 accessions whose protein content is above 50%. One hundred fifty one accessions have more than 22% oil content, of which 38 have more than 23%.
3. Stress resistance evaluation. A total of 82 soybean accessions identified with high salt tolerance at sprouting and seedling stage, while 463 accessions showed high drought-resistance.
4. Disease resistance evaluation. About 10 000 varieties were evaluated for soybean cyst nematode (SCN) resistance, 15 were found to be immune to race No. 1, 30 to No. 3, and 12 accessions showed high level of resistance to race No. 4. About 14 000 accessions were screened for soybean mosaic virus (SMV) resistance, a group of high-resistant materials have been found.

Evaluation by using DNA molecular markers. Chinese soybean germplasm resources were evaluated by using RAPDs and SSRs. Molecular marker research has been undertaken on some important genes like SMV-resistant gene, SCN-resistant gene, and salt-tolerant gene. Molecular markers were also used to study genetic diversity. So far, we have marked the salt-tolerant gene and SMV resistant-gene, and the identification of SCN and purple seed stain resistant genes is going on. Genetic diversity analysis has indicated that were obvious genetic differences between Chinese and American soybean ancestors and between accessions coming from south and north of each country. The SSR and RAPD analysis of Chinese superfine soybean varieties indicated that the soybean genetic resources of Shanxi province have remarkable genetic diversity.

Enhancing evaluation efforts

There are more than 23 000 soybean germplasm resources in China, but less than 50% of them have been evaluated. For example, only 7000 accessions have been screened for drought resistance, there are still two thirds of the accessions that should be evaluated. About 10 000 accessions have been evaluated for salt-tolerance, which makes up only 50% of the total. Evaluation for disease resistance is similar to these efforts. For example, about 1100 have been screened for SCN resistance, 7000 for soybean rust resistance, a small number has been evaluated for resistances to soybean downy mildew and soybean phytophthora rot. A systematic evaluation has not been started yet for these important traits as well as many others. In the case of resistance to insect pests, only a small part of the resources have been evaluated for their resistance to soybean pod borer, soybean aphid and leaf-feeding insects. For making full use of the soybean germplasm and to exploit its full potential, evaluation is the essential prerequisite. Therefore, it is important for the government to strengthen the support the efforts on soybean characterization and evaluation (Chang ***et al. 1994***).

Strategy for further study

Continue to conduct further evaluation

It is an important basic work to conduct comprehensive and systematic evaluation. Evaluation should go deeply on the basis what has already been done, first to enlarge the quantity and extend the scale of the identification, and multi-year and multi-site repeated evaluation needs to be conducted to confirm the desirable materials that we have already screened for obtaining more reliable and accurate information on them. For example, 42 and 93 accessions were screened for SMV-resistance during the seventh and eighth five-year plan period respectively, but after repeated testing using northeast No. 3 strain, 5 accessions were found to be resistant out of the 42; 47 showed resistance of the 93 accessions tested earlier. Similar results occurred in the case of salt tolerance.

After identification, further genetic analysis needs to be done on the materials with the desirable trait to determine their nature or inheritance (qualitative or quantitative), which is important to determine how to make use of it in improvement programme. Different materials often have different genetic basis, so some materials need specific analysis. For instance, the inheritance of SMV resistance was reported to be controlled by one or two recessive genes, but there have been other types of inheritance reported as well in some other material. So, it is necessary to conduct further studies, including the use of molecular techniques, to ascertain the correct mode of inheritance and exact genes that control the traits. Such information will be invaluable in making efficient use of germplasm for soybean improvement

Create novel germplasm

With the development of modern crop breeding techniques, it is possible to enhance the use genetic resources by researchers. Novel germplasm should be developed through germplasm enhancement by widening the genetic base and producing good materials that have many desirable traits. Such material should include high adaptability, high combining ability, and broad genetic base to provide the base for making a breakthrough in soybean breeding (Chang ***et al***. 1995).

The focal points of soybean germplasm innovation lie in

1. Accessions with high yield and high combining ability;
2. Accessions that have high resistance to major soybean diseases and insect pests, with multiple traits such as yellow seed coat that show resistance to multiple SCN strains and materials that have multiple disease –resistance;
3. With the increase in global temperature, drought-resistant and salt-resistant resources will be in great demand. Hence, there is need to develop a programme for producing stress-resistant new soybean materials and screening facilities for doing so should be established in those institutions that have research base as screening for stress resistance needs high investment.
4. Improve the quality of the materials. It is important to increase protein content or oil content, improve the composition of amino acid, and especially amino acids containing sulphur. The quality of soybean protein could improve if there is no lipoxygenase or it has low content of oligohaccharide. There are some active ingredients, such as isoflavone, in soybeans that resist cancer, We can select and develop soybean with high isoflavaone content and extract isoflavone from them for use in fight against cancer.
5. Create new genetic materials. Using heterosis is the most effective way to improve soybean yield. So far we have cytoplasmic-nuclear male sterile line, and the cultivar ”Three lines” was developed successfully using this system. Near isolines are important for breeding and biotechnology research. Developing Chinese soybean

isolines is the responsibility of researchers who are engaged in the study of germplasm resources and breeding.

Conduct genetic diversity analysis

There are abundant soybean germplasm accessions in China, different ecological regions have different types of soybeans. For example, spring-sown soybeans include Northeast spring-sown soybean, North spring-sown soybean, Huanghuaihai spring-sown soybean and south spring-sown soybean. Northeast spring-sown soybean varieties are not sensitive to short-day light, but the ones from South are relatively sensitive to short-days.. Northeast spring-sown soybeans mature during the mid to end of August; and south spring-sown soybeans mature during the last ten days of June to about mid-July. Northeast spring-sown varieties experience different levels of temperatures during their growth and are totally different from varieties from other regions. Therefore, it is necessary to conduct genetic diversity analysis for clearly understanding the variation that exists in Chinese soybean germplasm resources, which help in making effective use the genetic resources, to develop new types of materials and to widen the genetic base.

Soybean is a short-day plant and it adapts to a narrow geographic range, and so we need different materials for different regions, different cropping systems and different utilization requirements. The exchange of soybean germplasm between different regions was restricted due to the vast area, mountainous terrain and transportation problems in the past. So the diversity analysis of soybean accessions from the same geographic region but different areas can extend their utilization limits, accumulate more useful genes and develop more adaptable materials or varieties. Genetic diversity analysis should become an important research strategy of crop germplasm resources.

Application of molecular biology in research on genetic resources

Significant progress is being made using several different molecular techniques to detect variability in DNA sequences and use it in crop germplasm research and breeding. By using methods like RFLP, RAPD, SSR and AFLP, we can mark the genes, make genetic linkage maps, and analyze the genomic difference at the molecular level. More over, we can use of molecular markers crop breeding and through marker assisted-selection we can develop novel germplasm and can make the selection more accurate and effective (Qiu ***et al***. 1999).

At present, in soybean molecular-biological research, special emphasis has been put on two fields. One is QTL analysis of important genes and the other is genetic diversity analysis. Important genes for QTL analysis include disease-resistant genes (SCN, SMV, frogeye leaf spot), stress-resistant genes (salt tolerance, drought tolerance), high quality genes (genes that control protein content, oil content, lipoxygenase, Trypsin inhibitor), and high yield genes. Molecular markers can be used in analyzing genetic diversity, evaluating germplasm resources and establishing core collection. By setting up database, we can classify the germplasm resources according to molecular markers, carryout cluster analysis and classify accessions to better understand the diversity. Under the basic research project, work on soybean genetic diversity and establishment of core collection is going on. With all these new studies, our understanding of the soybean germplasm resources will be improved greatly, and we can provide more information and more materials for soybean breeding.

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Morphological diversity, enhancement and its utilization of wild soybean (*G. soja*) germplasm in China

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The wild soybean (***G. soja***), a wild annual progenitor of soybeans (***G. max***), is an important genetic resource because of its desirable traits such as high protein, more productive pods and seeds and resistances to environmental stresses. It is distributed nearly all over China (23°57'-53°N and 97°29'-134°E). About 6500 wild soybean accessions collected from various parts, including about 500 semi-wild accessions, have been preserved in the genebank, showing a wide range of morphological variations and the number of accessions is expected to increase in the forthcoming years.

Significant variation has been observed in the wild species collection for the following characteristics: plant height (30-300 cm), leaf shape (ovoid, elliptic, lanceolate, long-elliptic, long-ovoid, and long-narrow), flower petal colour (purple or white), pods per plant (30-3000), growth period 1(20-200 days), seed-coat colour (black, brown, green and yellow) and 100-seeds weight (0.5-10 g). Some rare types are also included in the collection, for example, accessions with brown, yellow and green seed-coat, those that do not bloom, white flower type and accessions with long-narrow leaf and green cotyledon.

Germplasm enhancement work done includes studies for over many years on the wild germplasm introgression by crossing wild and cultivars. This has demonstrated that introgression from wild species germplasm is a very effective method for germplasm enhancement as it offers useful target genes from the wild, broadens the genetic background for soybeans and creates new genotypes.

Germplasm enhancement by introgressing genes from wild species into cultivated soybeans has been in progress over the past two decades. Two high-yielding lines were obtained that contained part of the wild species genome, obtained through linear selection from a cross of Chayu No.1 × "wild ZYD3576" × Dawadali. The two lines that were selected have a 100-seed weight similar to that of commercial varieties, 20-30 g, normal plant height, nearly non-shattering of seeds, increased oil content (20-21%), higher protein content (42-43%) and salinity tolerance. The results showed that the low-yielding wild germplasm could be used for enhancing yield through effectively transmitting the yield-related traits into cultivars, such as number of productive flowers and pods, more nodes of main stem. The transgressive segregation for oil content which occurred in the two progeny lines implied that the wild parent used in this study could contain superior gene(s) that contribute for the recombinational alleles, suggesting a profound significance with respect to wild germplasm utilization.

Selection of "three lines" and locating restorer genes in soybean using SSR markers

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Three soybean male sterile lines, FuCMS1A (ZD0019 × SG01-BC_5F_1), FuCMS2A (ZD0019 × JX03- BC_5F_1), FuCMS3A (ZD0019 × PI004- BC_5F_1) were developed through six years of backcrossing using ZD0019 as cytoplasm donor and SG01, B_2, JX03 as nuclear donors. Through reciprocal crosses, it was shown that the three male sterile lines were cytoplasmic-nuclear male sterile lines. All the BC_5F_1 plants were male sterile and the average percentage of the sterile pollen grains was more than 98%. The results of parallel crosses suggested that the female of the CMS lines was fertile and its male sterility was stable. The percentage of sterile pollen grains of ZD0019, SG01, JX03, PI004 and their F_1, BC_1F_1, BC_1F_5 were calculated. The results showed that their sterility rates were different. Nuclear donors SG01, JX03 were similar, their F_1's male sterility rates were high, and their BC_1 and BC_5's sterility rates were similar, but compared to F_1, their sterility rates were slightly higher. On the contrary, sterility rate of F_1 between ZD0019 and PI004 was low. BC_1 and BC_5's sterility rates increased largely in a gradual manner. These results suggested that the nuclear male sterile genes of SG01, JX03 were dominant, and genes of PI004 were partially dominant and its male sterility was controlled by multiple quantitative genes. Five restoring lines, namely Meng-06, YC04, Fu84-5-4, ZY9010, and Z9001 were selected. The fertility of FuLMSIA and FuCMS2A was more easily restored than that of FuCMS3A with this development. To tag the restore genes of above lines, 60 pairs of SSR primers were screened and three of them produced polymorphic bands between sterile lines and R-lines, Satt143, Satt168 and Satt441 produced a unique band in five R-lines and two CMS-lines. Satt441 and Satt143 generated a 290bp, 500bp bands in all the five R-lines respectively. The three primers were locate on 6 linkage groups. From these data, we conclude that there are three Rf loci, which are distributed in the six linkage groups.

Improvement and utilization strategy for mungbean germplasm in China

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Mungbean is an excellent crop suitable for either intercropping or relay cropping with the cereals, cotton and sweet potatoes, and as a filler crop during the fallow period or in times of famine. It serves an important function in promoting the ecological benefits of recycling plant materials in the field. In order to improve the low yield situation of mungbean in China, the Institute of Crop Germplasm Resources Research of CAAS initiated research on this crop in cooperation with Asian Regional Center (ARC) of the Asian Vegetable Research and Development Centre (AVRDC) to improve and utilize mungbean germplasm. More than 200 AVRDC mungbean varieties or lines were introduced through ARC to China. After many years of field trials, evaluation and testing in multiple-sites, a number of promising varieties were selected from the AVRDC materials such as Zhong Lu No.1 (VC1973A), E Lu No.2 (VC2778A), Su Lu No.1 (VC2768A), Yue Yin No. 3 (VC1628A) and so on. All these new mungbean varieties have been extended throughout China with significant social and economic benefits. By 1989, Zhong Lu No. 1 has reached 266 667 ha, covering more than 45% of the mungbean plantings in China. This phenomenon caused a nation-wide renewal of mungbean cultivation in China.

In recent years, much progress has been made in the mungbean varietal improvement in China. A number of varieties have been bred and released by the Chinese scientists and researchers. These varieties included Zhong Lu No.2, Yu Lu No.2, Ji Lu No.2, Wei Lu No.1, Nan Lu No.1, Jin Lu No.1, E Lu No.3, Yu Lu No.3, Yu Lu No.4 etc. By 1998, area under these varieties reached 279 066 ha, thus the second mungbean renewal has been realized in China.

After joining World Trade Organization (WTO), the Chinese agricultural production structure will certainly be changing a great deal. The market superiority of mungbean will play increasingly important role. Therefore, we should pay more attention to the activities of mungbean research group in China. The cooperation with ARC-AVRDC, other International Research Organization and the different NARS of other countries in the region will be continued. Objectives for mungbean breeding are to breed varieties for starch and vermicelli industry, sprout production and beverage production; to establish mungbean seed production industry and to promote intercropping systems suitable to the local conditions so as to increase mungbean production.

Cowpea Zhong Jiang No.1

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A new cowpea variety Zhong Jiang No. 1 was developed at the Institute of Crop Germplasm Resources, CAAS, after a number of years selection from a single plant introduced from Nigeria. Hebei Crop Variety Appraisal Committee approved it in 1999. It is a special early-maturing and highly erect type with disease resistance to rust and virus. It is used mainly to produce dried seeds for human consumption. Its specific characters are dwarfness and erect habit. Zhong Jiang No. 1 is dwarf with a mean plant height of 34.3 cm, erect and compact with relatively centralized pods, which contribute to higher yield. Zhong Jiang No. 1 is extremely early maturing whether sown in spring, summer or autumn in Hebei province. In 1994, growth duration for spring-sown plant was about 85 days, for summer about 60-70 days, the shortest being only 54 days. The growth duration decreased with the delayed sowing. Crop sown after July 15, matured in about 70 days.

In 1992 and 1993, evaluation for agronomic characteristics of 230 elite cowpea resources selected during 6th and 7th Five-Year was carried out in Hebei, Anhui, Henan and other places. Average plot yield of germplasm lines tested was 54.85 kg (converted from yield per mu, 1 mu = 1/15 of ha). The mean yield of Zhong Jiang No. 1 was 96.8 kg which was 76.5% higher than the average yield of all varieties tested and ranked 4th. The yields of Zhong Jiang No. 1 in different sowing times were all higher than other varieties and it was stable in different plots and different seasons. It appears to have good adaptability (regression coefficient b =0.36).

Zhong Jiang No. 1 appears to have bright prospects for production and utilization, especially for intercropping and interplanting, crop rotation and cultivation in dry and unproductive areas. It is a good variety for future development of food legume production. The Zhong Jiang No. 1 also appears to be a promising parent material for breeding. In 1998, the ICGR of CAAS obtained seeds from seven cross combinations based on crossing Zhong Jiang No. 1 with large-seeded high-yielding cowpea varieties and yard long bean. According to the observations in 1999, five cross combinations performed well and it is hoped to develop from them high-yielding lines with even better characters.

The seeds of Zhong Jiang No. 1 are nutritious containing 25.3% of protein and 49.3% of starch; it is also rich in amino acids, minerals and vitamins, A1 and B1. It can not only be used directly as food grain but it also has potential for further processing to produce cakes, “eight treasure congee”, bean sprouts and cowpea seedlings as vegetable.

Industrial and other crops

Conservation and utilization of germplasm resources of fruit crops in northern China

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Advances in germplasm conservation of fruit crops in northern China

Establishment of national repositories of fruit crops

China, one of the centres of origin of several fruit crops in the world, is rich in fruit genetic resources. Chinese government has paid great attention to the study on the fruit genetic resources. As early as the 1950s, over 1000 people were assigned to survey fruit crops in the country. In early 1960s, another survey was carried out in remote areas of the country. Due to these 2 surveys, the status of fruit genetic resources in China was better understood. During the 5th "five-year-plan" period, large scale collecting of fruit genetic resources was carried out. In the 6th "five-year-plan" period, fifteen national repositories for 19 fruit crops were established. Altogether 10 043 accessions of apple, citrus, pear, hawthorn, peach, plum, apricot, date, persimmon, chestnut, walnut, grape, strawberry, banana, litchi, longan, loquat etc., were conserved in the repositories, with an area of 123.5 ha. Among them, 8161 accessions, covering 98.2 ha, belonged to temperate fruits.

Utilization of the repositories

The repositories are the bases for scientific studies on fruit genetic resources. In the 7th and 8th "five-year-plan" period, "Conservation and Evaluation of Fruit Genetic Resources" was placed as one of the "National Science and Technology Research Projects". Nineteen fruit crops were evaluated for 11 characteristics and the National genetic resources database was set up. From the conserved material, 921 superior accessions were selected. Studies on "Evaluation of Germplasm and Selection of Superior Accessions of Fruit Crops" won the second class award of National Science and Technology in 1995. On the basis of statistics, more than 60 accessions were directly used in production, with an average economic value of 45 000-75 000 RMB (US$ 1 = RMB 8.27) per ha and a total value of 10 250 million RMB (US$ 1239 million). In addition, the repositories supplied scions, plantlets and breeding materials for all the country. The repositories also served the society for international academic exchange and research by university students.

Problems and proposals

As fruit crops are perennial crops, planting in the field is the most important way for germplasm conservation. This may require a large amount of labour every year. Therefore, the main problem of the repositories has been lack of financial support. Because of this, most repositories were managed poorly and some materials suffered serious damage by various diseases and were lost. For example, 33 different accessions of apple were lost owing to apple rot disease. Since the plants became more susceptible when exposed to natural hazards due to poor management, 150 accessions of grape died due to a cold injury in the year 1996.

Another problem is that the researchers and managers could not give their full attention to the repositories. They received quite low level of remuneration, and sometime their salaries were not satisfactory. In the 8th "five-year-plan" period, one-third of the researchers left the "National Repository for Plums and Apricots", and 120 accessions were lost.

Some solutions for the above problems are proposed here.

1. A National Committee for Germplasm Management should be set up. It will be the supervisory body and will coordinate the work of all repositories, and will be in charge of making regulations, investigating and resolving the contradictions in germplasm research.
2. Collecting, conservation, identification and evaluation of germplasm should be regarded as the national basic research project. The government should give the full financial support for such basic research, including salaries of the scientists and assistants, expenses for the repository management to be able to maintain permanent research and management teams.
3. The leaders of the respective research institutes or universities where the repositories are established should promote greater attention and support to the repositories. The germplasm could be applied to production, and the earnings could be used for compensation for the expense of the repositories and improvement of staff's living standard. Improving the basic conservation facilities should be given priority, so as to increase the protection against natural hazards.
4. ***In vitro*** conservation facilities, including short, medium and long-term storage, should be developed.

Utilization of fruit germplasm resources

Use in production

Present status of fruit production in China: Based on the statistics in 1998, the total area of orchards in China reached 8 649 000 ha of which fruits grown in the north of China covered 7 162 000 ha, accounting for 82.7%. The gross production of fruit crops reached 50.9 million tons of which 37.4 million were northern fruits. In China, per capita consumption of fruits is 41.4 kg fruit of which 31.14 kg was northern fruit, compared to world average of 77.6 kg. Nowadays, the main problems of fruit production are the low quality and low economic return. Higher quality fruit accounted for 30% of the overall production, and the top quality accounted for only 5%. Fifty percent of the fruit was sold at lower price. The rest (20%) fruit produced could not be sold due to the bad quality. Besides growing conditions, shortage of good varieties was one of the most important reasons. In addition, the capacity of storage was very limited, accounting for less than 5% of the total output. The cultivars suitable for processing are seriously lacking. No more than 10% of the total production is available for processing. In recent years, the amount of fruit imported exceeded that was exported.

A key need for improving current status is to improve fruit quality. In addition to improving traditional techniques and using advanced techniques, we should take advantage of our superior germplasm resources to enhance quality fruit production.

Cultivation of special types: A strategy of 'branding' of special, outstanding and new cultivars needs to be developed. We have cultivars that can compete in the world market and such branded fruits can bring in more foreign exchange. For example, in recent years, we have bred 'Bayuehong', 'Hongxiangshu' and 'Hongnanguo' etc., big, crisp, fragrant and red pear cultivars. Only China has these cultivars that have much potential for export. Top-working methods need to be used to renew old cultivars to deal with senility problem in our production areas. The favourable cultivar constitution should be promoted so that such cultivars will be able to spread fast leading to the development of fruit industry in the country. Thus we can produce high quality fruit and compete in international market.

Intensive cultivation: Taking full advantage of better resources and suitable natural conditions, we should carry out intensive cultivation. Through intensive cultivation it is possible to obtain high quality fruit with good shelf life and greater economic return. For example, in ‘7th five year plan’ period, the ‘Lizao’ jujube, weighing 31.6 g per fruit, was selected and close-planting was suggested. Its planting area went up to 73 333 ha. In Shandong province, dwarf ‘Yimmeng spur’ Chinese chestnut (1.6 m in height at the age of 10) is grown closely planted (4995 trees / ha) and intensively cultivated and 3 years after planting, it fruited heavily and its yield was up to 7500 kg ha^{-1} in 5 years after planting. In addition, the region’s natural superiority should be fully taken advantage of to produce noted, special, high quality and rare varieties. For example, ‘Nanguo’ pear, only in Anshan city one can produce the highest quality fruit and is popular with customers fetching 10.00 – 40.00 RMB / kg after Spring Festival. In this city, “Zhongai No.1” pear, a dwarfing interstock selected from pear repository is used to achieve dwarfing and close planting cultivation.

Dwarf and early maturing cultivars: It is important to provide early ripening and high quality cultivars and developing adequate facilities (artificial and enclosed environment) for cultivation. In recent years, in pace with market economy, and changes in fruit industry, facilities for fruit tree cultivation have been improved significantly. To some extent, the customers’ needs at different times of the year and for fresh fruits were met and significant benefits were obtained. The facilities for fruit species cultivation have been increasing gradually. For example, production areas with facilities for cultivation of strawberry, grape, peach and cherry increased very fast, while those for plum and apricot increased more steadily. Using dwarfing pear resources to carry out pear facility cultivation have succeeded experimentally. Most cultivars and dwarfing stocks used in facility cultivation were obtained from research carried out on available genetic resources. Facility cultivation can increase returns as high as 10 to 20 times compared field cultivation, going up to 150 000 to 900 000 RMB per ha For example, peach repository in Zhengzhou City provided 7 nectarine cultivars for facility cultivation, and extended 2300 ha. The accumulated output value was up to 500 million RMB. From now on, through research on fruit genetic resources, the noted, special, high quality and new cultivars will be provided continuously.

Selecting cultivars for processing and establishing fruit production bases for processing: At the beginning of liberation of our nation, the fruit processing industry was nearly to zero. Today, 50 years later, fruit processing industry has developed to some extent. Fruit juice output is about 2 million tons, but this far behind that of developed countries and needs of the country. Every year, only about 10% of fruit produced in the country are used for processing, while in the USA it is about 45%. Our country is not only short of high quality cultivars suitable for processing but also in processing units. Genetic resources researchers can help in reducing the gap in cultivar base for processing. For example, plum and apricot repository selected ‘Chuanzhihong’ apricot. This apricot is suitable for making excellent quality juice and canning and in 1993, it was awarded gold medal in Singapore Beverage Exhibition. In china, the apricot extension area is up to 10 000 ha^{-1}, and only in Julu County, Hebei province has 3666 ha production base. Over a period of 10 years, the benefits went up to about 1 billion RMB. The apricot production has become this county’s main fruit industry. We should take advantage of the superiority of our cultivar resources and enrich cultivar constitution. For example, pear repository selected ‘Jinxiang’ pear and ‘Aixiang’ pear for making juice. Pear repository selected yellow flesh peach cultivar, persimmon repository selected persimmon for crisp slices. Plum and apricot repository selected ‘Caoren’, ‘Fengren’ and ‘Youren’ apricot for kernel, and among them the ‘Rongwangma’, a single kernel weight is up to 0.99g.

Use in breeding

Evaluation of fruit resources helped to select excellent and special germplasm that were used in breeding and made significant achievements. For example, peach repository provided parents for breeding 15 cultivars such as, 'Shuguang', 'Yianguang', 'Danmo', 'Hongsahu', 'Xiangshanhu' and 'Zaoxialu' nectarines and 'Zhenghuang No. 2', 'Zhenghuang No. 3', 'Zhenghuang No. 4' and 'Zhenghuang No. 5' yellow flesh peaches and 'Zhengyoupan No.1' and 'NF9260' Youpantao,Bailey; and 'Leyuan' and 'Ailihong' dwarfing ***P. persica*** var. ***platycarpa*** Bailey. Nanjing strawberry repository used heat-resistant and hard-flesh strawberry 'Suofeng' to cross with Japanese cultivar 'Fengxiang' and selected a cultivar 'Shuoxiang' with storable fruits. Shanxi Jujube Repository used dwarfing jujube resources to breed 4 dwarf cultivars suitable for processing. Pear Repository provided excellent parent 'Zaoxu' for breeders who used this germplasmand bred 6 cultivars such as red pear 'Bayuehong', extremely early ripening pear 'Qiyueshu', disease-resistant cultivar 'Zaomeisu' and Vitamin C high-content cultivar 'Beifeng'.

In order to enhance utilization of excellent and special germplasm in fruit breeding, we propose the following.

1. ***Fully utilize evaluated and special germplasm to serve modern breeding programmes***. In quality breeding, the high Vc content (808.8 mg/100 g) 'Pozao' jujube, the high sugar content (20%) 'Luotian' sweet persimmon, hard flesh strawberry 'Nufeng' and 'Fengxiang' could be used. In breeding dwarf cultivars, compact pear, apomixis apple, dwarfing resources 'Mengyang Dajingxing' hawthorn, 'Jiusan' apricot-plum hybrid, 'Lu 03' chestnut, and 'Pu126' walnut could be used. In early ripening variety breeding programmes, 'Luotuohuang' apricot with a fruit development period of 50 to 55 days, A11403 plum, 'Qiyuecao' persimmon which could be harvested at the end of June or at the beginning of July, and 'Pearl of Csaba No. 1' which ripens ten days before 'Pearl of Csaba' grape are excellent resources that could be used in breeding. In disease-resistant breeding programmes, breeders can use 37 selected accessions with resistance to ***Alternaria alternata***, ***Myzus persicae Sulzer*** and ***Plasmopara viticole*** .
2. ***Innovation and improvement of fruit breeding techniques***. According to needs of breeding, the following are proposed: Dwarf apple with apomixis trait; development of dwarfing stocks for apple; red, big, compact pear; nectarines that require 400 to 500 hours of chilling and a fruit development period of 58 to 70 days; big fruited sweet persimmon with small; dwarfing interstock for chestnut; early-ripening apricot with low chill-requirement; big, non-cracking and early ripening grape; dwarfing, dry-use jujube; and spike-like, thin shell and full kernel walnut.
3. ***Use of modern methods to assess and select germplasm***. At the beginning of '9th Five-Year Plan', modern research techniques such as allozyme analysis, RAPD, AFLP etc. techniques will be used to identify and select fruit germplasm.

Evaluation of Fuji apple pollen plants and their application in breeding

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Growth characteristics and fruit quality traits of pollen-derived strains of Fuji apple were evaluated. These strains were also included in further breeding. The length of one-year-old shoots and the thickness of the trunks were significantly larger than those of Fuji (control). Fruit quality was better than that of the control. Fruit weight, soluble solid content and hardiness of the plants were higher than all cultivated varieties. x-ray of 4000 Roentgen was suitable for inducing variation in pollen-derived Fuji plants, with a survival rate of 66.7%. Variation in phenotype was observed in F_1 progenies between pollen-derived plants of Fuji and Delicious, indicating that multiple genes controlled most of the agronomic characters of apple.

The achievements of and strategies for studying grape germplasm resources

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China is a centre of origin of ***Vitis***. Over 40 species of ***Vitis*** are native to China. Grapevine has been grown in China for more than 2000 years, so many places have their own landraces. In addition, many varieties from abroad have been introduced over the years. Thus the grape germplasm resources in China are rich and diverse.

The progress of studying on grape germplasm resources

Establishment of national grape germplasm repository

The scientific five-year-plan of the Chinese State Council initiated to investigate, collect, characterize and utilize germplasm resources of fruit trees all over the country in 1956. Some research institutes and universities had established cultivar repositories for grape breeding in 1960. In 1978, The Chinese Agricultural Department planned to establish National Fruit Tree Germplasm Repository. This plan started in 1981 and was completed in 1989. National Germplasm Repositories, which preserve grape collections, are Zhenzhou grape germplasm repository, Taigu grape germplasm repository, Gongzhuling fruit tree germplasm repository and Zuojia grape germplasm repository. Zhenzhou grape germplasm repository preserves about 1000 collections, which is the biggest grape germplasm repository in China. The germplasm is maintained on its own root (not on rootstock) and are field-grown.

Characterization and evaluation on grape germplasm resources

From 1985-1995, Zhengzhou Fruit Tree Research Institute and Shanxi Fruit Tree Research Institute characterized about 700 varieties and described 566 varieties. Through evaluation, we had selected many genotypes, which have more than one outstanding character. Northweast Agricultural University, Hunan Agricultural University and Shanghai Horticultural Institute have carried out many studies on wild species native to China. ***V. amurensis, V. yanshanensis*** and ***V. adstricta*** gave the highest scores for winter hardiness (He and Niu 1989). The East Asian species that possess genes for resistance to downy mildew are ***V. pseudorticulata, V. davidii, V. romaneti, V. piasezkii, V. hancockii*** and ***V. yanshanensis*** (He and Wang 1986). The species that possess tolerance to white rot are ***V. davidii, V. amurensis, V. aanshanensis*** and a wild species native to Qinba mountain (He and Niu 1988). Many wild species native to China are tolerant to black meastes. ***V. amurensis*** and V. davidii were found possess highest tolerance to anthracnose, while ***V. quingangularis, V. pseudoreticulata*** and ***V. bryonifolia*** were tolerant to anthracnose (Wang 1987).

The utilization of grape germplasm resources

The main purpose of germplasm study is to select accessions with desired traits for developing new cultivars. Beijing Botanical Garden, Beijing Forestry and Fruit Tree Institute, Shenyang Horticultural Institute and Zhenzhou Fruit Tree Research Institute succeeded in developing new cultivars by means of hybridization, some of which are still planted commercially, such as ‘Jingzaojing’, ‘Jiangxiu’, ‘Jingyu’, ‘Fenghuang No.51’, ‘Zizhenxiang’, ‘Zuijinxiang’, ‘18-5-1’, ‘Zhengzhou early red’, etc. Other cultivars originated as selections of clones from seedlings of unknown ancestry. ‘Jingya’, ‘Jingyou’ and ‘Fenghou’ are examples of these breeding activities. The fruits of ***V. davidii*** are the biggest of all wild species. Since the climatic conditions, especially abundant rainfall, are suitable for growth of this species, farmers in Yushan County have been growing it for many years. The cultivated area of this species is about 80% of the total area in the county. The acreage under of this wild species is about 80% of grape in Yushan County of Jingxi province (Zhang and Fan 1985). As an important germplasm for breeding for of cold resistance, ***V. amurensis*** is highly thought of by breeders in China. This species has been used to in intraspecific and interspecific hybridization and many cold-resistance varieties and hermaphrodite flower type had been selected.

Future prospects

Some proposals for future work are - to develop a core collection; to establish new repositories in different special ecological regions; to establish virus-free and ***in vitro*** germplasm repository; to strengthen collecting and utilization of wild and semi-wild species native to China.

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Evaluation and utility of ornamental characteristics of peach flower

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Ornamental value of 26 peach varieties was evaluated and the results indicated that there were many different types that could be used for ornamental purposes. Peach tree growth habits included standard, dwarf, weeping, pillar and compact type. Flower colours were dark red, pink and pure white. Different types of flowers were observed, such as single showy, double showy, single non-showy, double non-showy and chrysanthemum. Diameter of flower ranged from 3.1-5.5 cm. Petal numbers generally varied between 1 to –6, however, the highest petal number observed was 92. Flowering lasted for nearly 2 months, earliest being Honggengansutao and the latest in Sahongtao. It was also noted that some of the varieties, mostly local varieties, could be used for fresh flower purposes (Zhang 1991) and they might possess resistant genes to disease, insects and other stresses (Zhu ***et al***. 2000). Peach flower is a traditional ornamental flower; symbolizing happiness in China (Wang ***et al.*** 1998). Most Chinese like them and peach flower festivals are organized in many cities. So peach, as an ornamental tree, has good future in China. At the same time, these varieties could be used for resistant resources. Main varieties of ornamental peach flowers are listed in Table 1

Table 1. A brief description of the main ornamental peach flower varieties

Varieties	***Evaluation***
Zhouxingshantao	Early bloom, pillar tree, resistant to ***M. perica***, cold and dry
Baihuashantao	Early bloom, resistant to ***M. perica***, cold and dry
Honggengansutao	Early bloom, Flavour, Resistant to ***Meloidogyne incognita***, cold and dry
Baihuashanbitao	Low chill, early bloom, white flower, resistant to ***M. perica***
Ganxuan 4	Low chill, early bloom, double and pink flower
Xiantao2-7	Low chill, early bloom, single and pink flower, big, double and red flower, medium fruit size, white flesh and sweet
Huangjinmeili	Big and pink flower, big fruit size, yellow flesh and sweet taste
Honghuabitao	Open tree, double and light red flower
Jiangtao	Double and dark red flower
Chongbanyulu	Big and double flower, big fruit size, white flesh and sweet taste
Hongyetao	Double flower, dark red leaves and flower
Juhuatao	Double pink flower and chrysanthemum
Renmiantao	Double pink flower and lovely
Wubaotao	Double and light red flower
Feitao	Double and big and light flower
Sahongtao	Double and Pink, white and red flower, long bloom period
Bitao	Double and pink flower, anther colour white
Hongshouxing	Dwarf, double and dark red flower, resistant to ***M. perica*** and nematode
Daguoshouxing	Dwarf, double and dark red flower, big fruit size and sweet taste
Shoufen	Dwarf, double and pink flower
Shoubai	Dwarf, double and white flower
Leyuan	Dwarf, Single pink flower, nectarine and big size
Hongchuizhi	Weeping and double red flower
Zhufenchuizhi	Weeping and double pink flower
Yuanyangchuizhi	Weeping, double pink and red and white flower

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Collecting and maintenance of wild cotton germplasm and their utilization in China

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There are 51 species for ***Gossypium*** worldwide, and among these, four are cultivated including two tetraploids (***G. hirsutum*** and ***G. barbadense***) and two diploids (***G. arboreum*** and ***G. herbaceum***). The wild cotton resources include the wild species, races of the cultivated species (also called semi-wild cottons), relatives of ***Gossypium***, etc. Cotton is not native to China and the resources have to be introduced from abroad. However, their collecting, maintenance, improvement and utilization in our country have not only made significant achievements but also helped improving our cotton cultivars and production in the country.

Intensifying genetic evaluation and sustainable utilization of oil crop germplasm

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Much work has been done on collecting, evaluation, identification and utilization of oil crop germplasm in China. During the period from 1986 to 1999, the germplasm research was listed among the national key projects and over 20 institutions participated in the project for oil crops germplasm. These efforts resulted in collecting and assembling of 6251 accessions of rapeseed, 6050 of groundnut, 4200 of sesame, 2813 of sunflower, 529 of perilla, 2074 of castor and 4200 of safflower. For the first time this formed the basic germplasm collection of oil crops in China.

Following the establishment of the collection, multiplication and storage of oil crops, extensive evaluation and utilization of them was conducted. A large number of elite germplasm lines with one or more desirable characters were identified. Such elite germplasm included: rapeseed with low eruic acid and glucosinate and resistance to stem wilt caused by ***Sclerotinia*** ssp., yellow-seeded rapeseed without glucosinate, yellow-seeded rapeseed with high protein content, ***Brassica compestris*** and ***B. juncea*** genotypes with low glucosinate; groundnut lines with high protein content, high oil content, low lineolic acid, accessions with resistance to leafspot, rust and bacterial wilt diseases and nematode; sesame lines with resistance to ***Macrophomina*** ssp. and ***Fusarium*** wilt, tolerance to waterlogging, high protein and high oil content. These germplasm have been used in breeding programmes and even in production with significant impact on the economy and social development in the country.

Even though marked progress has been made in germplasm research in China, intensive evaluation of the germplasm has been lagging behind. There are some important aspects to be further investigated in terms of utilizing the germplasm in an efficient and sustainable way.

Genetic diversity of oil crops

With the support of national key projects for the 3rd five-year workplan, more than 2000 oil crop germplasm accessions have been assembled. However, the genetic diversity of these crops is still not clear. Therefore, systematic evaluation of the collections, including the use of molecular methods is necessary. With such a systematic evaluation, it is hoped to generate comprehensive information on genetic diversity and on desirable genes in oil plant genetic resources, which will greatly help oil crop improvement efforts.

Establishment of core collection of oil crops

The only research on core collection of oil crops in China is the one on sesame by the support of the International Plant Genetic Resource Institute (IPGRI). For rapeseed and groundnut, the number of accessions collected for each is over 6000 which is too large to analyze critically. Establishing core collections of the major oil crops is key to intensify germplasm research as well as its use.

Pest resistance and tolerance to nutrient deficiency

Though much work has been done on assessing oil crop genetic resources for their reaction to various diseases, very little work has been done on their reaction to insect pests. Thus resistance to insect pests should be a priority. As nutrient deficiency especially in south China is a common constraint to production, it is important to evaluate oil crop germplasm to identify accessions that are tolerant to nutrient deficiency.

Further collecting in some special regions

Up to now, very little germplasm has been collected from coastal regions and islands. It is hoped that some germplasm with tolerance to salt, heat and wind could be collected from the islands. Further collecting is needed in regions including Three Gorges, Baise in west Guangxi, southwest in Guizhou for rapeseed, prostrate and ***hirsuta*** types of groundnut, sunflower, castor, perilla, and sesame.

Introduction of elite germplasm from foreign countries

In the case of some new diseases and pests on the oil crops with narrow genetic background such as ***Brassica napus*** and groundnut, it is necessary to introduce some key germplasm lines and related wild species from foreign countries and utilize them by suitable means.

Study on genetic diversity of alfalfa (*Medicago sativa* L.) local varieties in China

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Genetic diversity and genetic structure of the 18 alfalfa local varieties were studied using agronomic traits, seed storage proteins and RAPD markers. Varieties representing the nine alfalfa basic sources in North America were compared. Results showed that genetic variation of ***Medicago sativa*** L. existed mainly within varieties. Compared with the 9 varieties in North America, polymorphic loci rate (P) and gene diversity within variety (HS) of the 18 local varieties were higher and genetic diversity coefficient (GST) and genetic distance (D) were smaller. These measures indicate that the local varieties of alfalfa are more heterozygous; difference between varieties is smaller and relatively more variation exits within varieties. These results also indicate that genetic structure of alfalfa variety is not only related to breeding system (out-breeding), but also to geographic distribution. Genetic diversity revealed by RAPD markers was about 2.5 times higher than that revealed by seed storage protein markers, indicating that the level of genetic diversity is related to the level of gene expression.

Study on identification, screening and use of forage germplasm resources in China

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The project on Study on Identification, Screening and Utilization of Forage Germplasm Resources was one of the National Science & Technology Key Projects during the seventh and eighth Five-Year-Plan period from 1986 to 1995. The Institute of Animal Science of CAAS was in charge of this project. Eight institutes and universities were involved in the project. Unified objectives, methods and standards for identification were made in different ecological regions in five climatic zones. Morphological characters and agronomic traits on 4543 accessions were recorded. Tolerances to different stress conditions of 1324 accessions were evaluated. Two hundred and thirteen accessions were selected for their outstanding traits. Sixty-five varieties were identified for direct utilization in forage production. Among them, fifteen varieties have been released by the Chinese Herbage Cultivar Registration Board.

The utilization status of Chinese mulberry germplasm resources

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China is the origin of sericulture and through years of evolution under domestication and natural selection, mulberry genetic resources now have rich genetic diversity. Significant progress has been made on germplasm collecting, documentation, evaluation and utilization of mulberry germplasm resources in China since 1984. Twenty seven provinces have been explored and 2600 accessions of mulberry germplasm have been collected. The national mulberry genebank at Zhenjiang was established in the Sericultural Research Institute of CAAS in 1990. About 1801 mulberry accessions, which include 12 species and 3 variants, have been conserved in this genebank, which is the only national genebank of sericulture in China and the biggest in the world.

Records of Chinese Mulberry Variety was published (SRI 1993). From 1984 to 1998 various kinds of mulberry germplasm were presented to the cultivators as breeding materials, from which 18 new mulberry races and fine descendant strains have been cultivated, such as Yu 71-1, Jialin 16, etc. These new mulberry varieties distributed over the national sericulture districts meet the demands of sericulture for mulberry cultivars.

Total of 1409 accessions of mulberry was catalogued, of which 709 accessions were documented and included in the information system of the Chinese Crop Germplasm. Chromosome identification was carried out for 713 accessions and diversity in ploidy level was found. Besides diploids there were 73 accessions were polyploids including docosaploid(1), octoploid (4), hexaploid (10), tetraploid (8) and triploid (50). A total of 771 accessions were characterized for various agronomic characters and 16 accessions with higher leaf yield per year were selected. The selected accessions yielded 10% more leaf per year than the control variety Husang 32. A total of 816 accessions were tested for raising silkworm and 14 accessions with 10% higher cocoon crop per 10 000 four-instar silkworms, cocoon shell weight per 10 000 four-instar silkworms and cocoon crop per 100 kg leaves than the control Husang 32 were identified. A total of 459 accessions were evaluated for resistance to yellow dwarf of mulberry and 8 accessions with high resistance were identified for which the disease index was 0 under artificial inoculation conditions. Of the 15 accessions with high leaf yield, good quality and resistance to disease identified, 8 accessions were selected for direct use in production. The leaf yield of the 8 accessions was 14.8-28.3% higher than that of Husang 32. Fengweiyabian, Suhu-16 and Xuan 81 showed medium-high resistance to yellow dwarf of mulberry and have been used in Shandong, Jiagsu, Zhejiang and Anhui Provinces.

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The current situation and development direction of tobacco germplasm research

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A total of 4014 tobacco accessions were collected and catalogued. A tobacco germplasm conservation system with medium and long-term genebanks was set up. The agricultural, quality and disease resistance characters of tobacco germplasm have partly been evaluated. Screening has revealed a number of germplasm that have desirable characters and these have been provided to breeders, producers and researchers. Thus significant achievements have been made in tobacco germplasm work. In the future, the research of tobacco germplasm will be carried out more intensively. The evaluation for phenotypic characters will be completed, a tobacco core collection will be established and use of molecular genetic markers will be made to study and use tobacco genetic resources. Germplasm of wild tobacco species will be established and used. The germplasm that have rich potassium will be screened and used. New tobacco germplasm with medicinal properties will be developed.

Preservation and utilization of tropical flower germplasm resources in Hainan

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There are 859 flower species in Hainan province. Among them, 406 are wild species and 453 are cultivated species, belonging to 97 families and 390 genera. They also include 47 species peculiar to Hainan, 3 orchids peculiar to East Asia and 93 excellent-quality germplasm.

To protect and develop tropical flower resources, a number of investigations have been made since the founding of the People's Republic of China. Some rare germplasm of wild tropical flowers have been listed as national first-rate, second-rate, and third-rate protected plants and conservancies have been set up to protect the surroundings of their habitats. In addition, South China University of Tropical Agriculture has set up the speciality of garden for viewing and admiring, and it has trained a number of advanced technicians who can undertake the research of tropical flower resources. All these measures have played an important role in protection, development and utilization of wild plant resources.

The measures for protecting tropical flowers resources and their continued utilization are as follow: Strengthening guidance to policy development and improving management; fulfilling the protective measures ***in situ***; establishing Tropical Flower Research Center and providing techniques for industrialization of tropical flower production.

To protect natural resources and create tropical flower germplasm collections, it is quite inadequate to depend only on several natural conservancies, a few plant gardens and some self-dependent small enterprises and family business owners. In order to better protect and suitably exploit tropical flower resources in Hainan and create new germplasm, it is necessary to set up a research centre of tropical flowers. The centre should rely on higher academies (such as South China University of Tropical Agriculture). It is necessary to organize a keen and capable team, for developing ***in vitro*** preservation and rescue of rare tropical flower resources in severe danger of extinction, launching effectively tissue culture and cultivation, cell hybridization, pollen hybridization (including test tube fertilization) and gene transformation and germplasm enhancement of tropical flowers. At the same time, the centre should undertake work on technology development and training in flower cultivation methods. Such a work will play major role in disseminating techniques to flower enterprises and professional garden owners. The research centre should also play a leading role in promoting the development of tropical flower industry, bringing out named/branded products, creating beautiful surroundings and ecosystem and contribute to the enrichment of human culture and life.

Status, problems and strategy of vegetable germplasm resources in China

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China is one of the countries in the world with the most rich plant resources. Wild and cultivated plants of about 213 families, 815 genera, 1822 species can be used as vegetables. About 5% of them have been domesticated into cultivation (Chen 1998). With the development of modern agriculture, only a few high-yielding vegetable species/cultivars are used in production and supply. Since late 1970s, exploitation of heterosis phenomenon, hybrid varieties of vegetables have gradually replaced all most all local varieties and many wild vegetable species have also disappeared. In addition, the loss of vegetable diversity and unbalanced diet and nutrition of people have been aggravated due to various reasons, including industrialization, urbanization and subsequent environmental pollution at a pace.

In early 1980s, Chinese government and scientists began to pay attention to the issue of erosion of plant germplasm resources in China. Through several large-scale scientific reviews, the general status of plant diversity, distribution, extent of erosion of plant resources ***in situ*** and potential dangers for crop germplasm resources has been understood. Collecting and conservation of crop germplasm resources were placed high on agenda. Since 1986, the project on vegetable germplasm resources research as a special activity or task was organized as part of the national key project "Research on Crop Germplasm Resources". It involved collecting, propagation, characterization, cataloguing, conservation, evaluation and enhancement. About 300 researchers from 38 institutes all over the country participated in this vegetable project led by Institute of Vegetables and Flowers, Chinese Academy of Agricultural Science. About 85% of local vegetable varieties from the most part of the country have been conserved in long-term storage. A large number of excellent vegetable germplasm with one or more desirable/outstanding characters have been identified and have been supplied to breeders or for direct use in production. Some of them have been effectively exploited. However, there are many different vegetable crops and more research is needed so that they could used in breeding and or in production to meet the needs of estimated 1.6 billion people in China in 21st century. In addition, there are many problems that limit the development of crop germplasm research and utilization and most of these have been seen as long-term and systematic projects. This paper reviews the past work and achievements, identify problems and make some recommendations for future work in vegetable germplasm resources.

Status of conservation and utilization of vegetable germplasm resources in China

Status of vegetable germplasm conservation

By the end of 1999, 29 912 vegetable accessions have been conserved in the long-term genebank as seed and in nurseries as living plants They include 21 families, 67 genera and 132 species. Among them, 28 573 can be propagated through seed. They are conserved in the national long-term genebank and medium-term genebank of vegetable germplasm in Beijing. A total of 1339 accessions are aquatic vegetables. They are conserved in the national garden of hydrophytic vegetable resources. About 90% of all vegetable germplasm are the old local varieties that fell into disuse or faced extinction. Some precious local varieties and wild species have been identified, such as black seed pumpkin, dwarf pumpkin, seed-capsule-free pumpkin, rain forest red taro, Alp red lotus, Lishui early sponge gourd, wild carrot, wild balsam pear, wild green onion, wild Chinese chives, wild eggplant, and so on. Some of them have been widely used in production, for example, Ershui early garlic, Beauty in the mind radish, March radish, Erbaipi stem lettuce, etc. However, it is a pity that no other vegetatively propagated vegetables have been conserved because of some technical and financial problems. Besides, wild vegetable germplasm account for only 0.5% of all conserved vegetables.

Evaluation and identification of accessions with desirable traits

About 30 morphological characteristics for each accession were investigated. A basic database of 900 thousand data items has been established.

So far, resistance sources of 13 different vegetables to 24 diseases have been identified by inoculation at seedling-stage or under natural infection in the field. From 20 962 accessions tested, 1409 elite germplasm with disease-resistance have been selected. Tolerance and resistance of 3 different vegetables to different environmental stresses was evaluated. From 1290 accessions, 123 germplasm with heat-tolerance, late-bolting or suitable for storage have been identified. About 16 442 accessions of 12 different vegetables were analyzed for 52 different quality traits and 347 accessions with good quality have been identified.

Based on multi-year and multi-site evaluation, a number of accessions with excellent and stable-inheriting characteristics have been chosen out (Table 1).

Table 1. Evaluation of vegetable germplasm conserved in national medium-term genebank from 1986-1998

Species	*No. of Accessions evaluated*	*No. of accessions with desirable traits*	*No. of accessions with highly desirable traits*	*Year*
Kidney bean	218	54	20	1986-1995
Capsicum	200	15	9	
Chinese cabbage	204	27	13	
Cucumber	248	10	10	
Chinese cabbage	75	45	3	1996-1998
Radish	120	100	3	
Kidney bean	35	25	2	
Capsicum	155	55	3	
Aquatic vegetables	96	26	2	
Cowpea	75	42	3	
Total	1208	399	68	

Use of vegetable germplasm

Distribution

Since 1986, 38 694 accessions of different vegetables were evaluated by the research group attached to the national medium-term vegetable genebank and its cooperative units all over the country. The accessions known to possess desirable traits have been distributed to users. In total, the national medium-term vegetable genebank has distributed 6943 accessions of 53 vegetables to 373 domestic production, breeding and research units, and 124 research units in 28 countries in 597 batches.

Direct utilization of vegetable germplasm

Since 1984, a large number of local vegetable varieties and introduced germplasm have been exploited. Use of these good vegetable germplasm in production will not only raise the level of vegetable production, but also will optimize vegetable variety structure and promote vegetable variety diversity, bringing significant economic and social benefits.

Indirect use of vegetable germplasm

While collecting, conserving and identifying vegetable germplasm resources, researchers pay attention to enhancement and use of vegetable germplasm. Based on the identified vegetable germplasm, many new varieties have been developed. Because of intellectual property rights, the origin of most new varieties could not be known freely. Therefore, it is difficult to know the number vegetable germplasm that have been used. However, some typical examples can describe the role of good vegetable germplasm in breeding.

Capsicum inbred lines 6421, 8214 and 5901 etc., developed from the local variety Hengyang fudijian, Hexi niujiao and Aishuzao, inbred line 7801 screened from germplasm Zaofeng 52 and inbred line 8501 chosen from germplasm Mala sandaojin by Institute of Vegetables, Hunan Academy of Agricultural Science were used for the development of hybrid series Xiangyan 1-13. These hybrids have different maturity, have multiple resistance to biotic- and abiotic- stresses. They have been extended to more than 30 provinces since 1986. Its cultivated area reached to about 500 000 hectares. Value realised from Capsicum production was raised by additional 6 billion yuan (Liu ***et al***. 1991, 1992; Zhang and Zhou 1990; Zhou ***et al*** 1998).

In spinach, inbred line 8605 developed from germplasm Chunqiudaye was used for developing the hybrid “Huabo 1” by Huazhong Agricultural University. The hybrid is fast growing and vigorous, tolerates high temperature and has good quality. It contributed an additional production value of 0.1 billion yuan by extending to 20 thousand hectares (Li ***et al.*** 1994, Yan ***et al.*** 1994).

Problems and opportunities in vegetable genetic resources

Problems in collection and conservation

Technology and management limit further collecting and conservation

In the past, many people from different regions were involved in the collecting and propagation of germplasm, and hence, a large number of vegetable accessions were collected in a short time. For the similar reason, characterization was extensive. However, it must be noted that there could be several duplicates in the collection, for example, some germplasm from different sources have the same names. Some accessions have the same name, but are actually different. Because of the limitation of fund and conservation methods, collecting of wild germplasm, vegetatively propagated vegetables and perennial vegetables have been ignored. In addition, introduction of exotic germplasm has been limited, as there was no proper agency to introduce, monitor and manage them.

Medium-term genebanks need more attention

For a long term, our government focused its attention on the developing long-term conservation facilities. More than 30 000 accessions are conserved in the medium-term genebank. The vegetable medium-term germplasm bank is responsible for the distribution of vegetable germplasm for use and study. In the past 15 years, the genebanks have supplied 45 637 accessions of various vegetables for study and breeding. There is also urgent to regenerate the germplasm accessions, as the viability of the seeds conserved may be being lost. Therefore, government should provide more resources for the medium-term genebank. The emphasis should been shifted from collecting to regeneration, safe conservation and further study.

Germplasm seed regeneration research

Species of vegetables are diverse, in terms of their biological traits such as breeding system, growth cycle, etc. Most of them are cross-pollinated crops and require isolation during propagation for their seed. Some of them have the specific propagation characteristics. Some times it is difficult to collect seed. So, it is important to study how to establish an optimum and cost-effective regeneration procedure in order to maintain the genetic integrity and genetic diversity while regenerating vegetable seed for conservation and use.

Problems in vegetable germplasm research

Germplasm research to meet the need of vegetable breeding and production

In vegetable breeding, relying upon hybrids has resulted in cultivars with narrow genetic background over the years. Their ability to resist the biotic and abiotic stress has been decreasing gradually. In vegetable production, worsened environments and diseases have greatly been influencing yield. As cultivation techniques are being transformed, specialized varieties suitable for different micro-niches and markets are needed. The future market will demand varieties with diversity. Hence, there is an urgent need to evaluate and screen good germplasm with multiple-resistances, good quality and so on. It is also necessary to enhance germplasm to have as many desirable characters as possible so that their use could be increased.

Research projects need to be regulated

In the present set up, vegetable and pasture are lumped together in a project. The research content contains collecting, propagation, regeneration, characterization, identification, evaluation and enhancement of various vegetables and pastures. Given this complexity of dealing with numerous plant species, it is difficult to manage and focus on main objectives. Some participating units can not take part effectively in the research as they lack proper facilities and needed skills. This situation limits seriously the proper development of vegetable germplasm research and needs to be urgently improved.

Less investment results in the lower research quality and unstable team

Under market economy, both applied and basic researches face serious challenges. The research units need to be reformed to be able to face the market, practise enterprise management and be cost-effective. The research fund as investment model excluding labour cost under planned economy can not meet the costs of germplasm research. This model is not good for the research that needs in depth studies. Because of the low income and less research fund, most of the young well-trained researchers tend to shift from germplasm research to breeding and extension departments. It can be said that there will not be good varieties without good germplasm, there will be not good germplasm without high investment.

Problems in vegetable germplasm utilization

Policy of encouragement

The present policy on evaluation of research results and encouragement is carried out according to area that has been extended and direct economical benefits realized. With this policy, it is easy for new varieties to gain important awards. And breeders can get research fund and award easily from governments. Compared to this, it is a hard to evaluate the work on collecting and evaluating germplasm resources. These activities, together with germplasm enhancement work, make it hard for germplasm researchers to be fairly evaluated. It is also difficult to show the direct economic benefits from the genetic resources work, as the impact of the work comes only after the successful utilization of the material and this takes very long time. In addition, most breeders in the past did not admit the contribution of the germplasm that they obtained from the genebank, even though they have used them in their variety development programmes.

Lack of operational mechanism of distribution, exchange and sustainable utilization

Decision-makers and managers usually stress that researchers should supply the best germplasm to breeders. But they pay less attention to the actual problems in germplasm research and do not realize the important link between germplasm resources and breeding. For example, amount of seed for every germplasm is limited. After distribution, who will be responsible for regenerating much germplasm for further identification, evaluation and use? Where is the fund coming from for regeneration and seed increase? All the germplasm have been accumulated by several generations of germplasm researchers' efforts. However, breeders use the germplasm free of charge to develop new varieties and get rewarded through national investment. Some breeders hold much germplasm by themselves and are not willing to share with others. Breeders introduce foreign germplasm by various ways, but do not share the samples to be conserved in the national genebank. This situation is needs to be improved.

Strategies for the future vegetable germplasm conservation, research and use

To reform the operating mechanism

The role of major special medium-term genebanks should be recognized. On the basis of technology used and amount conserved, the national long-term and medium term genebanks, may be provided with a special fund for collecting, conservation, regeneration and seed viability monitoring etc. While making systematic characterization, identification of desirable accessions and classification of conserved germplasm are important, genebanks should be in a position to collect germplasm at any time and in any place to rescue threatened material, carry out scientific regeneration and maintain seed and plant material in the store and filed in good condition. This will facilitate detailed characterization, and conserve and use them effectively.

To strengthen investigation and research

The germplasm resources research is a systematic project. The tasks mainly constitute three aspects: the first is the basic work, such as collecting, distribution and regeneration. The second is the basic and applied basic research. The third is germplasm enhancement for breeding and production. All of these activities are common good and do note generate profits. Hence, we must rely of funds research on the governments and society. Therefore, the research project and its scope should be in accordance with the need of production and breeding. There are some common areas of research between breeding and germplasm. The investment should be weighed according to the actual situation.

To increase investment to retain skilled research staff

Enough investment is the key to solve most of the above problems. Investment can also help to retain skilled scientists and technicians in this basic research field and encourage them to work actively and innovate. In addition, it can improve the research facilities and increase the level of research. Eventually, the sustainable development of germplasm resources research will be ensured.

Collecting and conservation of indigenous rare, special type, wild type, vegetable crop relatives, the vegetatively propagated vegetables and exotic vegetable germplasm should be emphasized in order to increase the genetic diversity in this group of important plant species. In conservation techniques, emphasis must be placed on the use of DNA technology for conservation and use, ***in vitro*** conservation and technology for decreasing conservation costs.

The eventual aim of germplasm research is to supply breeders with diverse germplasm with genetic stability, good economic characters and usability. Therefore, it is an urgent need to enhance work on identification and evaluation on vegetable germplasm. At the same time, systematic classification, genetic diversity and development of core collection, inheritance studies, use of molecular markers etc., should be carried out. In this way, the research can be move from only the phenotype to the genotype with higher efficiency.

To set up mechanism for increased interaction between breeders and germplasm researchers

Germplasm resources researchers should serve breeders by publicizing about good germplasm make available the seeds and information on them to breeders. Breeders, in turn, provide feed back the use of germplasm received from genebanks, provide additional information collected on them for the national database and help to increase investment on the germplasm resources research by sharing the benefits derived from the use of germplasm in developing the new cultivars / varieties. Breeders also could help in enriching the genebank by providing seed / plant material of good lines developed through their breeding efforts to the national genebank.

To establish the national genetic resources committee and the cooperative network

The establishment of the national genetic resources committee is good for making various related laws about germplasm exchange and use, strategies and broad policies on germplasm collecting, conservation and utilization.

Germplasm resources research projects are different from other short-term projects. They are long-term, require large investment, and systematic projects. They also require efforts through multidisciplinary teams. For example, the seed regeneration and evaluation of various vegetables need cooperation of germplasm researchers with other scientists from all over the country under different ecological and geographical environments. This requires establishment of a national network to work effectively on genetic resources.

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