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Root and Tuber Crops

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TEIJI TAKAHASHI
Research Councillor
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Distinguished guests and participants.

On behalf of the Agriculture, Forestry and Fisheries Research Council, it is my great pleasure to extend most sincere greetings and best wishes to all the participants in the "MAFF International Workshop on Genetic Resources". This workshop has been organised and sponsored by the Agriculture, Forestries and Fisheries Research Council and the National Institute for Agrobiological Resources in collaboration with the Japan International Research Center for Agricultural Sciences and the National Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries.

I would particularly like to extend a warm welcome to our guests who have travelled here to Tsukuba from different parts of Asia. We hope you will be comfortable here in Japan and develop new research linkages with Japanese scientists.

Last year, Japan celebrated 100 years of agricultural research. The first national agricultural research station was established in 1893 in Nishigahara, Tokyo. During the past 100 years genetic resources activities have supported basic agricultural research and furnished invaluable materials for plant breeding. As a response to the continuous and increasing need for the collection and preservation of genetic resources, the MAFF Genebank project was initiated in 1985.

Due to drastic changes in the global environment, the United Nations Conference on the Environment and Development was held in Rio de Janeiro in June 1992. The Convention on Biological Diversity which was one of the most important outcomes of the conference came into force on December 29, 1993.

One of the basic objectives of the Convention is the "conservation of biological diversity". It is in this role that the MAFF genebank project has played an important part in meeting the Conventions objectives. The main objective of the MAFF Gene Bank project is conservation of crop genetic diversity. It was with the implementation of the Convention in mind that the Council decided to hold this workshop in order to contribute to the promotion of research and global strategies for the conservation of genetic resources. Fostering increased interaction between Japan and other countries, as well as the international agricultural institutes, in the field of genetic resources conservation was another reason to hold this workshop.

I hope this workshop will be able to address important questions related to conservation, evaluation and use of root and tuber crops such as:

1. What are the main unsolved problems in conserving the different root and tuber crops and how can they be addressed?.

2. How can international cooperation be fostered to provide comprehensive conservation and evaluation of root and tuber crops?.

I would like to again express my cordial welcome to you all and hope that you all have a productive workshop.

Thank you.

Welcome Address

HIROSHI FUJIMAKI
Director General
National Institute of Agrobiological Resources

It is with great pleasure that I extend a warm welcome to all participants of this Ministry of Agriculture, Forestry and Fisheries workshop on the Conservation and Use of Root and Tuber Crop Genetic Resources. I would particularly like to extend a special welcome to all those who have travelled a long way to attend this workshop here in Tsukuba. We hope that the next few days will make that journey well worthwhile.

I would like to acknowledge the contribution of several organizations. The workshop was organised and sponsored by the Agriculture, Forestry and Fisheries Research council. Here in Tsukuba to prepare for this workshop the National Institute of Agrobiological Resources was helped by staff of the National Agricultural Research Center and Japan International Research Center for Agricultural Sciences.

The global concern for the conservation of, fast dwindling, genetic resources requires an international approach to protect this fundamental genetic base for humanity. Japan has in recent years significantly increased its commitment to conservation and evaluation of genetic resources. I would like to sight 3 examples of this commitment:

1. In 1985 MAFF embarked on an ambitious project called 'The Genebank Project'. This did not just involve the building of a new genebank, it involves hundreds of scientists from all over Japan and collaboration with scientists from all over the world in the conservation and evaluation of a multitude of crop, animal and micro-organism genetic resources.

2. The Japanese International Cooperation Agency (JICA), a department of the Ministry of Foreign Affairs, has also had a project on the conservation and use of genetic resources. This has focussed on helping other countries improve their ability to conserve their own germplasm. To date JICA has helped establish genebanks in Bangladesh, Chile, Myanmar, Sri Lanka, and Pakistan. The National Institute of Agrobiological Resources (NIAR) has assisted JICA in this project and particularly helped provide training during the annually held training course which has so far trained more than 100 scientists from 40 countries.

3. In the last decade of this century conservation and more particularly evaluation and use of genetic resources is inextricably linked to advances made in

biotechnology. NIAR-MAFF, 3 years ago, in cooperation with other institutes began to unravel the secrets of the rice genome in what has been called the 'Rice Genome Project'. This has rapidly resulted in rice becoming the most thoroughly understood genomes of any crop. This project continues and can serve as a model for other genome projects. It is one of the aims of this project to enable new and vital genes from rice genetic resources to be rapidly moved to improved cultivars ---- whether those cultivars be Japanese, Indian or Indonesian.

This workshop is planned to be the first in a series focussing attention on particular groups of organisms vital to human welfare. Root and tuber crops have a number of characteristics which make them problematic to conserve, but on the other hand, these crops are among the most important in the world for the poorest people. By bringing together experts in Asia, Oceania and from the CG system here to discuss conservation and evaluation of genetic resources of root and tuber crops it is hoped that:

a) a practical agenda for improving the conservation and evaluation of these crops may be formulated

b) cooperative research linkages will be established and improved.

Finally let me encourage you all to fully participate in the meeting. Please ask lots of questions and make full use of your time together.

Thank you.

KEYNOTE ADDRESS I

The Role of International Organizations in Root and Tuber Crops Conservation

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International Board for Plant Genetic Resources

Introduction

Root and tuber crops, including aroids, are main stays for millions of people and occupy an important position in world agriculture. In contrast to the major species, potato, sweet potato, cassava, taro and yams, there are about 100 root and tuber species of significance for agricultural or medicinal purposes. Most of these may be important only locally, but play a significant role in the subsistence economies and crop diversification. Root and tuber crop production has been steadily increasing and in 1992 it was about 586 million MTs from about 478 million hectares (FAO, 1992). About 268 million MTs of potato were produced from 180 million hectares, 128 million MTs of sweet potatoes from 92 million hectares, 152 million MT of cassava from 15 million hectares, 27 million MTs of yams from 2.8 million hectares, and 5.6 million MTs of taros from 9.9 million hectares. The figures of production and area for other root and tuber crops are not easy to compute. Nevertheless, these crops are very important in world food production and for industry, fodder, medicines and in subsistence agriculture (Prescott-Allen and Prescott-Allen, 1990). Many so-called minor species have great potential to become major crops, for example the material coming from the Andean region (Sperling and King, 1990).

Growth in agricultural production is not keeping pace with rapid population growth, demanding increased production and diversification crops more than ever. Roots and tubers can play a major role in addressing this issue. However, research on these crops is usually not on the agenda of many national programmes (Lynam, 1991). Therefore, there is a need for an international action on root and tuber improvement and on conservation and use of the genetic resources. We present here the status and challenges of conservation for root and tuber crops and some examples of the work by some institutes, including that of the International Board for Plant Genetic Resources (IBPGR), which is in now the International Plant Genetic Resources Institute (IPGRI).

Present Status of Conservation

Now, there are many organizations involved in collecting and conservation of root and tuber crop germplasm. It will not be possible to go into detail at the

species level, but the Table I attempts to summarize the existing collections around the globe. There are about 135,000 accessions belonging to 22 genera/species maintained in many organisations. The information provided here is from the Directory of Root and Tuber Crops (IBPGR, 1986) and the actual figures currently may be much larger. This is specially true for the minor species, such as the Andean roots and tubers and aroids on which there has been much interest in the last five years (Arbizu and Tapia, 1992; Brucher, 1989; Rea, 1992) and many collecting expeditions have been undertaken. The status of the root and tuber crops collections in some international research institutes is provided later.

Challenges of Conservation and Use of Root and Tuber Crop Germplasm

Most of the root and tuber crops propagate by asexual means and they present unique challenges for conservation and use of their germplasm. Some challenges are due to the effects of vegetative propagation on genetic diversity; the need for different methods of conservation – field genebanks, *in vitro* conservation, cryopreservation and *in situ* conservation –; the associated problems with each method and need for balanced approach and safe movement of germplasm.

Table I. Some major and minor species of root and tuber food crops, total number of accessions and total number of organizations with germplasm holdings.

Species	No. of accessions	No. of organizations
Alocasia spp.	231	18
Amorphophallus spp.	327	17
Arracacia spp.	418	6
Calathea spp.	6	3
Canna spp.	31	13
Coleus spp.	54	6
Colocasia spp.	5944	53
Cyrtosperma spp.	117	9
Dioscorea spp.	10661	53
Helianthus spp.	56	4
Ipomoea spp.	26020	83
Lepidium spp	6	1
Manihot spp.	25835	73
Maranta spp.	78	11
Mirabilis spp.	16	4
Oxalis spp.	1317	7
Pachyrhizus spp.	364	17
Polymnia spp.	42	3
Solanum spp.	60284	92
Tropaeolum	225	5
Ullucus spp.	471	5
Xanthosoma spp.	1035	41

Generally these are similar to those in other species, for example cereals. However, there are many specific differences that apply exclusively to roots and tubers (or broadly to vegetatively propagated species) only. In addition, one can also consider, even if it is rare, conservation of true seed in conventional cold storage conditions.

Genetic Diversity

Agriculture might have begun, at least in some parts of Southern America, with the harvest of roots or tubers, i.e. by the digging subterranean organs of wild plants (Sauer, 1965), which was probably enhanced by the detoxification properties of clays (Johns, 1988). Archaeological records where available show indeed a long history of crop husbandry of these species in that region (Hawkes, 1989). On the other hand, there is a clear tendency worldwide to prefer grain to root and tuber crops because of differences in taste, status and quick postharvest deterioration of the later (Heiser, 1990). In other words, root and tuber crops are often linked to primitive agricultural systems in place for hundreds of years, consequently, in comparison to other crops, roots and tubers often harbour a unique genetic diversity in landraces.

Understanding of the extent and distribution of genetic diversity in any gene pool is basic for any conservation effort, and root and tuber crops are no exception. While considering the issues in conservation of root and tuber crop germplasm, it is important to point out some major differences between root and tuber crops and other groups of crops, e.g. grains. First, there is a basic delay in the processes leading to meiosis and seed formation. The production of a thickened, edible organ is also used as a propagule; so, seed fertility is not critical to the survival of the species. This delay encouraged farmers to collect and plant some of these thickened organs. In such a system where biomass production is important and ploidy level and heterosis can be maintained easily, farmers look carefully for specific genotypes. Consequently, the factors that tend to affect the genome such as mutations, transposable elements, and from time to time the full cycle of breeding systems leading to sexual propagation, are the keys to understand the genetic diversity structure, Such knowledge is essential for all operations in germplasm conservation and use. It is important to understand reasons why farmers maintain morphological variation and test it.

Second, structure of gene pools in root and tuber crops is still poorly understood; perhaps with the exception of potato (both *Solanum tuberosum* subsp. *tuberosum* and subsp. *andigena*; (Grun, 1990), for all other Neotropical root/tuber crops, crop ancestry and place of domestication are still largely unknown (Table II and III). While considering the development of any action for germplasm conservation and use, one turns time and again to the following questions, which have heavy cost implications. Would one invest in *in vitro* conservation if one cannot conserve genetically diverse material? Would one launch a large-scale breeding programme if one is not certain of the basic germplasm and its pertinent information required for genetic progress?.

Table II. Origin and domestication of American tuber crops

Species	Wild ancestor	Place of domestication
Canna edulis	unknown	unknown
Dioscorea trifida	unknown (?)	N South America
Helianthus tuberosus	known (?)	SE USA
Oxalis tuberosa	unknown	Peru, Bolivia (?)
Solanum tuberosum	known (!)	Bolivia, Peru (!)
Tigridia pavonia	not relevant (?)	Mexico (?)
Tropaeolum tuberosum	known (?)	Peru (?)
Ullucus tuberosus	known	Peru (?)
Xanthosoma sagittifolium	unknown	N South America

Sources: Arbizu and Tapia, 1992; Brucher, 1967; Chu and Figueiredo–Ribeiro, 1991; De Azkue and Martínez, 1990; Giacometti and León, 1992; Grun, 1990; Hawkes, 1989; Heiser, 1969

Table III. Origin and domestication of American root crops

Species	Wild Ancestor	Place of domestication
Apios americana	not relevant	not relevant (SE USA)
Arracacia xanthorrhiza	unknown	unknown
Bomarea hirtella	not relevant	not relevant (Chiapas, Mexico)
Calathea allouia	not relevant	not relevant (Amazon)
Ipomoea batatas	unknown	unknown
Lepidium meyenii	unknown (?)	not relevant (?); Junín, Peru
Manihot esculenta	unknown (?)	unknown
Maranta arundinacea	not relevant	not relevant (Amazon)
Mirabilis expansa	known	unknown
Pachyrrhizus ahipa	unknown	unknown
Pachyrrhizus erosus	known	Guatemala (?)
Pachyrrhizus tuberosus	unknown (?)	unknown
Polymnia sonchifolia	unknown	unknown

Sources: Noda, *et al.*, 1992; Rea, 1992; Reynolds, *et al.*, 1990; Sauer, 1993; Sorensen, 1990; Zardini, 1991

Field Genebanks

Due to the asexual nature of reproduction of most of the root and tuber crops, it may not be always possible to conserve the germplasm of these crops in seed genebanks. So one method used, is to maintain them in field genebanks. Though the field genebanks make the germplasm readily available for use, there are some problems with them. Some of these include destruction by natural calamities, pest epidemics, number of plants to be maintained and the high cost of maintenance. Jarret and Florkowski (1990) considered conservation of germplasm of *Ipomoea batatas*. They compared the technique of conservation in field

genebanks with *in vitro* conservation in terms of security, availability and cost. They concluded that *in vitro* conservation was generally more secure and less expensive and labour intensive than maintenance in the field. One of the advantages of field genebanks is the continuous opportunity to evaluate and characterize germplasm. There is no need to wait until crops emerge from prolonged juvenile periods, as with *in vitro* methods. This is specially true for perennial species. However, this does not apply to species like *I. batatas*. Vine cuttings may be produced in less than eight weeks. The problem of somaclonal variation is not considered a major obstacle while genetic instability is monitored regularly.

In vitro Conservation

Because maintenance of field genebanks is often problematical and costly, *in vitro* conservation is increasingly being considered as the safer and practical option for crops that produce recalcitrant seeds or propagated clonally (Withers, 1991). Slow growth of shoot cultures offers a method of medium–term conservation comparable to that of active seed genebanks. For the long–term conservation of shoot cultures, cryopreservation in liquid nitrogen is becoming available often. Research has led to the development of some routine cryopreservation protocols for cell suspensions, but fully differentiated and complex structures, e.g. shoots and embryos, still present problems. *In vitro* techniques have a role to play at other stages of the conservation process, such as for the distribution of germplasm or for the collection of samples from the field. For several crops, including potato and cassava, most of the components of an *in vitro* conservation system are in place. IBPGR and International Center for Tropical Agriculture (CIAT) chose cassava for a pilot project to develop and test *in vitro* active genebank management procedures. Much research is still needed in monitoring genetic stability and ways of conserving diversity through *in vitro* conservation.

Florkowski and Jarret (1990) examined the relative monetary costs of different technologies for conservation. These methods included repeated field planting and propagation every season, *in vitro* culture and cryopreservation of tissues or organs that can regenerate. They calculated the costs per accession at $113.05 for *in vitro* culture, $128.00 for field collections and $147.85 for cryopreservation, based on 1,000 accessions. *In vitro* and cryopreservation technologies offer the highest quality preservation but the cost involved may require repeated evaluation. Okoli (1991) reviewed the prospect of using *in vitro* conservation to conserve the yam (*Dioscorea*) germplasm.

Vitrification may be an optimum method for cryopreservation of root and tuber crop germplasm. Vitrification is a technically simple method for cryopreserving plant germplasm, requiring only the application of suitable cryoprotectants and rapid cooling rates (Towill and Jarret, 1992). The percentage of shoot tips surviving vitrification and those subsequently forming a shoot varied widely among replications. Many laboratories around the world are undertaking work on these lines of research.

Safe Movement of Germplasm

Root and tuber crops, propagating vegetatively, pose special problems not only in collecting and storing, but also from a germplasm health point of view. In vegetatively propagated crops, for example, viruses present in the mother plant will inevitably be found in derived vegetative parts, such as tubers, roots, etc. In cassava, the causal agent of bacterial blight, *Xanthomonas manihotis*, is present in the xylem tissue of planting material, and difficult to detect. An example of a fungal pathogen that is spread through tubers is the causal agent of the infamous late blight disease, *Phytophthora infestans*. Although occurring worldwide nowadays, it is of quarantine concern because of the existing physiological races, some of them being resistant to modern fungicides such as metalaxyl. IBPGR has played a significant role in developing guidelines for safe movement of a few important root and tuber crops germplasm (see under Role of IBPGR).

The Role of International Organizations

It is certainly a difficult task to assign the 100 or so tuber and root crops worldwide to a handful of researchers that are available in the international arena. Additionally, most of them work on three of the crops (potato, cassava, sweet potato), on the aspects of germplasm conservation, germplasm enhancement and plant breeding. The story of the potato is illustrative in this regard (Hawkes, 1992). The crop was held in high suspicion till the 1800s in Europe, and now it ranks fourth among the leading crops worldwide proving tremendous potentia. In most cases, one would expect national programmes to take the lead in working on these minor but potential crops. However, this has not been the case in many instances (Lynam, 1991). Hence, it is important that the international organizations take up the case for most of the root and tuber crops and assist national programmes in their conservation and use.

The Role of IBPGR/IPGRI

Over the last 20 years, IBPGR has been closely associated with many activities related to conservation and use of root and tuber crop germplasm. Most of these activities have been carried out in collaboration with different national, regional or international programmes, including other Centers of the Consultative Group on International Agricultural Research. IBPGR it self does not maintain any germplasm, but it supports many national programmes in doing so. Some of these activities are highlighted below.

Germplasm collecting

IBPGR has over the years supported germplasm collecting, including that of root and tuber crops. About 19 900 accessions of root and tuber crops have been collected in IBPGR–supported missions and the details are given in Table IV. For example, since December, 1982, 5–7–day collecting expeditions each month

Table IV. Summary of root and tuber crop germplasm collected through IBPGR missions

Country	No. of missions	Species[1]	No. of samples
Argentina	4	MAN/SOL/ULU	950
Bangladesh	2	PAC	5
Bolivia	4	Andean tubers/IPO/SOL	1426
Brazil	7	MAN/IPO	765
Botswana	1	SOL	3
Burundi	1	COE/COL/DIO/IPO	51
Burkina Faso	2	COE/COL/DIO/IPO/XAN	274
Cameroon	1	DIO	2
Chile	3	OXA/SOL	345
Colombia	7	Andean tubers/IPO/MAN/SOL	1280
Costa Rica	2	DIO/MAN/XAN	6
Cote d'Ivore	4	DIO/MAN	1265
Cuba	1	COL/DIO/IPO/MAN/XAN	384
Dominican Rep.	1	IPO	68
Ecuador	6	Andean tubers/IPO/SOL	1229
Ghana	2	DIO/AMN	286
Guatemala	2	COL/DIO/MAN/PAC/XAN	404
Honduras	1	XAN	2
Indonesia	3	ARACEAE and DIO/IPO/MAN/MAR/XAN	875
Liberia	1	COL/DIO/IPO/MAN	8
Malawi	1	MAN	17
Mali	2	DIO/IPO	7
Mauritania	1	IPO	5
Mexico	5	DIO/IPO/MAN/PAC/SOL/XAN	203
Malaysia	1	ALO/AMO/COL/DIO/IPO/XAN	1535
Namibia	2	IPO/SOL	4
Nigeria	3	COL and other Araceae	162
Nepal	2	COL/DIO/IPO	52
Panama	1	DIO/MAN/MAR/XAN	14
Paraguay	1	MAN	210
Peru	10	Andean tubers/IPO/MAN/SOL	4505
Philippines	1	AMO/COL/CYR/XAN	315
Papua New	3	COL/DIO/IPO/MAN/XAN	854
Sierra Leone	1	DIO/MAN/IPO/XAN	134
Solomon Islands	2	ALO/AMO/COL/CYR/DIO/IPO/MAN/XAN	344
Sri Lanka	1	DIO	339
Sudan	1	IPO/SOL	7
Thailand	6	ALO/COL/DIO/IPO/MAN/PAC/XAN	983
Uruguay	1	SOL	32
Venezuela	2	DIO/IPO/MAN/XAN	291
Zaire	1	COL/DIO/IPO/MAN	148
Zambia	4	DIO/IPO/MAN/PAC/SOL	49

Source: IBPGR Collecting Database[1] ALO *Alocasia*, AMO *Amorphophallus*, CAN *Canna*, COE *Coleus*, COL *Colocasia*, CYR *Cyrtosperma*, DIO *Dioscorea*, IPO *Ipomoea*, MAN *Manihot*, MAR *Maranta*, OXA *Oxalis*, PAC *Pachyrrhizus*, ULU *Ulucus*, SOL *Solanum*, XAN= *Xanthosoma*

resulted in collecting 646 accessions of *Colocasia*, 239 of *Dioscorea* spp. and 528 accessions of *Ipomoea batatas* in eleven states of peninsular Malaysia. The accessions are maintained in a field genebank for evaluation and use (Hussain, 1986).

Another example is the support for collecting of minor Andean root and tuber crops as reported by Castillo (1989). In 1982, the National Institute of Agricultural Research of Ecuador, supported by the IBPGR, initiated a collecting expedition to the Andean region. Several species including *Ullucus tuberosus*, *Oxalis tuberosa*, *Tropaeolum tuberosum*, *Arracacia xanthorrhiza* and *Polymnia sonchifolia* were collected.

Besides supporting germplasm collecting, IBPGR will shortly of publish (in collaboration with FAO, IUCN and UNEP) a manual on germplasm collecting. This manual has chapters describing the procedures for collecting and transfer of root and tuber crop germplasm.

Evaluation and documentation

Germplasm collections without data on their attributes cannot be used to the fullest extent possible. Such data can be generated only through systematic characterization and evaluation of the material collected. IBPGR has supported many such efforts and helped the national programmes in documenting the information generated through such efforts. So far, we have published descriptor lists on potato variety (in cooperation with the Commission of European Communities) (IBPGR 1985), sweet potato (IBPGR, 1991), *Xanthosoma* (IBPGR 1989), *Colocasia* (IBPGR 1980) and Oca (IBPGR, 1982). Descriptors for yam and *Arracacia* are being developed. As indicated earlier, the Directory of Root and Tuber Crops was published in 1986 and efforts to update and revise it are under way. IBPGR supported the work on describing and documenting root crops in the South Pacific, which produced country catalogues containing descriptions and evaluations of root crop cultivars (Guarino and Jackson, 1983).

Safe movement of germplasm

IBPGR had, jointly with FAO, published a series of Guidelines for the Safe Movement of Germplasm. The importance given to root and tuber crops is illustrated by the fact that among the first ten issues four were dealing with root and tuber crops, namely "Edible Aroids" (FAO/IBPGR, 1989), "Sweet potato" (FAO/IBPGR, 1989), "Yam" (FAO/IBPGR, 1989) and "Cassava" FAO/IBPGR, 1991). It is planned to develop, jointly with CIP, guidelines for the safe movement of potato germplasm in 1995.

Current Programme

Presently, IBPGR–APO has a project entitled 'Improvement of taro and yam resources', focusing on taro and yams. Aroids, including taro, are important food crops of many parts of tropics. Because they rarely enter into commerce, except in local markets, it is difficult to estimate their production. *Alocasia* spp. and *Colocasia esculenta* are important in South Asia, South East Asia and the Pacific. Some types have special significance as crops for difficult lands, for they can produce large yields under flooded or swampy conditions. Yams are a staple food crop in many tropical countries of Southeast Asia and Oceania. As taro, these are essentially crops of subsistence agriculture. The variation in taro and yams and related species is vast and have potential not only as food crops but also for industrial and medicinal purposes.

In various consultations, including RECSEA and SAC meetings, the priority for action on taro and yam was identified. So the Regional Office, finalized a project on of taro and yam resources which aims at improving the conservation and utilization of yam and taro genetic resources in the APO region. Activities under this project include: 1. assess the status of taro and yam genetic resources in the Pacific, Southeast Asia, South Asia and Oceania and collate the status report in APO region from the information gathered, 2. assist in formulation a network of

activities on taro and yam genetic resource conservation, information exchange and improvement, 3. assist in analysing extant genetic diversity and in developing *in vitro* conservation protocols and complementary conservation strategies, 4. assist in carrying out ethnobotanical studies and 5. assist in virus detection and therapy for safe movement taro and yam germplasm.

The assessment of taro and yam genetic resources in the APO region is in progress, initially using the work started by our New Delhi office in 1991. The initial analysis indicated high degree of interest and the need for enhancing genetic resource activities on these locally important and difficult species. Some of the national programmes visited during the year have indicated a need to develop a network of activities, may be as a part of network of a major root crop such as sweet potato. Future plans include promotion of studies on genetic diversity, *in vitro* conservation, development of complementary conservation strategies and assisting virus detection. The ethnobotanical information that has been collected, mainly from India, has been documented.

The Role of Other CGIAR Centers

Besides IBPGR, three other CG Centers are involved in work on root and tuber crops. These are International Potato Center, (CIP) in Peru, International Center for Tropical Agriculture (CIAT), in Columbia and International Institute for Tropical Agriculture (IITA) in Nigeria. Their work on root crop genetic resource conservation, giving a brief picture on the status and activities, is described below.

CIAT has the responsibility for conserving cassava germplasm. It provides a high level of security for conservation complete characterization and evaluation, documentation and a system for effective pathogen-free exchange of germplasm. CIAT maintains the collection in both *in vitro* and field genebanks. CIAT holds 5035 accessions in field genebanks and 4788 clones from 23 countries *in vitro*. Duplicate identification within the filed genebank is possible based on preliminary grouping using biochemical and morphological descriptors with high reliability. A conservation strategy for cassava includes core collection and duplication in an other genebank, *in vitro* and cryopreservation.

CIP's potato genebank contains more than 15,000 accessions of cultivated and wild tuber-bearing *Solanum* species; over 13,000 samples represent native Andean cultivars. CIP also maintains a collection of more than 5,500 accessions of *Ipomoea*; 3,200 are of *I. batatas* cultivars and 1,500 are of breeding lines, while eight related wild species of section *Batatas* are represented by 800 accessions, with recent collections being incorporated (Austin, 1991, Austin, *et al.*, 1991). Additionally there are 48 other species belonging to other sections. CIP is involved in some collaborative projects to conserve resources of minor tuber crops, especially of the Andean origin (Huaman, 1991). In the region, CIP has a major collection in Bogor, with more than a thousand accessions of sweet potato, collected mostly from different parts of Indonesia. The collection is in different stages of morphological characterization. Additional collecting in the eastern part of highland Irian Jaya,

efforts to eliminate duplicates in the collection and developing core collection in Bogor are planned (Dr. Jurg Schneider, 1994. Pers. Comm.). Through the User's Perspective with Agricultural Research and Development (UPWARD), CIP is supporting the collection and conservation of root crop germplasm and its associated indigenous knowledge, with funding from Netherlands and IDRC. In order to explore ways to support existing conservation of both root crop cultivars and indigenous knowledge 'on farm', *in situ* sites were selected. Work is in progress to look in detail at current conservation practices, especially the relation between diversity and management of planting material over seasons (Dr. Gordon Prain, 1994. Pers. Comm.).

IITA mandated crops include yam and cassava. Sweet potato was transferred to CIP (Ng, 1991a). About 1000 *Dioscorea* spp. and 2048 *Manihot* species are conserved both in field genebanks and in *in vitro*. IITA is involved with exploration, collecting, characterization and other activities on these four crops. Research on *in vitro* conservation is carried out and Ng (1991b) describes two *in vitro* techniques for the storage of root crop germplasm, a reduced growth storage method for short to medium term storage and cryopreservation for long term storage. The first technique has been used widely to conserve root crop germplasm. A total of 2,000 accessions of different root crop species are maintained at IITA in reduced growth storage. Cultures can be maintained for 1–2 years before subculturing.

The Role of Other Organizations

Numerous organizations, including national, regional and international, are active in the area of root and tuber crop germplasm conservation and use. It will not be possible to cover all of them here. So only a few examples are provided below.

National programmes are the most important partners in any conservation effort and it is true for root and tuber crops as well. Many national programmes are focusing on the conservation of these crops, for e.g., collecting of potato genetic resources in China began in the early 1980s. The total collection now comprises some 800 accessions, 123 of which are local varieties. The collection is maintained in the field at the Research Institute of Heilongjiang Academy of Agricultural Sciences. It is also maintained under low temperature and in *in vitro* conditions at the Institute of Crop Genetic Resources of the Chinese Academy of Agricultural Sciences (IBPGR, 1991). However, it must be noted that most of the efforts are mainly on major crop species.

As a regional programme, the Asian Vegetables Research and Development Center (AVRDC) had within its genebank 1,671 form 32 different countries (AVRDC, 1992). The collection was maintained as a field gene bank although much progress has been achieved on *in vitro* storage as well. In 1988, 6,710 meristems were excised from 1,116 accessions; those from 456 accessions were cultured successfully (AVRDC, 1990). In 1991, AVRDC terminated its research on

sweet potato and transferred most of the germplasm to CIP. However, it should be possible to consider other species in the future.

International Development and Research Center (IDRC) of Canada has been supporting national programmes to strengthen their research and development work related to breeding and cultural management practices for cassava, sweet potato and other minor root crops (Dr. John Graham, Pers. Comm.). A component of this support was directed towards a few germplasm related activities and some African, South American and South and South East Asian countries were recipients of this support. Following the United Nations Conference on Environment and Development in June 1992, the focus of IDRC's programme and activities has shifted with explicit orientation towards sustainable and equitable themes and issues. Under the biodiversity theme, IDRC will support research on the development of technical, social and economic interventions that are appropriate and necessary if indigenous people and local communities, as key stakeholders, are to participate in a process that will allow for the conservation and use of our biological diversity. Considering the need for increased attention on *in situ* conservation of many root and tuber crops and their role at subsistence farmer level, there should be some scope for support under the new policy. A recent example of this type is its support to Vietnam through an IBPGR project.

Future Prospects

Some serious drawbacks for effective conservation and use of root and tuber crops are: insufficient knowledge on structure of genetic diversity among gene pools, the lack of investment in basic biology, plant geography and short–sighted collecting (i.e. focusing only on a few landraces and ignoring the gene pools as a whole). These drawbacks need to be urgently remedied. In other words, any significant effort to conserve the germplasm of root and tuber crops should pass through genetic diversity assessment of the materials in *ex situ* collection(s). This should, preferably, be compared with what is still present in the wild or in the farmers fields.

Any effort to be meaningful, it has to be interactive (back and forth, between *ex situ* and *in situ* germplasm collections) and should not be limited to a small collection at the local (national) level. The effort should span but across gene pools that most often means across national boundaries. A true international effort, well in line with the Convention on Biodiversity, will be required.

The studies on genetic diversity will lead to the identification of gaps in diversity and will help in the collecting of new diversity. Such an effort will be helped by increased focus on ecogeographic surveys in areas of diversity, and this is particularly significant in the context of *in situ* conservation. We must base our plans on crop by crop in order to capture maximum diversity and to put in place the best conservation option. There is a general need to strengthen the evaluation and documentation efforts in many national programmes. The international and

regional organizations can play a major role in helping the national programmes in this matter.

The tendency to prefer grains to underground parts (Heiser, 1990) may continue into the conservation scene. This will be particularly so if the process of domestication of certain root and tuber crops is still incomplete. This is especially true if narrow, "economistic" concept of plant genetic resource conservation prevails. However, in the recent past there has been a renewed interest due to the increasing recognition of economic and social significance of root and tuber crops in rural development. The increased interest in the cultivation of indigenous species by local communities further enhanced the interest in these crops. There is a need for the conservation community to capitalise on this increased interest.

Roots and tubers offer a test for biodiversity conservation: either we will save them or we will loose the whole set. This way, there is the choice method of conservation for roots and tubers: *in situ*. If the purpose is to conserve genotypes (some conservationists may differ), as the method of propagation is mostly asexual, there will be hundreds and thousands of genotypes, both in cultivation and in the wild. Thus the conservation cost, especially if *in vitro* approach is taken up, may be enormous. Cryopreservation is not the panacea to it, in the sense that several developing countries have little or no access to that technology. The term cryopreservation might also mean 'frozen without further generation of genetic diversity'! So, there is a need to pay increased attention to *in situ* conservation for root and tuber crop germplasm. This should also consider the appropriate balance of field collections, where possible, to complement other methods and for ready use. It should have component of *in vitro* conservation, as a means for safe germplasm transfer and for medium term conservation. Cryopreservation can be used, when possible, as a safety back up. We also should look at the possibility of seed conservation in long term storage conditions. We need to look for methods and locations for flowering and fruiting and seed production in as many crops as possible. If seed can be produced and stored, we can conserve genetic diversity as populations for future generations.

To conclude, this approach would require a more thorough and multidisciplinary understanding of the genetic diversity, agrocecosystems and the methods that could be applied to the conservation of genetic diversity. It will need identification of genetic diversity rich areas and knowledge on the speed and/or reasons of genetic erosion or absence of it. An example of such studies is the one by Brush (1992). These efforts to conserve and use the root and tuber crops better will also need collaboration at various levels, national and international. This will facilitate for a successful complementary conservation of root and tuber crops genetic resources.

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References

Arbizu, C. and Tapia, M. 1992. Tubérculos andinos. *In:* "Cultivos Marginados: Otra Perspectiva de 1492", Hernández Bermejo, E. and León, J. (ed.), Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 147–161.

Austin, D. F. 1991. Ipomoea sawyeri (Convolvulaceae), a new species from Peru. Brittonia 43 (2) : 93–95.

Austin, D. F., de la Puente, F. and Contreras, J. 1991. *Ipomoea tabascana*, an endangered tropical species. Econ. Bot. 45 (3) : 435.

AVRDC. 1990. Sweet potato germplasm introduction and distribution. 1988 progress report. 1990, 371–375. Shanhua, Taiwan: AVRDC.

AVRDC. 1992. Germplasm Catalog – Sweet potato. Shanhua, Taiwan: AVRDC. 237p.

Brucher, H. 1967. *Ullucus aborigineus* spec.nov., die Wildform einer andine Kulturpflanze. Ber. Deutsch. Bot. Ges. 80 : 376–381.

Brucher, H. 1989. Useful plants of neotropical origin and their wild relatives. Springer–Verlag, Berlin, Heidelberg, Germany, 296p.

Brush, S.B. 1992. Ethnoecology, biodiversity, and modernization in Andean potato agriculture. J. Ethnobiol. 12: 161–185.

Castillo, R.O. 1989. Andean crops in Ecuador: collecting, conservation and characterization. PGR NL No. 77: 35–36.

Chu, E. P. and Figueiredo–Ribeiro, R. C. L. 1991. Native and exotic species of *Dioscorea* used as food in Brazil. Econ. Bot. 45 (4) : 467–479.

De Azkue, D. and Martínez, A. 1990. Chromosome number of the *Oxalis tuberosa* alliance (*Oxalidaceae*). Pl. Syst. Evol. 169 : 25–29.

FAO. 1992. FAO Yearbook 46. FAO Statistics Series No. 112.

FAO/IBPGR. 1989. FAO/IBPGR technical guidelines for the safe movement of edible aroid germplasm. Zettler, F.W., Jackson, G.V.H. and Frison, E.A. (Eds.) 24 pp. Rome, Italy: FAO/IBPGR.

FAO/IBPGR. 1989. FAO/IBPGR technical guidelines for the safe movement of yam germplasm. Brunt, A.A. Jackson, G.V.H. and Frison, E.A. (Eds.) 20 pp. Rome, Italy: FAO/IBPGR.

FAO/IBPGR. 1989. FAO/IBPGR technical guidelines for the safe movement of sweet potato germplasm. Moyer, J.W., Jackson, G.V.H. and Frison, E.A. (Eds.) 29 pp. Rome Italy: FAO/IBPGR.

FAO/IBPGR. 1991. FAO/IBPGR technical guidelines for the safe movement of cassava germplasm. Frison, E.A. and Feliu, E. (Eds.), 48 pp. Rome, Italy: FAO/IBPGR.

Florkowski, W.J. and Jarret, R.L. 1990. The cost of alternative strategies for the maintenance of sweet potato germplasm. Quart. J. Intl. Agric. 29: 79–87.

Giacometti, D. and León, J. 1992. Yautía o malanga (*Xanthosoma sagittifolium*). *In:* "Cultivos marginados: otra perspectiva de 1492", Hernández Bermejo, E. and León, J. (ed.), Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 253–258.

Grun, P. 1990. The evolution of cultivated potatoes. Econ. Bot. 44 (3 Supplement) : 39–55.

Guarino, L. and Jackson, G. 1983. Strengthening plant protection and root crops development in South

Pacific. RAS/83/001, Field Document 12: FAO, Rome.

Hawkes, J. G. 1989. The domestication of roots and tubers in the American tropics. *In:* "Foraging and farming – The evolution of plant exploitation", Harris, D.R. and Hillman, G.C. (Eds.), Unwin Hyman, London, United Kingdom, pp. 481–503.

Hawkes, J. G. 1992. History of the potato. *In:* "The potato crop – The scientific basis for improvement", Harris, P.M. (ed.), Chapman and Hall, London, United Kingdom, pp. 1–12.

Heiser, C. B. 1969. The North American sunflowers (*Helianthus*). Mem. Torrey Bot. Club 22 (3) : 1–218.

Heiser, C. B. 1990. Seed to civilization – The story of food. Harvard University Press, Cambridge, Massachusetts, USA, 228p.

Huaman, Z. 1991.International Potato Center safeguards plant genetic resources in Peru. Diversity. 7: 1–2: 16.

Hussain, K.M. 1986. Prospection and collection of sweet potato, *Colocasia* and *Dioscorea* in West Malaysia. IBPGR Regional Committee for Southeast Asia NL. 10: 10–11.

IBPGR. 1980. Colocasia Descriptors. 16 pp. Rome, Italy: IBPGR.

IBPGR. 1982. Oca Descriptors. 23 pp. Rome, Italy: IBPGR.

IBPGR. 1985. Potato Variety Descriptors. Mackay, G.R., Hijink, M.J. and Mix, G. (Eds.) 27 pp. Rome, Italy: IBPGR.

IBPGR. 1986. Directory of Germplasm Collections: Root and Tuber Crops (revised). 178 pp. Rome, Italy: IBPGR.

IBPGR. 1989. Xanthosoma Descriptors. 23 pp. Rome, Italy: IBPGR.

IBPGR. 1991. Potato germplasm project. IBPGR NL for Asia and the Pacific. No. 5: 5.

IBPGR. 1991. Sweet Potato Descriptors. Huaman, Z. (Ed.) 134 pp. Rome, Italy: IBPGR

Jarret, R.L. and Florkowski, W.J. 1990. *In vitro* active vs. field genebank maintenance of sweet potato germplasm: major costs and considerations. HortScience. 1990, 25: 141–146.

Johns, T. 1988. A survey of traditional methods employed for the detoxification of food plants. J. Ethnobiol. 8 (1) : 81–129.

Lynam, J.K. 1991. The development potential of root crops in Africa. Entwicklung Landlicher–Raum 25: 8–12.

Ng, S.Y.C. 1991a. Genetic resources activities of the International Institute of Tropical Agriculture (IITA). IN Crop genetic resources of Africa. Volume II. Proceedings of an international symposium, Ibadan, Nigeria, 17–20 October 1988. Ng, N. Q.; Perrino, P.; Attere, F.; Zedan, H. (Eds.). pp. 27–33, Ibadan, Nigeria: IITA.

Ng, S.Y.C. 1991b. *In vitro* conservation and distribution of root and tuber crop germplasm. IN Crop genetic resources of Africa. Volume II. Proceedings of an international symposium, Ibadan, Nigeria, 17–20 October 1988. Ng, N. Q.; Perrino, P.; Attere, F.; Zedan, H. (Eds.). pp. 95–106, Ibadan, Nigeria: IITA.

Okoli, O.O. 1991. Yam germplasm diversity, uses and prospects for crop improvement in Africa. *In* Crop genetic resources of Africa. Volume II. Proceedings of an international symposium, Ibadan, Nigeria, 17–20 October 1988. Ng, N. Q.; Perrino, P.; Attere, F.; Zedan, H. (Eds.). 1991, 109–117, Ibadan, Nigeria;: IITA.

Rea, J. 1992. Raíces andinas. *In:* "Cultivos Marginados: Otra Perspectiva de 1492", Hernández Bermejo, E. and León, J. (ed.), Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 163–177.

Noda, H., Bueno, C. R. and Silva Filho, D. F. 1992. Lerén (*Calathea allouia*). *In:* "Cultivos marginados: otra perspectiva de 1492", Hernández Bermejo, E. and León, J. (ed.), Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 237–243.

Prescott–Allen, R. and Prescott–Allen, C. 1990. How many plants feed the world? Conservation Biol. 4 (4) : 365–374.

Reynolds, B. D., Blackmon, W. J., Wickremesinhe, E., Wells, M. H. and Constantin, R. J. 1990.

Domestication of *Apios americana*. *In:* "Advance in new crops", Janick, J. and Simon, J.E. (Eds.), Timber Press Inc., Portland, Oregon, USA, pp. 436–442.

Sauer, C. O. 1965. Cultural factors in plant domestication in the New World. Euphytica 14 : 301–306.

Sauer, J. D. 1993. Historical geography of crop plants – A select roster. CRC Press, Boca Raton, Florida, USA, 309p.

Sorensen, M. 1990. Observations on distribution, ecology and cultivation of the tuber–bearing legume genus *Pachyrrhizus* Rich. ex DC. Wageningen Agric. Univ. Papers 90 (3) : 1–38.

Sperling, C. R. and King, S. R. 1990. Andean tuber crops: worldwide potential. *In:* "Advance in new crops", Janick, J. and Simon, J.E. (Eds.), Timber Press Inc., Portland, Oregon, USA, pp. 428–435.

Towill, L.E. and Jarret, R.L. 1992. Cryopreservation of sweet potato (*Ipomoea batatas* (L.) Lam.) shoot tips by vitrification. Plant–Cell–Reports. 11: 4, 175–178.

Withers, L.A. 1991. Tissue culture in the conservation of plant genetic resources. *IN* Conservation of plant genetic resources through *in vitro* methods. Proceedings of the MNCPGR/CSC international workshop on tissue culture for the conservation of biodiversity and plant genetic resources held in Kuala Lumpur, Malaysia, 28–31 May 1990. Zakri, A. H.; Normah, M. N.; Karim, A. G. A.; Senawi, M. T. (Eds.)1–18; Kuala Lumpur, Malaysia: FRIM and MNCPGR.

Zardini, E. 1991. Ethnobotanical notes on 'Yacon', *Polymnia sonchifolia* (Asteraceae). Econ. Bot. 45 (1) : 72–85.

KEYNOTE ADDRESS II

Use of Root and Tuber Crop Genetic Resources in Japan

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Abstract

The immeasurable value of plant genetic resources, represented by local cultivars of crops and their wild relatives, is now well accepted. Many leading experts from around the globe have joined the present MAFF workshop to discuss common interests in root and tuber crop genetic resources and to exchange ideas. The author reviewed, as an example of the use of germplasm, results of the programs for improving the starch yield in potato and sweet potato based on data from Japanese centers for breeding. The release of modern varieties caused rapid replacement of local cultivars. The significant role of local cultivars in the past, present and future are discussed. Taro (sato–imo) and yams (yama–imo), crops integral to the Japanese traditional diets, have not normally been subjected to breeding. They seem to be the only crops whose genetic resources are still well preserved in the form of local cultivars in Japan today. Recent basic research on these crops has revealed genetic information on valuable traits for local agriculture.

Since the first regional meeting of the International Board for Plant Genetic Resources (IBPGR) was held at the University of Tsukuba in 1980, genetic resources issues have become of general interest, and recent agrobiological approaches on how to manage such genetic resources for agricultural production and people's welfare have been actively pursued in Japan. The activities and recent technical papers in root and tuber crops were well reviewed by Toriyama (1992).

Many leading experts of international and national projects have joined the present MAFF workshop to discuss our common interests on root and tuber crop genetic resources. This workshop is an opportunity to exchange information on this important subject. In this paper, I give examples of the extensive use of wild species germplasm to improve yield, particularly starch yield, in potato and sweet potato in Japan. The significant role of sweet potato local cultivars in the past is demonstrated and, further, their role as genetic donors to modern varieties is discussed. Finally, some recent studies on taro and yam are briefly reviewed from the viewpoint of their improvement.

1. Improvement of Starch Yield in Potato and Sweet Potato

There are some objectives common in both potato and sweet potato breeding, and one such objective is to improve the starch yield of these domestic starch crops. At present, cultivation of these starch producing crops is done at the northern and southern ends of Japan: potato production for starch is focussed in eastern Hokkaido

and sweet potato starch production is concentrated in southern Kyushu.

1-1. Potato breeding

The breeding program was conducted to generate cultivars superior to the current leading variety Benimaru, released in 1938. The starch value of 16.5% of this variety is not high when compared with values of more than 20% in recent selections. However, the outstanding tuber yield of this variety has been favorably received and now it is cultivated on 22.7% of the total planted area, 67,300ha in Hokkaido based on a 1992 Survey. The other two starch-use varieties, Eniwa (released in 1961) and Toyoakari (1986), have not expanded in planted area and now occupy less than 3% of the total area.

A breeding projects in Hokkaido Natl. Agric. Exp. Stn. and Hokkaido Pref. Konsen Agric. Exp. Stn. (HPKAES) developed the high-starch variety Konafubuki in 1981. With its starch value of 22-26% and appreciable tuber yield, the variety gives a starch yield that is about 10% higher than that of Benimaru (Asama *et al.* 1982). Then, Konafubuki is now planted on 11.4% of the total potato area.

As shown in the genealogic map of Konafubuki (Fig. 1), the variety was generated from a cross between high tuber yielding Toyoshiro with a18% starch value and the low yielding line WB66201-10 with an extremely high starch value of 26%. The high-starch characteristic of this variety can be traced back to two unique genetic resources, (1) the German cultivar Hochprozentige having the starch value as high as 26%, and (2) the autotetraploid *Solanum chacoense* and the *S.*

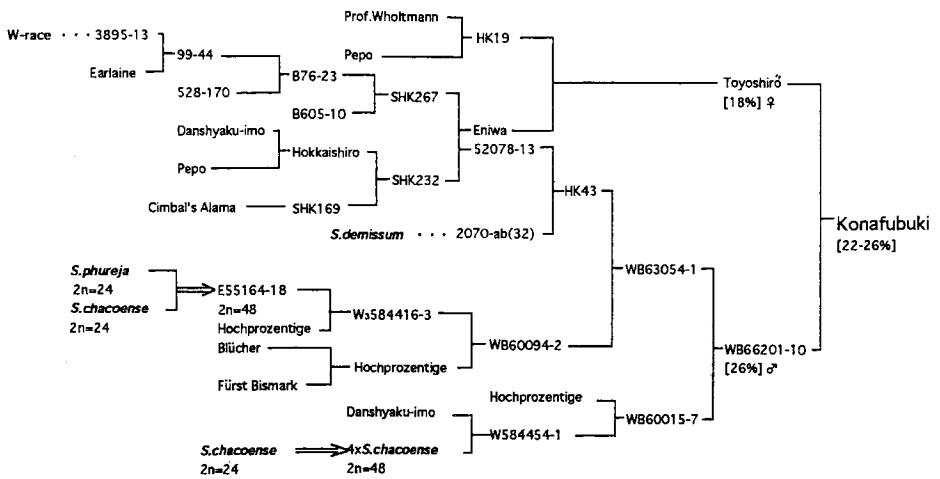

Figure. 1. Genealogic map of the high-starch potato variety Konafubuki that was generated in the HNAES-HKAES programme from the cross between Toyoshiro of high tuber-yield lineage and WB66201-10 of high-starch lineage. The wild species *S. chacoense* in the autotetraploid and amphidiploid forms and the high-starch cultivar Hochprozentige were used to develop the high-starch lineage. Percent starch values are shown in brackets. Arrows indicate chromosome duplication.

chacoense–S. phureja amphidiploid line, E55164–18. In the studies on interspecific cross–incompatibility of *Solanum* species to potato, Irikura (1968) succeeded in overcoming the cross–incompatibility of diploid *S. chacoense* by using either autotetraploid forms or *S. chacoense–S. phureja* amphidiploid forms as parents. Further, Irikura *et al.* (1982) have reported the high–starch values of more than 20 % shown by some accessions of *S. chacoense* to be an useful character. These findings provided a basis of the use of this wild species germplasm for high–starch potato. On the other hand, in the Toyoshiro lineage, selections 2070–ab(32) and 3895–13 are both derived from introgression of *S. demissum* which was employed as a donor of resistance genes to late blight (*Pytophthora infestans*).

There are some remarks on the traits other than its strach value of this variety. Konafubuki was resistant to late blight as expected. However, it turned to susceptible 2–3 years after the release, and now the resistance of this variety to potato virus Y is attracted considerable attention (M. Mori, personal communication). Konahubuki is susceptible to potato cyst nematode (*Globodera rostochiensis*). According to the 1993 Report of HPKAES, one new promising high–starch line showing 23% starch value and resistance to the cyst nematode has been generated from crosses involving the variety Konafubuki.

1–2. Sweet potato breeding

Improvement of starch yield is also a major objective in sweet potato breeding. The program to improve cultivars by using wild species germplasm started with interspecific hybridization between a few cultivars and *Ipomoea trifida* in 1957 at the Kyushu Natl. Agric. Exp. Stn. (KNAES). Among the 20 *I. trifida* accessions (K123), one accession (K123–11, 19.6% starch content) with resistance to two major *Meloidogyne* nematode pests provided acceptable progenies from successive back crossings with sweet potato parents. From 1957 onwards, a number of lines with high starch yield have been generated from the progenies in the subsequent generations of the interspecific cross.

To examine the breeding effect of the *I. trifida* germplasm involved in the interspecific cross with sweet potato, two groups of lines were compared in terms of their starch yield traits, starch content(%) and root yield per are (kg/a).

Group 1: 43 lines, Kyushu 8 (selected in 1943) to Kyushu 57 (1965).

Group 2: 28 lines, Kyushu 58 (1965) to Kyushu 101 (1991).

Measurements of traits were expressed by the values relative to those of standard varieties in the same yield–performance tests of the KNAES breeding program (Anonymous 2,3,4). The Group 1 lines are those derived from crosses not involving the wild species. In the trials of these 43 lines, high–starch variety Norin 2 was used as a standard variety. On the other hand, the Group 2 lines are those derived from crosses involving the wild species. In this case, the standard variety

was Kogenesengan (KS), a more productive variety than Norin 2.

Frequency distributions of lines are shown in two horizontal axes, Norin 2–axis (A) and KS–axis (B) in Fig. 2. Positioning of the two axes were determined by using the measurements for Norin 2 and KS in the 1965–1966 performance tests as described in Fig. 2. Comparisons between distributions A and B in terms of root weight and starch content, respectively, indicate the following:

(1) Group 2 represents an improvement upon Group 1 for both yield traits,
(2) about half of the lines in Group 2 exceed the KS level in root weight,
(3) most lines of Group 2 are beyond the KS level in starch content.

On this basis, it may be asserted that the breeding program which started with interspecific hybridization succeeded in changing the starch yielding ability of sweet potato. Among the lines in Group 2 are the variety Minami–yutaka (24% starch content, released in 1975) and the line Kyushu 79 (28.4%), both lines have root yields that are more or less at the KS level.

In addition, there are other high–starch lines, not included in the above comparison, developed from the same K123–related lineage in the breeding program of Natl. Agric. Res. Center (NARC). They are the varieties Shirosatsuma, released in 1986 and having the starch content of 24.6% (Sakamoto *et al.*,1989), and Hi–starch, released in 1988 and exhibiting starch content as high as 28.0% (Tarumoto *et al.* 1989a), and the recently selected line Kanto 106, with 28.0% starch content (Anonymous 1).

By assuming the starch content value of a newly released variety is the potential level of the breeding material of the time, an increment for starch content per unit time was estimated. The change in starch content from that of the variety Norin 2 (21.4%, 1942) to that of the variety KS (23.9%, 1966) is 2.5% based on the data from 38 trials carried out over 13 years at KNAES, which gives an increase of 1.0% /10 years. As today's cultivars almost reach the 28% starch level, the change from the variety KS's level is about 4%. This gives again an increase in starch content of about 1.4%/10 years. The overall improvement in starch level since the time of Norin 2 (1942) is about 1.0%/10 years. This increase has been achieved by effective use of a wide range of germplasm resources including a wild relative, native local cultivars, local cultivars and improved varieties from foreign countries.

1–3. Starch as a future clean natural source

As a massive change in consumer behavior, starch consumption has drastically increased during the past decade. The total amount of starch supply rose to almost 3 million tons in the 1990's. However, the proportion of domestic starches from potato and sweet potato has stayed a less than 20% of the total. On

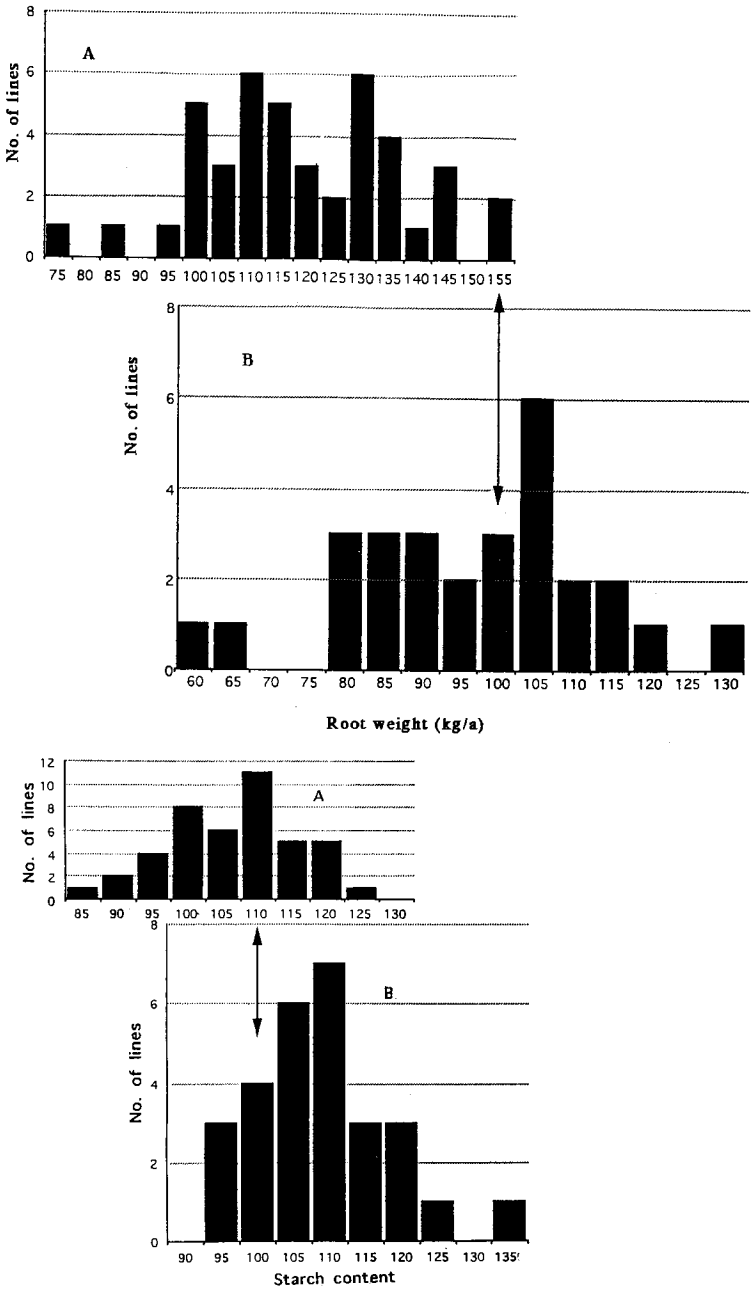

Figure 2. Improvement of starch yield using the wild *I. trifida* in sweet potato. Distribution (A) includes 43 Kyushu selections, and distribution (B) 28 Kyushu selections in crosses involving the wild species. Root weight and starch content measurements were both expressed in values relative to those of Norin 2 in distribution (A) and those of Koganesengan in distribution (B). The two-headed arrow points to the value of KS in both distributions. In distribution A, the value of KS (root weight, 379kg/a=151; starch content, 26.0%=112) is expressed relative to that of Norin 2 (251kg/a=100, 23.3%), the standard variety of the Group 1 trial. In distribution B, KS is the standard variety, so it is assigned the value of 100.

the other hand, the amounts of imported raw starch from manioc, sago, corn, potato and others have been rising over the past few years. This situation has hampered domestic starch production, and triggered talks of a collapse in starch-use potato or sweet potato production. Any ideas and plans to lower the cost of agricultural products by inputting improved cultivars and other technology seem impractical because the price of domestic starches is about two to four times higher than import prices. Starch production in Japan have some problems that need to be solved.as soon as possible.

From another perspective, the potential of starch as source of clean energy is recognized. Starch could help alleviate current problems of environmental pollution arising from use of petroleum. A survey by the Institute of Energy Economics, Japan has ranked alcohol fuels made from starch as an important energy that can be substituted partly for petroleum. Further, exploiting biodegradable polymers and plastics is a remarkable subject with respect to the effective use of agricultural products, particularly starches, in the MAFF Bio-Renaissance Project being conducted at present. In this project, Shiotani *et al.* (1991) and Asante *et al.* (1993) have proposed a breeding plan to improve the amylose component of sweet potato starch by using their wild relatives. In the near future starch supply-demand for the Asian region will be watched by all the world. The root and tuber crop improvement programs can play an active role in providing a material base to resolve this global problem.

2. Local Cultivars and Modern Cultivars of Sweet Potato

2-1. The gain and loss

Replacement of traditional local cultivars by modern varieties has often been stressed and is called genetic erosion. Based on MAFF Crop Statistics (Anonymous 5, 6), replacement of local cultivars have occurred (Fig. 3). Percentages of the areas planting local cultivars (ALC) during the period 1940-91 are shown and sweet potato yields (kg/10a) during the period 1935-91 in this figure. The percent ALC was 95.9% in 1940 and it had decreased to only 12.3% by 1955. In 1940, 4.1% of the sweet potato area was planted to three improved cultivars that were developed in the early Okinawa breeding program prior to the full-scale modern breeding . Two modern varieties, Norin 1 and Norin 2, were released in 1942, and subsequently, other released varieties found their way into remote farming villages. The replacement of local cultivars was triggered by the release of these improved cultivars, although food famine during and after World War II may have accelerated replacement of local cultivars.

Another pronounced feature incidental to the replacement was a yield increase: the average yield of 1300kg/10a in 1940 rose to 1900kg /10a in 1955. The gain from increased yield and loss of traditional local cultivars are twisted together in a thread. Fortunately, some native local cultivars from the early days are preserved in the MAFF genebanks, 32 cultivars in NARC and 78 cultivars in

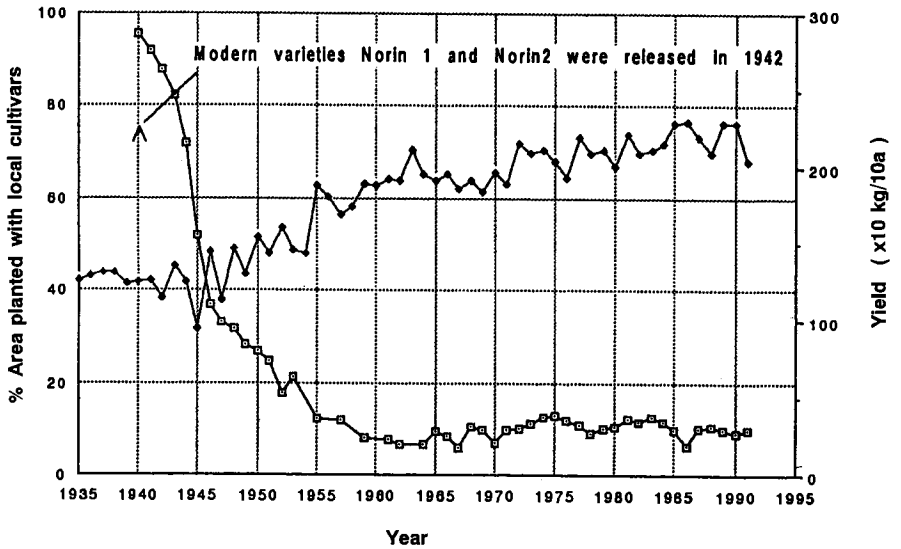

Figure 3. Sweet potato local cultivars were rapidly replaced by modern varieties between 1940 and 1955. Since then, the percentage of area planted with local cultivars has been kept constant at about 10%. The incidental to the replacement was an increase in yield per unit area.

KNAES.

2-2. Local cultivars being grown today

The percent area of local cultivars (ALC) has been nearly constant at the 10% level on average since 1955, but there is a great variation in the percentage ALC among the prefectures. The percent ALC and total area producing this crop in each prefecture were illustrated in Fig. 4 based on the Statistic data in 1993 (Anonymous 6). Although no simple interpretation of this wide regional variation seems to be possible, only a lucid feature is that the percents are quite low in the prefectures which have large shares in the big three, Tokyo, Osaka and Nagoya Markets (1993 Market Survey). These prefectures are Kagoshima (0%ALC), Miyazaki(5), Kumamoto (0) and Oita (0) in Kyushu, and Kochi (0), Tokushima (0) and Kagawa (0) in Shikoku, and Ibaraki (4) and Chiba (18) in Kanto district. Production in these districts have been conducted with their cultivation-post harvest management-marketing package plans. Under the circumstances, it is almost inevitable that only a few cultivars are carefully chosen to hold the marketability such as standardized size of root, excellent texture, high-quality on a commercial basis.

On the other hand, a high percent ALC is seen in a prefecture not known for this crop, e. g., ALC is100% in both Aomori and Tottori, 74% in Miyagi, 63% in Fukushima, 57% in Iwate and 53% in Aichi. At present there is a lack of detailed information on local cultivars. Among local cultivars is the high-quality, table-use

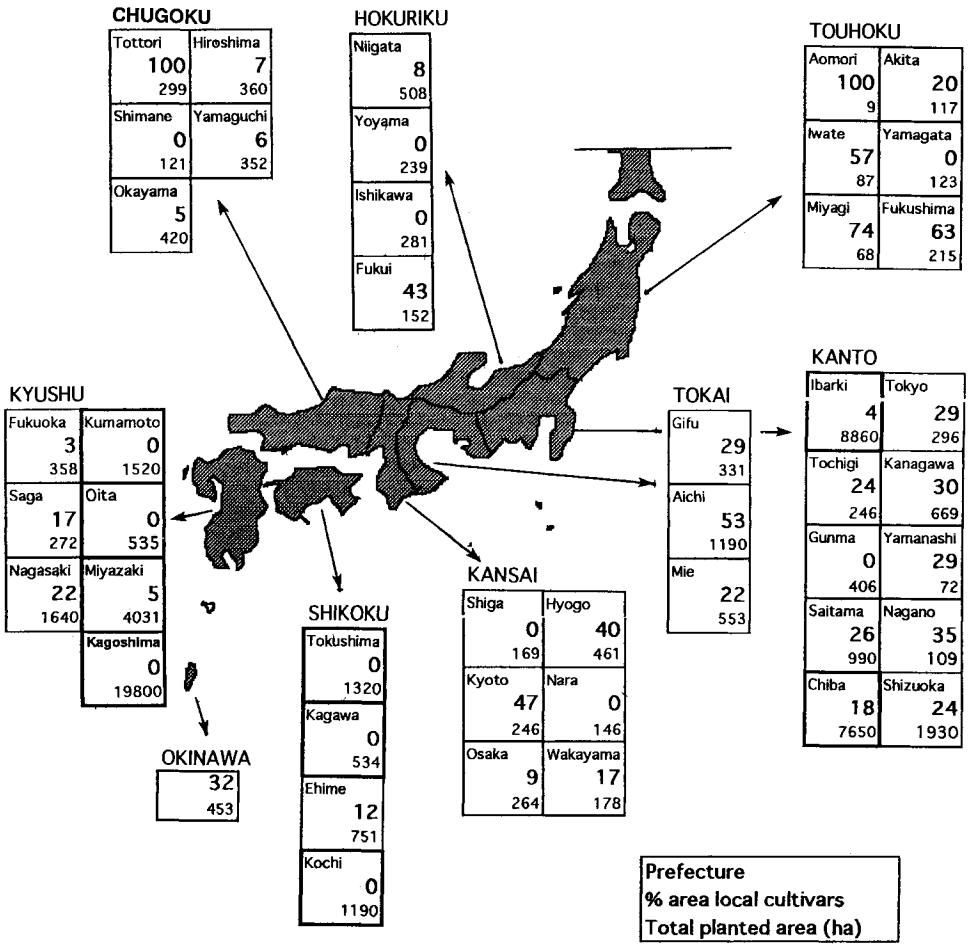

Figure 4. Great regional variation exists in percentage of area planted with sweet potato local cultivars (MAFF 1991 Statistics). Some prefectures show a high percentage of more than 50%, while most major sweet potato producing prefectures (bold boxes) show zero or low percentages.

cultivar Beniaka which is cultivated mostly in Chiba Prefecture and other districts. However, most of these cultivars are grown for home consumption by farmers. Local cultivars are closely linked to the traditional foods in every locality, the following accounts may illustrate this: People of the fishing towns in Shima, the southern part of Mie Prefecture, have cultivated two local cultivars (Hayato and Hichi-fuku) for dried sweet potato (*kinko*) as use as a winter food on their fishing boats and as well at home. Since the two cultivars have low yield, they have tried to introduce new cultivars. However, local people say, "Products made from any other cultivars are not as satisfactory compared with the ones from our cultivars". The plan to commercialize products made from their cultivars started in 1957 among the farmer's group in cooperation with Ise-Shima Agriculture Cooperatives,

and shipping of the product to the large city markets was realized for the first time in 1992. The next is the word of a woman who is in charge of managing "crop genetic resources" in her yard. It was her reply to the inquiry about the source of her sweet potatoes by Tarumoto *et al.* (1989b) during a collection trips for local cultivars in Okinawa. She told them, " This was one I brought with me when I got married, those were inherited with this home, and I got that sort as a sweet one from my neighbor ".

The ties that bind crops and humans may be strengthened by mutual adjustment. Crops adapt to the cultivation pressure by their phenotypic adaptability and genotypic change due to natural mutations and gene recombination by some chance in southern districts, while humans may use crops in different ways as their various uses become known. This co-adaptation, operating on a daily basis in every farmer's yard, is not only a driving force to enrich genetic diversity but also a dynamic reservoir of cultigens.

2-3 Biodata of local cultivars

Noteworthy traits of sweet potato local cultivars were quoted from the inspiring papers (Anonymous 2; Ono,1981; Sakamoto, 1986). Nine native cultivars cited in this report are familiar to breeders as important ancestors of modern varieties. They are Beniaka, Genji, Hayato, Hichi-fuku, Oiran, Taihaku,

Table 1. Noteworthy traits of some local Sweetpotato cultivars

Trait	Local cultivar
Crop management	
Sprouting at a low temperature (28°C)	Beniaka
Moderately high temperature between 32° and 35°C	Oiran, Taihaku
Early maturity, yielding ability by early cropping in growth season	Yonju-nichi
Low response to nitrogen supply, moderate yield without excess vegetative growth	Yonju-nichi
Excellent storability	Hichi-fuku, Genji
Resistance and Tolerance	
Resistance to black rot, *Ceratocystis fimbriata*	Hichi-fuku
Resistance to stem rot, *Fusarium oxysporum* f. sp. *batatas*	Hichi-fuku Tsurunashi-genji
High resistance to root-knot nematode, *Meloidogyne incognita*	Taihaku, Yoshida
Moterate resistance to root-lesion nematoda, *Pratylenchus coffeae*	Hichi-fuku
Drought tolerance	HIchi-fuku
Tolerance to excess soil moisture	Taihaku
Root quality	
High-starch content	Hichi-fuku, Genji
Low polyphenol content	Beniaka, Taihaku
Low fructose and glucose and high maltose(steamed root)	Beniaka
High-carotine content	Hayato

Turunashi-genji, Yonju-nichi, and Yoshida. Most of the traits mentioned here seem to be heritable characteristics, and have been subjected to the will of breeders, and are still attracting planner's concern in the creative breeding work for future cultivars. The traits and the local cultivars possessing the useful traits are shown (Table 1).

A genealogic map show how local cultivars have taken part in the cross-breeding program. The first of the modern types, Norin 1 was a derived from a cross between two local cultivars, Genki and Hichi-fuku. With an increase in the number (n) of hybridizations, the number of the parents involved increased by as many as 2n in the single-cross sequential program. Consequently, every recent variety generally has a complex genealogy. For example, the complete genealogic map of variety Hi-starch (Fig. 5), released in 1988, includes a total of 66 original entries from 14 parent stocks. The parent stocks involved in full-sib and half-sib matings were counted repeatedly. The 14 stocks and their frequencies of entry use in the Hi-starch map are shown (Table 2).

Out of 14 parents, seven cultivars occupy 74.2% of the total entries, indicating that they provided the major genetic background of this variety. Among the native cultivars having high entry values, Hichi-fuku, Tsurunashi-genji and Yoshida were local cultivars already mentioned for their noteworthy traits.

In conclusion, I like to emphasize two points: (1) local cultivar germplasm

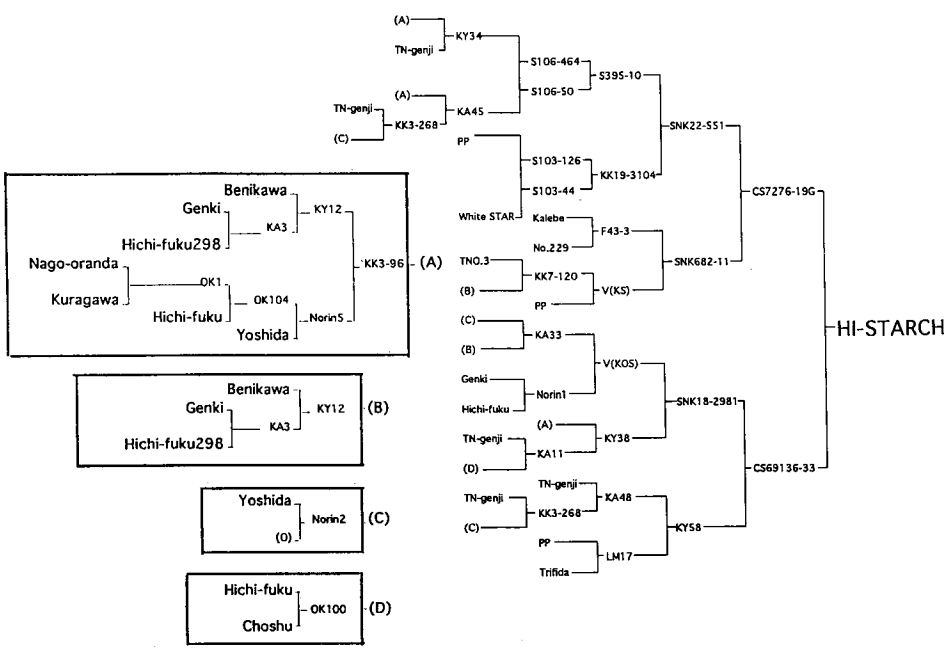

Figure 5. Genealogic map of the variety Hi-starch developed from a wide range of genetic resources. It comprises fourteen parent stocks, a wild relative, native cultivars, local and improved cultivars from foreign countries. Of a total of 66 entries, seven native cultivars (see Table 2) make up 49 entries (74.2%).

Table 2. The parent stocks and their frequencies of use in the lineage of the sweetpotato variety Hi-starch

Cultivar	Frequency		
Native cultivar			
Nago-aranda		5	
Kuragawa		5	
Choshu		1	
Hichi-fuku		14	
Genki		8	
Tsurunashi-genji		7	
Yoshida		9	
	Subtotal	49	74.20 %
Introduced cultivar			
Benikawa(China)		7	
Kalebe(Uganda)		1	
No.229(Mexico)		1	
T.No.3(Indonesia)		1	
Pelican Professor(U.S.A.)		4	
White Star(U.S.A.)		2	
	Subtotal	16	24.20 %
Wild relative			
Ipomea trifida(Mexico)		1	1.50 %
	Total	66	

have an incalculable value because they have a genetic background which make them adaptable to the local climatic and edaphic conditions, and (2) breeding is partly trial and error, biodata including characteristics and genealogic relationship of the local cultivars provides a guid to make a reliable breeding plan.

3. Taro

According to the FAO Statistics (FAO, 1993), after China Japan has the second largest taro production (20%) in Asia. This reflects the importance of this crop in Japanese daily food.

Taros (sato-imo, village's tuber) in Japan include *Colocasia esculenta* and *Xanthosoma sagittifolium.* Considerable numbers of local cultivars of *C. esculenta* are cultivated all over Japan. It seems as if each farmer has his own cultivars. *Xanthosoma* taros are occasionally grown in areas of low soil moisture in Okinawa.

Genetic diversity of taros was studied by Tanimoto *et al.* (1986), and they reported that the isozyme analysis supported the previous classification based on morphological characters. Mathews *et al.* (1992) suggested the phylogenic connections of a few Japanese cultivars to certain cultivars in Nepal and to wild forms in northern Australia based on the rDNA and mtDNA analyses. Further, Hirai *et al.* (1989) have stated, based on the corm-protein electrophoretic pattern analysis, that most of the Japanese cultivars are most likely generated by mutations in a few cultivars.

Effective methods to improve cultivars are, of course, systematic breeding

and mutation breeding programs. Recently, superior taro cultivars were developed from a 15 year-progam based on sexually propagated population in Western Samoa (Wilson *et al.*, 1991). Furthermore, genetic analysis of resistance to root rot blight complex in *Xanthosoma* taro was made in the diallel cross design (Aguegua *et al.*,1991). These two reports suggest an effective cross-breeding method to improve taro.

4. Yam

Japan is the largest producer of yam, showing 88% of the Asian total production (FAO, 1993). It used to be a symbol of the autumn harvest; however, today yams are available all the year round in food shops. The majority of yam cultivars (yama-imo, yama-no-imo, mountain's tuber) in Japan belong the species *Dioscorea opposita*. Cultivated throughout Japan, a great deal of genetic variation exists as indicated by numerous named or unnamed local cultivars. *D. alata* is supposedly a recent introduction and restricted to warm districts. There is also a wild relative, *D. japonica*, distributed from all over Japan except Hokkaido. This wild species may become valuable sources of genes for breeding improved cultivated yamsto. Araki *et al.* (1983) studied cytologically and morphologically two fertile male hybrids (2n=110) derived from the natural cross betweem *D. opposita* (2n=140) and *D. japonica* (2n=80), and they suggested the possibility of developing a cross-breeding scheme to select seedling-derived clones.

Recent studies by Nagashima *et al.* (1985) have revealed marked differences in properties such as carbohydrate, protein and mucilage content and amino acid composition among four yam cultivars. Further, Nagashima *et al.* (1990) indicated differences in chemical and physical starch properties among the same four cultivars.

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References

Aguegua, A., C.A. Fatokun, and S.K.Hahn,1991. Genetics of resistance to cocoyam root rot blight complex disease in *Xanthosoma sagittifolium* (L.) Schott. Abstract; Ninth Symposium of the International Society for Tropical Root Crops, 1991, Ghana.

Anonymous 1, 1989, 1990 & 1991. 1989 Annual Report of Sweet Potato Breeding Laboratory, No.1, pp. 247. 1990&1991 ibid., No.2&3, pp.147, pp.177, Natl. Agric. Res. Center, MAFF. Japan.

Anonymous 2, 1972. Characters of the Sweet Potato Varieties and Breeding Strains. Research Report 43, pp.205, Kyushu Natl.Agric. Exp. Stn., Fukuoka, Japan.

Anonymous 3, 1990, 1991,1992,1993. Annual Report of Sweet Potato Breeding. No. 1, 1990, pp. 84; No. 2, 1991, pp.11; No 3, 1992, pp.130; N0. 4, 1993 pp.131, Kyushu Natl. Agric. Exp. Stn., Fukuoka, Japan.

Anonymous 4, 1989, 1990, 1991, 1992. Annual Report of Sweet Potato Breeding. No. 1, 1989; No 2, 1990; No. 3, 1991; No 4, 1992, Kyushu Natl. Agric. Exp. Stn., Fukuoka, Japan.

Anonymous 5, 1950–1993. Statistics of Agriculture, Forestry and Fisheries. (Pocket edition), Association of Agriculture, Forestry and Fisheries, MAFF, Japan.

Anonymous 6, 1955–1981. Statistics of Sweet Potato Production and Marketing, [1982–1993, Statistics of Root and Tuber Crop Production and Marketing]. Upland Crops Division, Agricultural Production Bureau, MAFF, Japan.

Araki, H., T. Harada, and T, Yakuwa, 1983. Some characteristics of interspecific hybrids between *Dioscorea japonica* Thunb. and *Dioscorea opposita* Thunb. J. Japan. Soc. Hort. Sci., 52:153–158.

Asama, K., H. Ito, N. Murakami, and T. Itoh, 1982. New potato variety "Konafubuki." The Bulletin of Hokkaido Prefectural Agricultural Experiment Station, 48:75–84.

Asante, S. A., T. Yamada, M. Hisamatsu, and I. Shiotani, 1993. Studies on the starch properties of diploid *Ipomoea trifida* (H.B.K.) Don. strains. Starch/Starke, 45:299–306.

FAO, 1993. FAO Yearbook Production, 1992, 46:103–104, FAO Statistics Series No. 112, Food and Agriculture Organization of the United Nations, Rome.

Hirai, M., T. Sato, and K. Takayanagi, 1989. Classification of Japanese cultivars of taro (*Colocasia esculenta* (L.) Schott) based on electrophoretic pattern of the tuber proteins and morphological characters. Japan. J. Breed., 39:307–317.

Irikura, Y.,1968. Studies on interspecific crosses of tuber–bearing Solanums. 1. Overcoming cross–incompatibility between *Solanum tuberosum* and other *Solanum* species by mean of induced polyploids and haploids. Research Bulletin of the Hokkaido Nat. Agr. Exp. Stat., 92:21–37.

Irikura, Y., Y. Nishibe, Y. Mitsui, and K, Shimizu, 1982. Classification and characteristics of wild and cultivated *Solanum* species. Chap. 2. Breeding by the Genome Manipulation. p.59–61.*In* Development of Cell–engineering Breeding Methods in Crops and Application. Research Report 138, The Secretariat of Agriculture, Forestry and Fisheries Research Council, MAFF.

Matthews, P., Y. Matsushita, T. Sato, and M. Hirai, 1992. Ribosomal and mitochondrial DNA variation in Japanese taro (*Colocasia esculenta* L. Schott). Japan. J. Breed., 42:825–833.

Nagashima, T., T. Asari, I. Komai, and T. Obara, 1985. Study on Yam (*Dioscorea batatas* Dence). Part 2. Differences in viscosity and suitability for processing. Journal of Agricultural Science, Tokyo Nogyo Daigaku, 29:155–159.

Nagashima, T., and I. Komai, 1990. Some properties of starches from yam (Dioscorea). Nippon Shokuhin Kogyo Gakkaishi 37:124–129.

Ono, T., 1981. Characteristics of Sweet Potato Cultivars. *In* Imo–rui Hen [Root and Tuber crops], Hatasaku–zenshu, 467–498, Nosangyoson Bunka Kyokai, Tokyo.

Sakamoto, S., 1986. Breeding approach against the injury by continuos cropping of sweet potato. Recent Advances in Breeding 27:121–130., Japanese Society of Breeding, Tokyo.

Sakamoto, S., T. Shiga, H. Ishikawa, S. Kato, T. Takemata, M. Umehara, and T. Ando, 1989. New sweet potato cultivar "Shirosatsuma." Bulletin of the Natl. Agric. Res. Center, 15:1–13, Tsukuba, Ibaraki, Japan.

Shiotani, I., A. Nishimura, S. Yamanaka, M. Taki, and T. Yamada, 1991. Starch properties of the

sweet potato, diploid *Ipomoea trifida* (H.B.K.) Don. and tetraploid hybrids. Starch/Starke, 43:133–138.

Tarumoto, I., T. Shiga, S. Sakamoto, H. Ishikawa, S. Kato, T. Takemata, and M. Umehara, 1989a. New sweet potato cultivar "Hi-starch." Bulletin of the Natl. Agric. Res. Center, 15:15–29, Tsukuba, Ibaraki, Japan.

Tarumoto, I. and H. Ishikawa, 1989b. Collection and inventory of local sweet potato cultivars in Okinawa Islands, 1988. 5:47–79, Annual Report of Exploration and Introduction of Plant Genetic Resources. National Institute of Agrobiological Resources, Tsukuba, Ibaraki.

Tanimoto, T. and T. Matsumoto, 1986. Variation of morphological characters and isozyme patterns in Japanese cultivars of *Colocasia esculenta* Schott and *C. gigantea* Hook. Japan. J. Breed. 36:100–111.

Toriyama, K., 1992. Tuber and root crops. utilization of plant genetic resources for crop improve ment–Technical Assistance Activities for Genetic Resources Projects. No.5:47–55. Japan International Cooperation Agency.

Wilson, J. E., P. Sivan, and C. Munroe, 1991. Alahua Sunrise and Samoa Hybrid improve the population of taro (*Colocasia esculenta* [L.] Schott) in the Pacific. Abstract; Ninth Symposium of the International Society for Tropical Root Crops, 1991, Ghana.

TECHNICAL REPORTS

Session 1

CASSAVA

Chairmen
Shoji Miyazaki
Muhamad Djazuli

Genetic Resource Management of Cassava at CIAT

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Abstract

The responsibility for the conservation of the genetic resources of cassava implies a commitment to gather a representative sample of overall diversity, and to ensure its long-term availability with low risk of loss, contamination by pests or pathogens, or genetic modification. Activities include acquisition, maintenance, description, documentation, distribution, and the identification and implementation of appropriate conditions and facilities for long term storage of germplasm. The base collection of cassava at CIAT consists of 5263 accessions representing diversity from most cassava producing countries of the world. A core collection of 630 accessions from the base collection has been identified to orient the agronomic evaluation and use of the germplasm. This collection provides the genetic base for cassava improvement at CIAT, and is shared through frequent requests for material with certain characteristics or adaptation for use in national breeding programs, genebanks or advanced labs. To date, these activities have been concentrated on cassava (*Manihot esculenta*), with more limited efforts in collection, *ex situ* conservation and characterization of the crop's wild relatives.

The other important facets of CIAT cassava germplasm activity are the generation of advanced breeding materials, their distributions to national programs and the joint evaluation/selection of superior cultivars with national programs. These have been frequently described elsewhere; thus, we present only a most illustrative example in this text.

THE WORLD CASSAVA COLLECTION

Representation and Acquisition

The basis for conservation and genetic improvement of cassava at CIAT is the world collection of 5263 accessions, comprised of entries from most of the cassava growing countries of the world. Representation in the base collection is shown in **Table 1**. The majority of the accessions are from Latin America, which is the primary center of diversity for the crop. Within Latin and Central America, gaps in the collection are recognized for Argentina, Bolivia, Haiti, Dominican Republic, Nicaragua, Salvador and Honduras.

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Table 1. Number of cassava accessions by country of origin maintained in the field active genebank at CIAT.

Country of Origin	Total number of accessions	Last code assigned at CIAT
Argentina	16	MARG 16
Bolivia	3	MBOL 3
Brazil	1288	MBRA 1386
Colombia	2008	MCOL 2732
China	2	MCHN 2
Costa Rica	147	MCR 149
Cuba	74	MCUB 74
Dominican Republic	5	MDOM 5
Ecuador	117	MECU 200
Fiji Island	6	MFJI 6
Guatemala	91	MGUA 92
Indonesia	51	MIND 51
Malaysia	67	MMAL 69
Mexico	100	MMEX 111
Nigeria	19	MNGA 19
Panama	42	MPAN 139
Paraguay	192	MPAR 195
Peru	405	MPER 615
Philippines	6	MPHI 6
Puerto Rico	15	MPTR 102
Thailand	31	MTAI 31
United States	9	MUSA 9
Venezuela	240	MVEN 332
Elite Hybrids-CIAT	329	SM 524-1
TOTAL	5263	

As with all new accessions, the material will be introduced to CIAT as *in vitro* cultures, and tested for diseases before becoming available for field characterization and distribution. The introduction to the world collection of nearly 800 accessions from Brazil, currently maintained at the Centro Nacional de Mandioca e Fruticultura Tropical (CNPMF), 178 new accessions recently collected in the underrepresented semi-arid ecosystem, of Brazil, and 165 new accessions recently collected in Argentina and currently kept at the Instituto Nacional de Recursos Biologicos del INTA is in progress. Landraces form China, Vietnam, Thailand, and the Philippines are among the priorities for germplasm acquisition in the near future, in order to have good representation of the diversity available in Asia.

The acquisition of the most elite genotypes from the national breeding

program of Thailand provided 23 new genotypes to the world collection in 1993. The absence of a centralized African collection, and quarantine problems with diseases present on one continent but not the other, have restricted the representation of African germplasm. Current efforts by IITA to consolidate information and collections from regional cassava collections, together with recent advances in virus indexing will allow better representation of African germplasm in the near future. To facilitate the collection/ acquisition process, a series of workshops in the early 1980's recommended procedures for the collection of cassava in the field, and elaborated a form which encourages the recording of data critical to the eventual value and use of the collected germplasm (Gulick et. al., 1983).

Several wild *Manihot* species are also maintained at CIAT both *in vitro* and in the field. Thirty species have been collected and introduced to CIAT, principally as true seed. Problems with seed viability and poor rooting of the more exotic species, both *in vitro* and as vegetative stakes have hindered conservation efforts, resulting in the current holding of very few accessions of each species. Nevertheless, this collection has provided some preliminary results on root quality, photosynthetic characteristics and pest resistance, which are currently being confirmed by the Cassava Program, in parallel with efforts to expand the collection.

Conservation

Accessions of the world collection are maintained both *in vitro* and in an active field bank at CIAT headquarters in Palmira, Colombia. In the field bank, each genotype is classified by its growth habit into one of three vigor groups, and planted in two rows of three plants each. Spacing is 0.5 meters between plants and 1.0 meter between rows, with 1.0, 1.5, or 2.2 meters between plots, depending on growth habit. This arrangement minimizes competition, reducing the risk of losing materials with poor adaptation, and ensures efficient weed control. Special attention is paid to health status and to obtaining a good stand, often involving replanting of individual genotypes. As a working collection, the field bank provides planting material for experimental purposes and enables direct characterization and evaluation. The 18 month growing cycles for the field bank overlap in time to provide security of planting material during the establishment period. Each planting occupies 4.5 hectares and another 4.5 ha is required for the overlapping period. The cost of maintenance and evaluation of the collection is estimated to be approximtely 15 dollars per accession per cycle, 80% of which is labor. Thus, the maintenance of the field bank at CIAT/HQ is an expensive process needing 9.0 ha of field area and the annual budget of US$90,000.

The *in vitro* collection provides safe duplication of the world collection, in an internationally acceptable condition for germplasm storage and exchange. The cultures are maintained in under slow growth conditions: 23±1°C constant temperature with 1000–3000 lux illumination during a 12H photoperiod provided by cool white fluorescent lamps, at 70–90% relative humidity. One to three plants

are grown in each 20 x 150 mm glass tube containing a modified Morishige and Skoog medium (Roca et. al., 1984) developed at CIAT. Five test tubes of each clone are routinely maintained. The need for periodic renovation of the cultures varies among the genotypes conserved, but ranges between six months and two years, with an average of 12 months. The cost of maintaining each genotype *in vitro* is estimated at 40 dollars (US). Procedures for acclimatization of the cultures to soil conditions were described by Roca et. al. (1984) in a manual which is currently being updated. Germplasm requests for material in the collection are directed to the Cassava Program, and are prepared and shipped by the Genetic Resources Unit (GRU).

The Biotechnology Research Unit (BRU) at CIAT has developed and begun to standardize techniques for cryopreservation of cassava shoot tips (Escobar et. al., 1993), which will provide a long term, low cost conservation method to back up the world collection. Using a standard cultivar, small shoot tips treated with a purified cryoprotectant before immersion in liquid nitrogen, have proven most viable. The response of different genotypes to the steps of pre-conditioning, cooling, and thawing are variable, and further research is needed to determine methods that will be broadly applicable across cassava accessions.

Health testing

This process begins with observations that should be made in the field at the time material is identified for entry into a collection (Lozano et. al., 1981). Clones in the *in vitro* collection at CIAT are subject to thermotherapy (40°C day and 35°C night temperatures on a 12 hour cycle for 3-4 weeks) and indexed for viruses and virus-like diseases before they are declared eligible for exchange. CIAT's Virology Research Unit (VRU) has developed or adapted sensitive diagnostic techniques for several diseases (**Table 2**), enabling the establishment of pathogen tested cassava clones for conservation and exchange with the most up to date methods. Current research in the VRU addresses the improvement of methods for health testing. To date, 20% of the germplasm collection (and 80% of the core collection) have been indexed for the viruses in **Table 2**; and priority is being given to the core collection (next section) for future indexing. Further research is needed in the area of Frog Skin Disease, and efforts to produce and distribute antisera for use in national programs are global priorities. Specific guidelines for the safe movement of cassava germplasm have been prepared by FAO/IBPGR (Frison and Feliu, 1991).

Documentation

A relational database system (ORACLE v 6.0) used for management of the germplasm collection is maintained and updated by the GRU and the Cassava Program to organize information related to all aspects of conservation and associated areas, such as renovation, disease indexing, distribution and passport data. The database includes information on 5,040 accessions, with the facility to

Table 2. Virus and Virus-like Diseases and Assay Methods used in indexing cassava collections at CIAT (ELISA = Enzyme-linked ammunosorbent assay; PCR = Polymerase chain reaction).

Disease	Assay
Cassava Common Mosaic Virus (CCMV)	Serology: ELISA
Cassava Colombian Symptomless Virus (CCSpV)	Serology: ELISA
Cassava x Virus (CsXV)	Serology: ELISA
Cassava Frogskin Disease (CFSD)	Grafting & DsRNA detection
Cassava American Latent Virus (CALV)	Serology: ELISA
Cassava Vein Mosaic Virus (CVMC)	PCR assay & serology
African Cassava Mosaic Virus	Serology: ELISA
Indian Cassava Mosaic Virus	Serology: ELISA

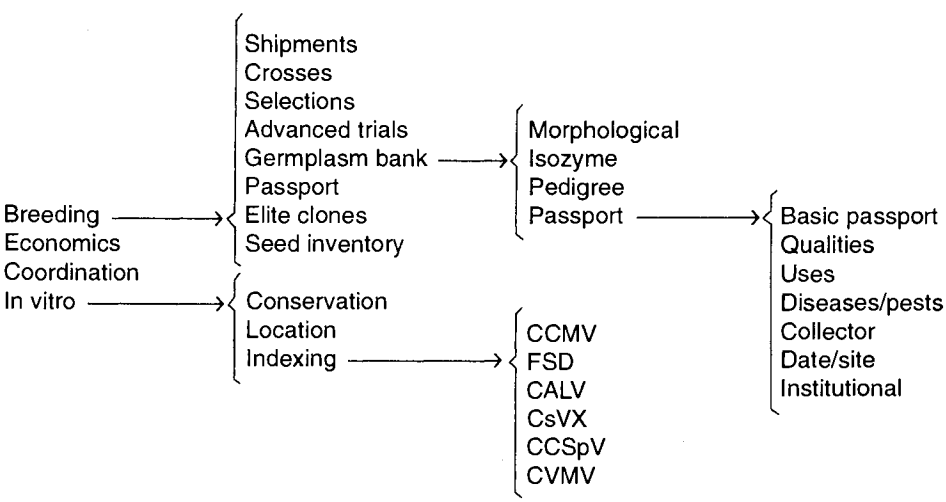

Figure 1. Sample of information fields in relational database of cassava germplasm at CIAT. Each column lists optional data fields accessed through the area indicated by the respective arrow.

retrieve data in any one or a combination of various fields of information (**Figure 1**). Twenty one morphological characters and 22 isozyme bands (esterase) are used to describe each accession, in addition to its basic passport data. Additional data

on agronomic performance, taken on subsets of the collection in experimental trials complement the preliminary description in the database. The *in vitro* and field collections are linked in the database, so that both field characteristics and maintenance information can be accessed simultaneously.

CORE COLLECTION

A sample of accessions, or core collection, has been assembled at CIAT to represent the genetic diversity of the base collection in a more manageable size (Hershey et. al., 1994). The core collection was defined by the use of three specific parameters; geographic origin, morphological diversity, and diversity of esterase banding patterns, with approximately 100 accessions being added on an *a priori* basis, to include material of importance to particular breeding programs. The inclusion of isozyme diversity as a selection criterion for the core was an effort to include a good representation of alleles present in the base collection, on the assumption that biochemical markers are neutral traits with respect to selection and /or environmental effects. The base collection was stratified by the three parameters of diversity and random samples were drawn from the resulting groups. The accessions in the core collection and the parameters by which they were selected are presented in **Table 3**. The collection is expected to be dynamic as a consequence of the elimination of duplicates, acquisition of new material, and better characterization of the genetic diversity of the genepool, including wild relatives.

The use of the core collection by CIAT's Cassava Program was recently described by Iglesias et. al (1993). This more manageable sample of the world collection can be evaluated across different ecosystems and years in order to determine the genotype by environment effects for important traits. A plan is being developed for the safety duplication of the core collection with two institutions outside Colombia; likely candidates to house the core collection are EMBRAPA (Brazil), and Rayong Field Crop Research Center (Thailand). This will provide important characterization data, and the first opportunities for national programs to use this large source of diversity in their breeding programs.

CHARACTERIZATION

Evaluation of the core germplasm under field conditions

The core collection has been used consistently at CIAT to assess existing genetic variability for important agronomic characteristics, and to indicate starting points for more intensive evaluation where promising preliminary results are obtained. Several traits of importance for cassava breeding require highly specific and expensive evaluations, and are difficult to apply to the entire germplasm collection. Among these traits are photosynthetic rate, activity of C4 enzymes, starch amylose/amylopectin ratios, nutrient and water use efficiency, quantitative

Table 3. Accessions included in the core collection according to different parameters.

Origin	Number of clones for distinct parameters				
	Geographic origin	Morpho-logical diversity	Diversity of esterase	A priori selections	Final number in core
Argentina	2	4	0	3	8
Bolivia	1	2	0	3	3
Brazil	100	13	15	20	101
China	1	0	0	2	2
Colombia	111	15	13	14	146
Costa Rica	9	7	5	4	23
Cuba	10	5	1	2	18
Dominican Republic	2	2	0	4	5
Ecuador	25	6	0	4	32
Fiji	1	0	0	2	2
Guatemala	8	6	0	2	15
Indonesia	1	0	2	5	7
Malaysia	8	0	1	6	15
Mexico	14	6	0	2	20
Panama	6	2	0	2	9
Paraguay	25	8	3	7	40
Peru	63	10	3	2	76
Philippines	1	0	0	2	2
Puerto Rico	1	2	2	4	7
Thailand	0	0	0	4	4
United States	0	0	0	4	4
Venezuela	41	9	3	3	55
CIAT clones	0	3	5	27	33
IITA clones	0	0	0	3	3
TOTAL:	440	100	51	121	630

levels of cyanogens, resistance to diseases and pests, and others. To orient this evaluation, a series of testing sites in Colombia has been identified as "ecological homologues", corresponding to the major edaphoclimatic conditions of cassava production regions of the world (Hershey, 1984). A description of the important ecozones is presented in **Table 4**, with reference to the respective testing sites, homologous production regions, and principal biotic and abiotic constraints. The core accessions are evaluated in selected field sites each year to contribute morphological and agronomic data, and as a source of germplasm for the ecosystem-oriented improved genepools developed by CIAT.

Duplicate identification

An important consideration in the management of any germplasm collection is the minimization of duplicate accessions, whose maintenance consumes valuable resources with no return. The strategy currently being applied at CIAT to the

Table 4. Description of edaphoclimatic zones defined by CIAT Cassava Program for germplasm development.

No.	Description	Representative Countries/Regions	Principal Constraints
1	Subhumid lowland tropics.	NE Brazil; Colombia (Atl. coast and Santanderes); N. Venezuela; Mexico (Yucatan Peninsula); E. Thailand;S. Vietnam; E. Java; subhumid belt of sub-sahelian Africa; S. India.	Drought stress; mites; thrips; *Diplodia* and *Fusarium* root rots; mealybug.
2	Acid soil, lowland tropical savannas.	Brazil (Cerrado); Colombia (Llanos); Venezuela (Llanos); W. Africa savannas.	Soil acidity; bacterial blight; superelongation; anthracnose; mites; mealybug; African Cassava Mosaic Virus.
3	Humid lowland tropics.	Amazon basin (Brazil, Colombia, Peru); West Java and Sumatra; Malaysia; Philippines; Equatorial West Africa.	*Phytophthera* and *Fusarium* root rots; African Cassava Mosaic Virus; anthracnose *Cercospora* and *Cercosporidium* spp. mealybug.
4	Mid-altitude tropics (800-1400 masl).	Andean zone; central Brazilian highlands; Jos plateau of Nigeria; Cameroon, East Africa.	Thrips; mites; root rots.
5	High altitude tropics (1400-2200 masl).	Andean zone; Rwanda, Burundi.	Concentric ring leaf spot; low temperature.
6	Subtropics	S. Brazil; N. Argentina; Paraguay; Cuba; China; N. Vietnam; S. Africa.	Low winter temperature; bacterial blight; superelongation; *Cercospora* and *Cercosporidium* leaf spots.
7	Semiarid lowland tropics	NE Brazil; NE Colombia (Guajira); NE Thailand; semiarid belt of West Africa; Tanzania; Mozambique; Rwanda; Burundi.	Drought stress; mealybug; mites.

[1] Not all constraints are found in all regions of a given edaphoclimatic zone.

identification of duplicates in the cassava collection relies on the database of characterization information, and consists of three steps: 1) First, candidate duplicates are identified by screening the data base for accessions with identical characterization data, including morphological descriptors and isozyme patterns. 2) As the morphological data often results from activities conducted on distinct parts of the collection in different years, it is necessary to grow the putative duplicates together side–by–side in the same year, and repeat the morphological characterization process. 3) Finally, when the number of putative duplicates is reduced, the remaining groups are characterized with a molecular probe, M13

minisatellite, which assays many regions of the genome at the same time, presenting a highly discriminatory "fingerprint" for each genotype. Together with the preceding data, the fingerprint is considered sufficient evidence to confirm duplication (**Figure 2**). According to the level of duplication so far detected, it is expected that around 600 accessions could be eliminated from the collection, saving

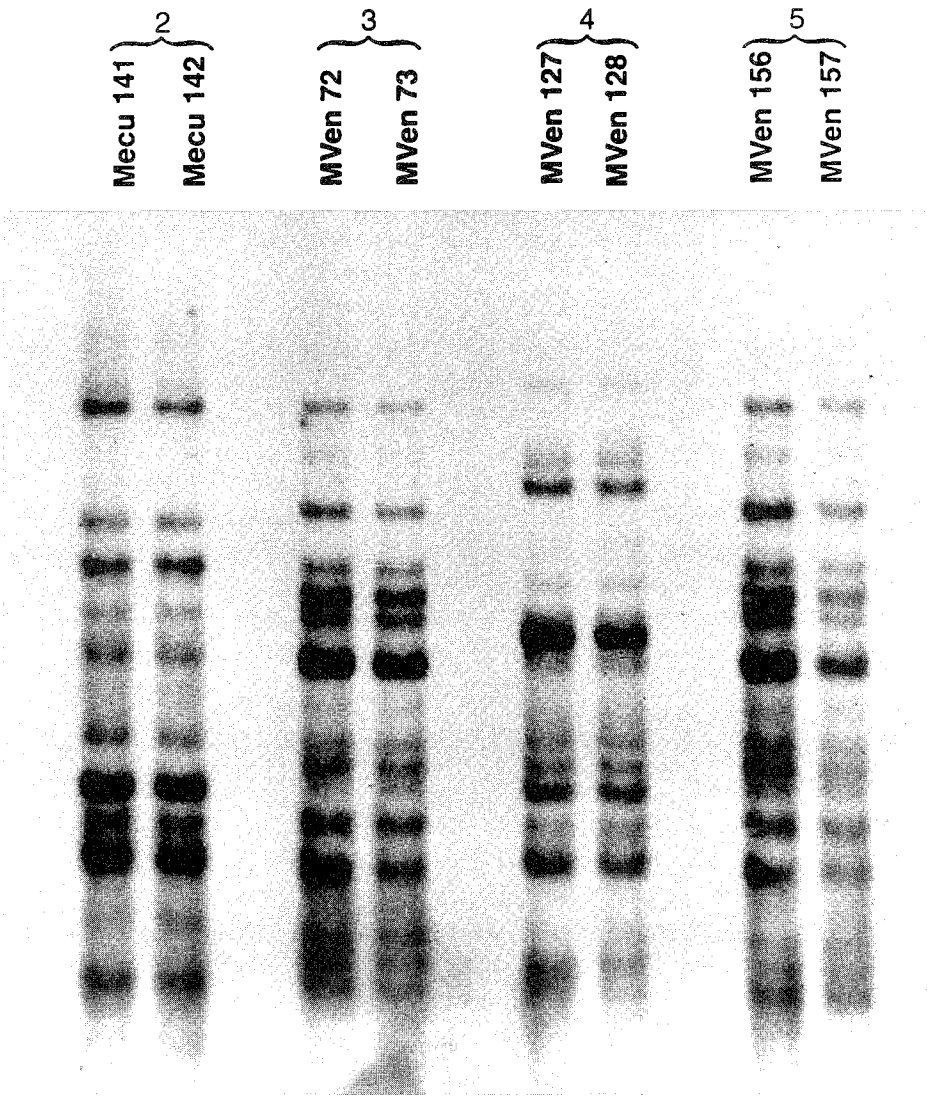

Figure 2. Analysis of putative duplicates in the cassava collection by molecular fingerprinting. DNA from pairs of accessions with similar morphology and isozyme pattern is digested with Hae III, and Southern blots are probed with a cloned sequence from the bacteriophage M13.

considerable resources in germplasm conservation.

DEVELOPMENT OF ADVANCED BREEDING MATERIALS

The role of CIAT could be limited to the collection, evaluation, maintenance and distribution of basic germplasm materials if the research capacity of all the national programs were satisfactory. However, the research capacity in many tropical countries is far from this and it was necessary that CIAT upgraded the immediate usefulness of germplasm materials to be offered to national programs. Thus, the development of advanced breeding materials has been the most important undertaking of the germplasm-related research at the CIAT Cassava Program. We have been frequently reporting this (e.g. Kawano *et al.* 1990, Kawano 1992; also see CIAT Annual Reports from 1973 to 1993 and can summarize as follows. This started with the enhancement of basic physiological yield capacity of the breeding population at the CIAT HQ in the 1970s and accomplished a 100% increase in the yield capacity of the breeding population compared with that of the original unselected population thanks largely to improved harvest index. A simultaneous selection in a high stress environment added tolerance to numerous diseases and pests as well as adaptation to infertile and acid soils. The more decentralized breeding program conducted by CIAT/HQ during the 1980s and thereafter added further adaptations to specific edapho-climatic conditions and resistances to specific diseases and pests to the breeding population. The population improvement at the Field Crop Research Center by the CIAT/Thai collaborative program further upgraded the total biomass production, root dry matter content and tolerance to drought of the breeding population. We consider that the current CIAT cassava breeding materials provide national program breeders with immediate selection opportunities.

DISTRIBUTION

Germplasm from the core collection, or from CIAT hybrids involving more advanced generations, is freely available to interested programs as true seeds, indexed meristem cultures or disease indexed stakes. National programs with capacity to handle and evaluate true seed progenies frequently request controlled or open pollinated families from parents adapted to their needs and this has been the most frequently used means of germplasm transfer. Advanced labs, or genebanks are more likely to request clones as *in vitro* cultures. A third form of germplasm distribution stems from the availability of selected elite clones as stakes from disease-indexed mother plants. This method simplifies handling of the material by the recipient, but is recommended only for countries with homologous disease spectrums. Training is available at CIAT to national program scientists in the transfer, maintenance, and subsequent utilization of cassava germplasm. **Table 5** illustrates the pattern of germplasm distribution over the past ten years, in terms of

Table 5. Cassava germplasm distribution by CIAT during 1984-1993.

Region	Type of shipment	No. of shipment	No. of clones/families	Total No.
Africa	Indexed stakes	0	-	-
	In vitro plantlets	2	17	84
	Botanical seed	18	1707	276508
Asia	Indexed stakes	1	6	54
	In vitro plantlets	38	442	2207
	Botanical seed	110	5466	328384
Latin America	Indexed stakes	18	198	1554
	In vitro plantlets	115	2613	11298
	Botanical seed	60	2942	181372
Europe	Indexed stakes	1	13	78
	In vitro plantlets	14	160	2175
	Botanical seed	20	147	42050
North America	Indexed stakes	0	-	-
	In vitro plantlets	23	99	803
	Botanical seed	19	77	13250

type of material, and destination. The amount of genetic variability transfered in this way to Asia should far exceed all the genetic variability which existed there before.

UTILIZATION BY NATIONAL PROGRAMS

Aside from genetic resources, an efficient research network with national programs is another important asset of CIAT. Through this network, we have been distributing advanced breeding materials, working hand in hand with the national program breeders and, most importantly, producing results. Much have been reported on this process (e.g. Kawano, 1994) and we can appreciate an example of good collaboration with a strong national program in the other paper from Thailand to be presented in this Workshop. We present here only the most illustrative case for the utilization of advanced breeding materials by national program.

Cassava research in Vietnam had been isolated for a long period of time and systematic introduction of cassava germplasm did not take place until our contact with their research program. A spectacular yield and root dry matter content upgrading followed after the introduction of selected clonal materials from the Thai–CIAT collaborative breeding program in 1989 (Fig. 3). This yield jump reflects the progress accumulated through the breeding work by the Thai breeders and our collaborative breeding work in the past 20 years. One of the best clones in this scheme is now being officially released for all over Vietnam, the 22nd CIAT

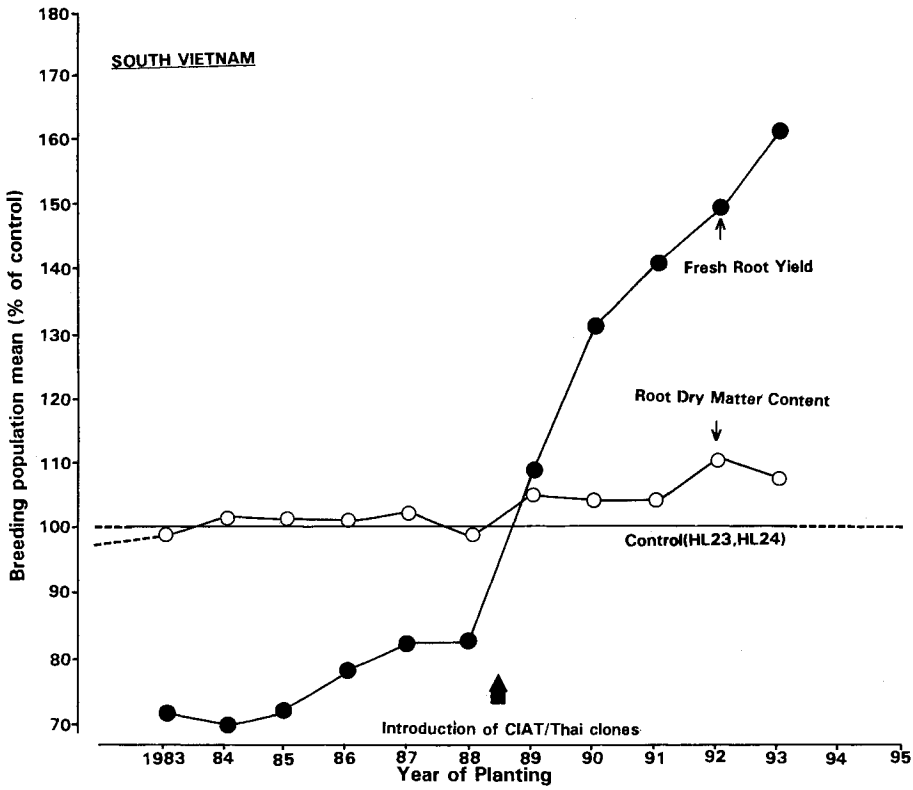

Fig 3. Change in the mean of breeding population (all entry mean in yield trials) in fresh root yield and root dry matter content at Hung Loc Research Center, South Vietnam.

related cultivar officially released by the national programs in Asia.

The network collaboration functions as a significant source of feed-back information. Recently, we have been identifying several officially recommended cultivars showing excellent results also in other countries with different climatic conditions. This may indicate the potential for broad adaptation and stability across variable environmental conditions.

PRIORITIES FOR FUTURE RESEARCH IN GENETIC RESOURCE MANAGEMENT FOR CASSAVA

Several areas of cassava production, particularly in sparsely populated areas where the crop is of primary importance, and in areas of traditional, small plot cultivation, have not yet been subject to systematic collection or conservation efforts. Wild relatives of cassava are still poorly represented in germplam collections, the improvement of which will require collection and of conservation techniques, probably including a combination of *ex situ* and in situ methods. Threats to local diversity, including the expansion of modern agriculture and social change

or instability in these areas contribute to the urgency of collecting and conserving cassava genetic resources.

Another subject in need of future effort is that of our understanding of the distribution, generation, and maintenance of genetic variability of the crop genepool in the field situation. Related to this is improved knowledge of the ecological and geographic distribution of the cultigen and its relatives, and the taxonomic and cytogenetic relations among them. For example, the involvement of *Manihot* species in the evolution of cassava is not yet clearly understood, and despite the tremendous amount of morphological diversity among cassava genotypes, the extent of a founder effect (Ladizinsky, 1985) for the crop is not yet known. Basic studies in genetics, biochemistry, morphology, ecology and biogeography are needed to contribute to concepts of interspecific relationships, and the distribution of diversity within and among different components of the genepool. Crossability of exotic accessions with the cultigen and subsequent characterization of hybrids for fertility / viability define the limits to genetic exchange, providing information on the feasibility of use of diversity by breeders. The value of wild relatives lies in some of the adaptive characters they possess, as potential sources of variation for characters of limited range in the cultivated genepool, and, for the unknown value of potential combinations of alleles from cultivated and exotic sources, which may result in heterosis or transgressive segregation for critical traits (deVicente and Tanksley, 1993).

The genetic resources of cassava will be of greater value if a global database of collection and characterization data is developed. These area has been given high priority by the Manihot Genetic Resources Network, which is in the process of defining a 'minimum descriptor list' and a common database system to be shared among members. In the future, new methods such as molecular and accompanying statistical analyses will be valuable in achieving objective, quantitative measures of genetic diversity, not affected by environmental conditions, for application to sampling strategies for germplasm conservation and use.

REFERENCES

DeVicente, M.C. and S. Tanksley. 1993. QTL analysis of transgressive segregation in an interspecific cross of tomato. Genetics. 134: 585–596.

Escobar, R.H., W. Roca, and G. Mafla. 1993. Cryopreservation of cassava shoot tips. pp. 166–121. In: Roca, W. and A.M. Thro (eds.). Proceedings of the First International Scientific Meeting of the Cassava Biotechnology Network. Cartagena, Colombia. CIAT, Cali, Colombia (Working Document no. 123).

Frison, E.A. and E. Feliu (eds.). 1991. FAO/IBPGR Technical guidelines for the safe movement of cassava germplasm. FAO Rome. IBPGR Rome. 48 pp.

Gulick, P., C. Hershey, and J. Esquinas–Alcazar. 1983. Appendices III and IV. In: Genetic resources of cassava an wild relatives. IBPGR Secretariat, Rome.

Hernández Romero, Luis A. Evaluación de nuevas variedades de yuca con la participación de agricultores/asesoría científica, Jacqueline Ashby, Clair Hershey, Carlos Iglesias. Centro Internacional de Agricultura Tropical CIAT, 1993. (Documento de Trabajo No. 130).

Hershey, C., C. Iglesias, M. Iwanaga and J. Tohme. 1994. Definition of a core collection for cassava.In: Iglesias, C. and M. Iwanaga (eds). Proceedings from an International Workshop on Cassava Genetic Resources. August 1992. Cali, Colombia, CIAT/IITA/IBPGR (in press).

_____. 1984. Breeding cassava for adaptation to stress conditions: Development of a methodology. In: CIP (Centro Internacional de la Papa). Proc. 6th Symp. Inte. Soc. Trop. Root Crops. Lima, Peru. pp. 303–314.

Iglesias, C., M.W. Bonierbale, M. El–Sharkawy, C. Lozano., A. Bellotti, and C. Wheatley. In press. Focusing basic research for cassava variety improvement. Proceedings of the International Society on Tropical Tuber Crops 6–9 November, 1993. Trivandrum, India. Central Tuber Crops Research Institute, Kerala, India.

Kawano, K., S. Sarakarn, A. Limsila, A. Tongglum and D. Suparharn. 1990. Cassava cultivar evoluation viewed through harvest index and biomass production. 202–209. *In*: R. Howeler (ed.). Proc. 8th Symp. Internaitonal Society for Tropical Root Crops. Bangkok, Thailand.

Kawano, K. 1992. CIAT cassava germplasm and its role in cassava varietal improvement in Asia. 170–184. *In*: R. Howeler (ed.). Cassava Breeding Agronomy and Utilization Research in Asia. Bangok, Thailand.

Kawano, K. 1994. "Green Revolution" and cassava breeding. In press. *In*: R. Howeler (ed.) Proc. IV Asian Cassava Research Workshop, Trivandrum, India, Nov. 1993. CIAT, Bangkok, Thailand.

Ladizinsky, G. 1985. Founder effect in crop–plant evolution. Econ. Bot. 39(2): 191–199.

Lozano, J.C., A. Bellotti, J.A. Reyes, R. Howeler, D. Leihner, J. Doll. 1981. Field problems of cassava. Cali, Colombia. CIAT. 208 pp.

Roca, W.M., J.A. Rodriguez, G. Mafla and J. Roa. 1984. Procedures for recovering cassava clones distributed *in vitro*. CIAT, Cali, Colombia. 8pp.

Physiological Characteristics of Cassava in Southeast Asia

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Abstract

Cassava is one of the most productive crops in dry regions having infertile soils. Most cassava is grown in unirrigated fields without fertilizers in the main areas of production in Southeast Asia with pronounced dry periods. Dry matter production varies markedly from season to season. The change in productivity between the rainy and dry seasons, is closely correlated with the changes in leaf canopy. Physiological and morphological characteristics of leaves were studied in relation to dry matter production. Plant characteristics related to yield, such as plant type, sink– source balance and germination ability, were further investigated using Thai local and newly released cultivars including CIAT hybrid clones. Yield stability of cassava can also be achieved by selecting germplasm well adapted to the local conditions, as well as by improving cultural practices which lead to sustainable production.

Introduction

Cassava (*Manihot esculenta* Crantz) originated and was domesticated in South America more than three thousand years ago. From South America cassava spread to Africa and in 18 to 19 century to Asia (Leon, 1977). Among tropical crops, cassava has great potential as a source of carbohydrates. Further increases in cassava productivity may be expected from cultivar development and improved cultural practices (Cock, 1985, De–Vries et al., 1967 and Kawano & Jennings, 1983). Cassava is the fourth most important crop in terms of dietary calories for humans. Asia produces nearly 35% of the worlds total production of cassava. In Asia, Thailand, Indonesia and India are the major producers (Table 1). Average cassava yield in Southeast Asia is about 13t/ha compared to the world average of 10t/ha. Yield, however, varies considerably from country to country. Yields in Thailand, Indonesia and China range from 12 to 15 t/ha.

The unique characteristic of cassava is its ability to be highly productive in dry soil with low fertility (Howeler, 1981). Generally cassava is grown in unirrigated fields and without fertilizers in tropical areas with pronounced dry

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Table 1 Cassava root production, harvested area and yield for selected southeast Asian countries.

Countries	Production 1,000Mt	Harvested area 1,000ha	Yield t/ha
Asia	51,237	3,788	13.5
Thailand	21,130	1,442	14.7
Indonesia	16,318	1,333	12.2
India	5,200	247	21.1
China	3,358	231	14.6
Vietnam	3,000	278	10.8
Philippines	1,320	160	8.3
Africa	70,444	9,303	7.6
South America	29,343	2,453	12.0
Central America	999	196	5.1
Oceania	194	278	10.8
World Total	152,218	15,757	9.7

Source: FAO production year book 1992.

periods.

Under adverse conditions of acid, infertile soils with a long dry season, yields of 15 to 20 tons of fresh roots can be expected. Factors responsible for low yields in Southeast Asia has been identified as poor agronomic practices, low soil fertility, absence of fertilizer use and, probably, the use of local cultivars. To increase and stabilized cassava yields, improvement both in agronomic practices and cultivars is desirable. This report deals with the growth characteristics and several other physiological factors related to yielding ability.

The experiment reported were conducted in the Southeast Thailand between the Rayong Filed Crops Research Center, Thailand and the Tropical Agriculture Research Center, Japan, during 4.5 years from 1983 to 1987.

Growth Characteristics

At the onset of the rainy season cassava sprout easily and leaves expand. About 3 months after planting, dry matter weight of the whole plant markedly increases with vigorous growth and development of the leaf canopy (Fig. 1). Leaf area index (LAI) reaches to 3 to 5 by the middle of the rainy season and is maintained throughout the season. During this period, while maintaining high LAI, crop growth rate (CGR) shows a maximum rate of 15 to 20g/m^2 day. With the onset dry season, leaves are dropped, and LAI and CGR decreases rapidly. Cassava continues to produce leaves even in the dry season. The leaf production rate, represented by the leaf number produced per apex and per day, decrease to 0.05/apex day compared as 0.8 in the rainy season. Single leaf area is only 20% of that in the rainy season (Table 2). Leaves again expand leaves and dry matter production picks up again with the coming of rainy season.

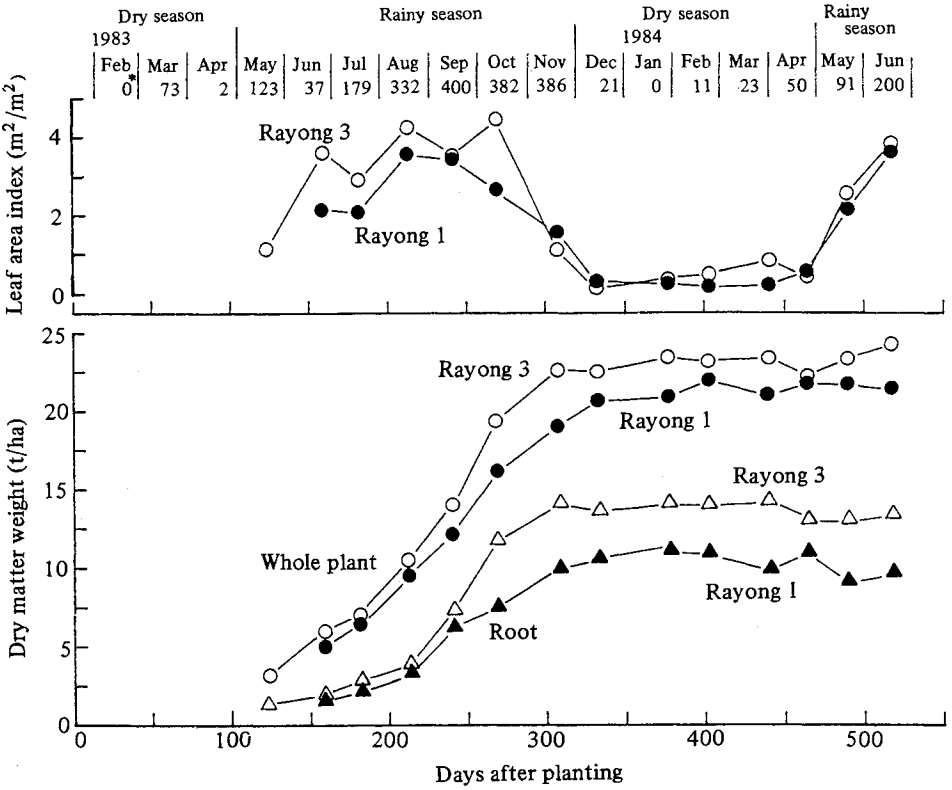

Fig. 1 Cassava growth pattern observed in Thailand in rainy and dry seasons.
Note: *Numerals in the upper figure show monthly rainfall (mm).

Table 2. Difference in physiological characteristeics of leaf canopy between rainy and dry seasons in Thailand

Parameters	Rainy season	Dry season
Leaf area index	4.5	0.30 m^2/m^2
Single leaf area	331.0	75.2 cm^2
Nitrogen content	16.7	17.9 mg/dm^2
Chlorophyll content	4.3	4.0 mg/dm^2
Stomata per unit area	556	661 No/mm^2
Transpiration rate	22.0	14.0 $\mu gH_2O/cm^2s$
Stomatal conductance	2.77	0.67 cm/s
Photosynthetic rate	27.0	10.0 $mgCO_2/dm^2h$

The annual growth pattern is shown for a representative sample of cultivars growing in Northeast Thailand which has a pronounced wet and dry seasons (Fig. 1). In insular of Southeast Asia, such as Indonesia which have a short dry season, cassava also shows the similar growth pattern. Dry matter production of cassava is closely correlated with leaf development and maintenance. It is important to maintain the developed leaf canopy throughout the growing cycle for high dry matter and root production (Cock et al., 1979).

There are large differences in physiological and morphological characteristics of leaves produced in the rainy and dry seasons (Table 2). As already mentioned, cassava expands lots of large leaves in the rainy season. Leaf nitrogen content (mg/g) on a dry matter basis of leave is significantly higher in the rainy season than in the dry season. On the other hand, nitrogen and chlorophyll content, given on leaf area basis (mg/dm^2), show no significant difference between seasons. Leaves are thicker in the dry season. Observations of stomata on the abaxial surface show significant difference in stomatal density between seasons. Leaves in the dry season show xeromorphism, characterized by the small thick leaves and the development of a thick wax layer on the leaf surface (Fig. 2).

The photosynthetic rate of single leaves follows an asymptotic curve with increasing light intensity and saturates with the maximum rate of about $27mgCO_2/dm^2h$. The maximum rates for cassava are within the range of 23 to $30mgCO_2/dm^2h$ (Palta, 1984) and are not high compared with those of major crops, such as rice, maize, sugercane which have rates of 35–70 $mgCO_2/dm^2h$. During the rainy season, the rate changes around $25mgCO_2/dm^2h$ in daytime. On the other hand, the rate in the dry season decreases to one-third of that in the rainy season in parallel with the decrease of transpiration rate and stomatal conductance (Table 2). Judging from the comparisons in the physiological and morphological characteristics of leaf canopy between both seasons, significant total dry matter increase can not be expected for the storage root production in the producing areas with a pronounced dry season lasting for 6 months. Therefore, it is important to select the appropriate cropping seasons and cultivars to achieve high root yield.

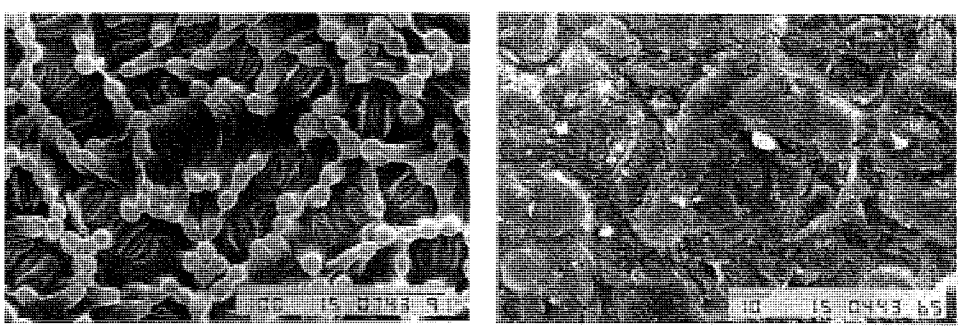

Fig. 2 Comparison of abaxial leaf surface in rainy(left) and dry(right) seasons.

Note: The length of bar shows 100 and 10 μm in the left and right figures, respectively.

The onset of root bulking occurs about 3 months after planting with the development of the leaf canopy and the maximum increases of root weight coincides well with the period of maximum dry matter production (Fig. 1). Large amounts of photosynthate are translocated to the roots with the progress of growth and starch content of root become to be above 30% at harvest time in the dry season. Cassava shows the highest caloric production per hectare and per year due to high root yield (De-Vries et al., 1967). The high annual economic yield in cassava is associated with the maintenance of LAI and CGR close to the maximum for long periods and with the high rate of translocation of photosynthate to roots.

Cultivars and High Yielding Ability

Traditional cultivars of cassava show genetic variation for growth characteristics and yielding ability. CIAT (1974) reported a ten fold difference in yield among 2,500 traditional cultivars which were collected from the Central and South America, and high yielding cultivars generally were associated with high harvest index, represented by the ratio of root weight to total weight. Among the cassava genetic resources, CIAT accession number MCol1684 showed high yielding ability and harvest index.

In tropical Asia, as in the American tropics, there are many traditional cassava cultivars, used mainly for fresh human consumption, that have been cultivated on a small-scale for a long time (Table 3). These cultivars, such as Golden Yellow in Philippines, and Kretek in Indonesia usually have low harvest index. Other traditional cultivars for large-scale production, such as Black Twig in Malaysia, Lakan in the Philippines and Rayong 1 in Thailand show moderately high yielding ability and harvest index (Kawano, 1988). The selection of Rayong 1 from Thai local cultivars is considered to be one of the most important factors in the successful production of cassava in Thailand.

High yielding cultivars show a high harvest index, as observed by comparing yields among many traditional cultivars (CIAT, 1975). During varietal

Table 3. Traditional and promising cassava cultivars in Southeast Asia

Countries	Traditional cultivars	Promising cultivars	Characteristics of promising cultivars
Thailand	Rayong 1	Rayong 3	High HI & starch, Earliness
		Rayong 60	High Y, HI & starch, Earliness
Indonesia	Kretek	Adira 1*	High starch, Low HCN, Earliness
		Adira 4	High Y, HI & starch
Philippines	Golden Yellow	Colombia	High Y
	Kadabao	VC-1	HIgh Y & HI
Malaysia	Black Twig	C-5	High Y & starch, Earliness

Source: Howeler(1988) and Kawano(1988)
*Edible type, HI:harvest index, Y:root yield, HCN:cyanide content

improvement of cassava, it has become evident that harvest index is the most important indicator for selecting high yielding cultivars (Kawano, 1990). We investigated the plant types which were observed in Thai local and CIAT hybrid clones in relation to dry matter and root production. They could be classified into 4 main types according to the branching habit (Fig. 3). High yielding cultivars and clones belonged to the non- branching type with 3 or 4 stakes per plant (B type) and sparse branching type (C1 type), The two plant types were characterized by 3 to 10 apices with short stakes. Both types appears to be ideal for achieving high yield in view of the balance between biological yield and harvest index.

At present, many promising cultivars have been released in Asia. They show high yielding ability and harvest index while having other good agronomic characteristics, such as high starch, early harvestability and low cyanide content of roots (Table 3).

Cultivation and Sustainable Production

Cassava planting materials are taken as long stakes obtained from the stems of plants which should be 8–12 months old and free of diseases o7 3 or pests. Before planting, long stakes kept under the shade of trees for a while are cut into cuttings of 15 to 20 cm length with sharp knife. They are planted vertically in most countries except in china, Malaysia and Philippines where they are planted horizontally. Planting density is around 1m between cuttings in the major producing areas of southeast Asia.

Successful germination in one of the most important factors for production. It depends upon the quality of cuttings and the growing conditions (Cock, 1985). Variation in germination ability is considerable among cassava cultivars. For example in Thailand, Rayong 1 has a higher germination ability than Rayong 3 under moisture stress. The characteristics of cuttings related to germination and

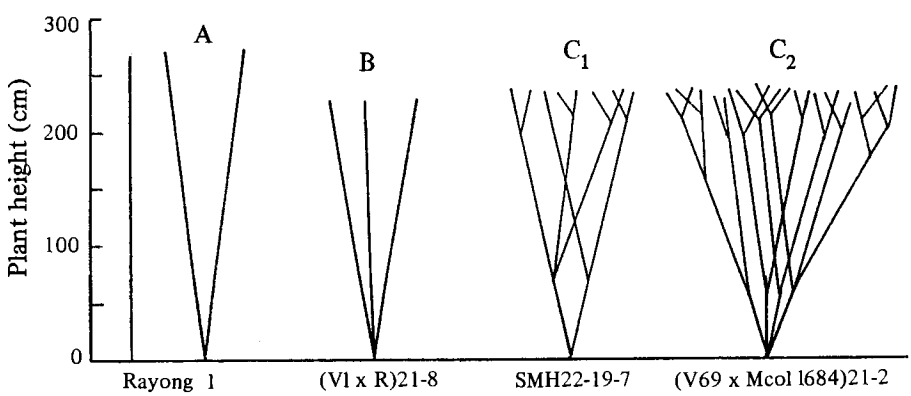

Fig. 3 Major plant types of cassava observed in Thai local cultivars and CIAT hybrid clones.

subsequent survival were investigated using Rayong 1 and 3 in the rainy and dry seasons. Multiple regression analysis showed that the major factors controlling the survival rate included the volume density, fresh weight and volume of cuttings in the dry season and volume density in the rainy season. Thus, the volume density was the main determinant of successful germination for both seasons. Volume density can be used as a useful indicator for the quality of planting stakes and breeding criteria (Oka et al., 1987).

Cassava can be planted all year round even in regions that have distinct rainy and dry seasons. However, there is an optimum planting time for achieving the highest yield depending upon the local conditions. Timing of planting depends on many factors, most important of which is the onset of the rains. Most cassava is planted early in the rainy season or late in the rainy season and harvested during the dry season in major producing areas of Southeast Asia. In Thailand also most cassava is planted in the early rainy season in April and May, but a large proportion is also planted at the end of rainy season in October to November. The plantings in both seasons can produce high yields, since they lead to large leaf area throughout all the growth cycles, especially during the rainy season (Oka et al., 1987).

Cassava has the ability to grow and give moderate yield under very low fertility conditions where no other crop can be grown beneficially (Howeler, 1981). Cassava can tolerate low calcium, nitrogen and potassium in the root environment better than other crops and has the ability to produce bulked roots at low phosphorus levels. At the same time, cassava is also known as a crop that exhausts soil nutrients. However, Howeler (1981) noted that cassava does not exhaust soil more than other crops. Cassava extracts large amounts of potassium and, to lesser degree, nitrogen from the soil. There are many reports that emphasize the importance of potassium are nitrogen in achieving high root yields (Cock, 1985. Howeler, 1981 & 1988).

In general fertilizer use is very low in Southeast Asia except in cassava plantations in Sumatra,Indonesia, and Malaysia and in some areas in Java (Howeler, 1988). In Thailand fertilizer is rarely in farmers' field because of the high price of fertilizer, although farmers know its importance. Recommended amount of fertilizer depends upon the country and soil fertility. Howeler (1988) concluded that generally in Southeast Asia nitrogen, phosphorus and potassium is recommended within the range from 50 to 100 kg per hectare. In our trial with the fertilizer use on a gray podzolic soil with sandy texture in Thailand, the uptake of nitrogen, phosphorus and potassium per hectare and per year was 154, 35 and 93kg, respectively. Even in this trial with the application of fertilizer, only the uptake of potassium showed a significant effect on increasing root yield and it is considered to be a more important element than nitrogen under less fertile soil conditions in Southeast Asia.

It has been found that soil productivity has steadily declined in long-term cultivation of cassava without fertilization. In the trials in the northeastern and

southeastern parts of Thailand, yields decreased from nearly 30 to 18 t/ha, indicating a rapid initial loss of fertility in the first 15–20 years of continuous cassava production (Sittibusaya et al., 1988). Long-term sustainable productivity of cassava can only be maintained by preventing soil exhaustion through the judicious use of fertilizers, organic manures, green manures, or intercropping with grain or tree legumes, and by preventing soil erosion or degradation through the loss of organic matter (Howeler, 1988).

Conclusions

Cassava had distributed throughout the tropics including southeast Asia from the original areas in South America, because it produces large amounts of starch but also well tolerate low soil fertility and long dry periods.

The growth characteristics of cassava can be summarized as follows;

1. High and stable productivity under low and medium-input condi-tions.
2. High resistance to diseases and pests and tolerance to adverse soil and climatic conditions.
3. Easy propagation from stakes.
4. Large variations in cultural practices in cassava based-cropping systems with other crops and trees.

The root yield of cassava under commercial conditions obviously depends on the levels of management and inputs. Using the present cultural practices the fresh yield can be expected to be within the range of 20 to 30t/ha even in adverse soil and climatic conditions. Cock et al. (1979) stated that the potential annual yield could be 90t/ha when cassava is grown under ideal growing conditions.

There are many cassava cultivars which are well adapted to various growing conditions and different cropping systems in the tropics. The genetic diversity within cassava for physiological and characters needs to be clarified so that germplasm which meets breeding objectives is readily available.

Acknowledgement

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References

CIAT 1975. Cassava production systems in CIAT Annual report 1974. 54–109. Cock, J.H. 1985. Cassava – New potential for a neglected crop. Frederik A. Praeger Publisher, Colorado, USA. pp191.

Cock, J.H. 1986. The agronomic potential of cassava for the upland areas of tropical Asia. Pages 203–212. *In* Cassava in Asia, its Potential and Research Development Needs: Proceedings of a Regional Workshop held in Bangkok, Thailand, 5–8 June 1984. CIAT & ESCAP CGRPT Center, Cali, Colombia.

Cock, J.H., Franklin, D., Sandoval, G. and Juri, P. 1979. The ideal cassava plant for maximum yield. Crop Sci. 19:271–279.

De–Vries, C.A., Ferwerda, J.D. and Flach M. 1967. Choice of food crop in relation to actual and potential production in the tropics. Neth. J. Agri. Sci., 15:241–248.

Kawano, K. 1988. CIAT cassava germplasm development in Asia – Cooperation with national programs. Pages 117–129. *In* R.H. Howeler & K. Kawano (eds), Cassava Breeding and Agronomy Research in Asia. CIAT, Cali, Colombia.

Kawano, K. 1990. Harvest index and evaluation of major food cultivars in the tropics. Euphytica 46:195–202.

Kawano, K. and Jennings, P.R. 1983. Tropical crop breeding – achievements and challenges. Pages 81–99. *In* Potential Productivity of Field Crops under Different Environments. IRRI, Manila, Philippines.

Howeler, R.H. 1981. Mineral nutrition and fertilization of cassava, CIAT, Cali, Colombia, pp52.

Howeler, R.H. 1988. Agronomic practices for cassava production in Asia. Pages 313–340. *In* R.H. Howeler & K. Kawano (eds), Cassava Breeding and Agronomy Research in Asia. CIAT, Cali, Colombia.

Leon, T., 1977. Origin, evaluation, and early dispersal of root and tuber crops. Pages 20–36. *In* J.H. Cock et al.(eds), Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops. CIAT, Cali Colombia, 1–7 August 1976, IDRC, Ottawa.

Oka, M., Limsila, J., Sarakarn, S., Sinthuprama, S. and Tiraporn C. 1987. Eco– physiological studies on cassava(*Manihot esculenta* Crantz) in Thailand. The final report of the cooperative research works between Thailand and Japan. pp241.

Palta, J. 1984. Influence of water deficient on gas exchange and the leaf area development of cassava cultivars. J. Exp. Bot., 159:1441–1449.

Sittbusaya, C., Nakaviroj, C. and Tunmaphirom, D. 1988. Cassava soil research in Thailand. Pages 145–156. *In* R.H. Howeler & K. Kawano (eds), Cassava Breeding and Agronomy Research in Asia. CIAT, Cali, Colombia.

Cassava Genetic Resources and Breeding in Thailand

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Abstract

Thai cassava production and processing industry heavily depends on the export market. With the anticipated removal of preferential tarif treatment to the Thai tapioca importation to the major market EC, an export ceiling and more competitive price may be imminent to Thai cassava products. Thus, the general Thai cassava policy is to reduce the cassava planted area and increase the productivity. To respond to this situation, cultivars with higher yielding capacity and better quality roots are required. To achieve this goal, creating broad genetic variability through germplasm introduction from abroad, recombining desirable characters with local cultivars and selecting superior clones may be the most promising approach.

Only a small number of local cultivars existed in Thailand and the current germplasm collection consists of mostly introduced clones, cultivars or seed selections from the foreign countries especially from CIAT, Virgin Island and Indonesia. The hybridizations and selections based on this germplasm have achieved the official release of seven cultivars as of now; five from the Department of Agriculture and two from Kasetsart University. These new cultivars are characterized by higher yielding capacity, high harvest index, higher root starch content and early harvestability. For further improvement, Thai cassava researchers will emphasize on selecting higher biomass, yield, root dry matter content while maintaining the high harvest index.

Introduction

Cassava is a promising crop for the tropic as a source of carbohydrates because it is very efficient in converting solar energy into carbohydrates, can be grown in a diverse range of conditions, and can be harvested over an extended

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period of time. Although it is not a staple food for the Thai people, cassava is a cash crop produced by a large number of small farmers in Thailand and nearly all the production is processed into animal feed components or starch. In 1992 Thailand exported 9.1 million tons of cassava products, earning US $ 1139.1 million. About 95% of the total production is exported, mainly as pellets (89%), followed by starch (8%) and chips (3%). The most important market is the European Community, amounting to 5.48 million tons in 1992. Domestic use is only about 5% of the total production and is utilized as starch for industrial use or as pellets for animal feed (Office of Agricultural Statistics, 1992).

In Thailand cassava occupies the second largest area, only next to rice, among the crops. During the 1980s its acreage increased from 1.38 million ha in 1983 to 1.62 million ha in 1989 while the average yield varied between 12.7 ton/ha and 15.2 ton/ha. The major cassava area is in the Northeast region amounting to 61 %of the total cassava planting area, followed by the Central Plain region with 33 % and the North region with 6 %. However, during the recent years (1989–1992) total cassava planting area decreased by 8 % from 1.62 million ha in 1989 to 1.49 million ha in 1992 (Office of Agricultural Statistics, 1992). Total cassava production also decreased by 16 % from 24.3 million tons of fresh root to 20.4 million tons (Table1). The decrease was almost entirely due to a decrease in planted area. The minor fluctuations from year to year are mainly caused by price variations which in turn are due to the foreign market situation.

Although the planted area was considerably decreased over these years, the Thai cassava policy still aims at reducing the cassava planting by 160,000 ha in 5 years because the reduced cassava export price is imminent due to the anticipated removal of preferential tariff treatment to cassava importation in EC. As the cassava acreage decreases the higher yielding cultivar will be necessary to increase cassava productivity which in turn will lead to the higher competitiveness of cassava productions in international market. To achieve this goal, broadening genetic variability through cassava collection in the country, introduction from

Table 1. Cassava planted area, production and average yield in Thailand

Year	Planted (000 ha)	Production (000 t)	Yield (t/ha)
1983	1,385	19,316	13.95
1984	1,405	19,985	14.22
1985	1,477	19,263	13.04
1986	1,240	15,255	12.66
1987	1,411	19,554	14.26
1988	1,580	22,307	14.41
1989	1,621	24,264	15.23
1990	1,529	20,701	13.91
1991	1,491	19,705	13.74
1992	1,491	20,356	14.03

Source : Office of Agricultural Economics, 1992.

foreign countries and also recombination of the desirable characters among them would be important and challenging task.

Cassava Genetic Resources in Thailand

Germplasm collection and introduction

The first step in any crop improvement program is the collection of both local and exotic germplasm and its evaluation. This phase has received substantial international support and has resulted in two large cassava germplasm collections at two international research centers, CIAT and IITA. This was followed by the detailed plans for further collections, and continuing attempts to standardize the evaluation and dissemination of the results (Jennings and Martin 1973; Kawano et al 1978; Hahn et al 1979) CIAT 1980). Both international centers have been very active in identification of elite genotypes, development of advanced breeding materials and distribution of improved populations to the national programs throughout the world.

In Thailand cassava breeding research began with the collection of local cultivars throughout the country and their systematic evaluation in 1956 at Rayong Field Crops Research Center in Rayong province. There were not many cultivars and several accessions, collected from various locations and having different names, were identified to be the same genotype. This was called "Local Rayong" to be used in comparison with introduced cultivars.

Before 1960, some twenty cultivars had been introduced, probably from Malaysia, Java and Mauritius. From this stock, the venerable Local Rayong probably emerged. During the 1960's, more clones were introduced, from Java in 1963, and from the Virgin Islands in 1965. The first introduction of planting material from CIAT took place in 1970 (Table 2). It appeared that Local Rayong had higher yielding capacity than any of the introduced clones from Java, the Virgin Islands and CIAT then available. This cultivar was named Rayong 1 by the Department of Agriculture in 1975 and constituted the central pilar of the highly

Table 2. Introduction of cassava germplasm to Thailand through the Department of Agriculture.

Year	Number of genotypes introduced	Origin
Before 1960	about 20	Malaya, Java, Mauritius, etc
1963	7 cultivars	Java
1965	44 clones	Virgin Island
1970	5 accessions	CIAT
1977	10 hybrid clones	CIAT
1975-1993	130,387 seeds	CIAT

Source : Field Crops Research Institute, Department of Agriculture.

successful Thai cassava production industry (Field Crop Research Institute, 1992).

During the 1970s, we attempted to improve Rayong 1 by producing hybrids using solely Thai germplasm; however, we could not select many recombinants clearly superior to Rayong 1 in yield and adaptation. Thus, introduction of exotic germplasm became inevitable (Field Crops Research Institute, 1992).

The introduction of CIAT germplasm in the form of hybrid seeds started in 1975. Hybrid clones were first introduced in the form of meristem culture from CIAT in 1979. Introduction of CIAT seed populations from more specifically defined cross parents, adapted to the Thai conditions, started in 1982 and continues in the shape of annual introduction of 8000 to 10000 seeds from many crosses. All these introductions have passed and are passing through several evaluation steps of the breeding program and selected clones are utilized in hybridizations.

Germplasm introduced from CIAT contributed to increase the genetic variability. Many crosses were made every year between Thai and CIAT clones, supplemented by a smaller number of crosses between Thai clones. Recently, we plan to receive a duplicate of the core cassava collection of the CIAT World cassava collection at Rayong Research Center.

Preservation of genetic materials

Since cassava is highly heterozygous, vegetative propagation is required to maintain genetic integrity. Field maintenance is expensive and risk the loss of genotypes due to occasional years of environmental stress or heavy pathogen/pest attacks. In response to these problems, Rayong Field Crops Research Center under the Field Crops Research Institute, Department of Agriculture, plans to develop a minimum growth germplasm conservation system through the tissue culture technique in addition to the traditional field conservation. However, the cassava research staff at this center still faced so many problems including fund and certain facilities to initiate this work. Many advantages such as lower cost of maintenance compared with field maintenance and, the most importantly, the avoidance of pest or pathogen contamination as well as biotic and abiotic field pressures will give a long term advantage to this method.

Cassava Breeding Program

Cassava breeding including hybridization in Thailand has been conducted at Rayong Field Crops Research Center (RAY-FCRC), Field Crops Research Institute of the Department of Agriculture, and at Sriracha Research Station (SRS) of Kasetsart university since 1975 and 1983, respectively (Sinthuprama and Thiraporn, 1987).

The major objectives of the cassava breeding program are:

1. higher yielding capacity
2. higher root dry matter content
3. early harvestability
4. good adaptation to local production environment with drought tolerance, etc.
5. disease and pest resistance
6. good plant type
7. good stake quality(handling, storage and germination)
8. root color
9. lower root cyanide content

Breeding high yielding culivar is based on high yield, high harvest index, and high root dry matter content.

The development of new cassava cultivars involves the following steps annually (Sinthuprama and Thiraporn, 1989):

1. Hybridization	
2. Seedling selection	15,000–20,000 seedlings
3. Single–Row trial:	1,500–2,000 clones
4. Preliminary trial:	100–140 clones
5. Standard yield trial:	20–30 clones, 3 locations
6. Regional yield trial:	8–12 clones, 8 locations
7. On–farm trial	3–5 clones, many locations
8. On–farm test:	2–3 clones, many locations

Table 3. Recommended cassava cultivars in Thailand

Cultivars	Year released	Parents	Main features
Rayong 1	–	Selected from local cultiver	yield, plant type
Rayong 2	1984	MCol 113 x MCol 22	edible use
Rayong 3	1983	MMex 55 x Mven 307	root DM
Rayong 60	1987	MCol 1684 x Rayong 1	early harvest, yield
Rayong 9	1991	CMC 76 x V 43	root DM, yield
Sriracha 1	1991	(MCol 113 x MCol 22) x Rayong 1	root DM, plant type
Kasetsart 50	1992	Rayong 1 x Rayong 90	root DM, yield plant type

Source : Field Crops Research Institute, Department of Agriculture.

Achievements
Recommended Cultivars

The Department of Agriculture has released five cultivars up to present (Table 4). Rayong 1 is basically a farmers' cultivar. However, it was collected, purified, evaluated, named and recommended by the Department of Agriculture. It is a high yielding cultivar with moderately high harvest index. The cultivar provides a good quantity of high quality planting stakes and sprouts well even under water deficient conditions, which makes this cultivar highly versatile. Data from CIAT suggest that Rayong 1 is superior to most Latin American cultivars under conditions similar to those found in the Thai cassava area.

Rayong 2 was selected from the hybrid seeds introduced from CIAT in 1975. This cultivar is especially suitable for making fried chips and other convenient foods, and has a higher yielding capacity than its counterpart Hanatee, the traditional table type cultivar. Its yellow root flesh contains high carotene. Rayong 2 was released in 1985.

Rayong 3 was selected from hybrid seeds introduced from CIAT in 1975. The results of experiment conducted from 1979 to 1984 show that the root dry matter and starch content of Rayong 3 are higher than those of Rayong 1 while fresh root yield is similar to that of Rayong 1. Higher starch content results in a higher price being paid for roots of Rayong 3. The higher dry matter content of Rayong 3 is prefered by the chippers because it requires in a shorter time for drying. Rayong 3 was relesed in 1984.

Rayong 60 was selected from a cross produced at RAY-FCRC between CIAT and Thai clones (MCol 1684 x Rayong 1). It has outyielded Rayong 1 at both early (6–8 month) and regular (12 month) harvests by 8% and 5% in fresh root, respectively, from a series of regional and on-farm trial during the period of four years (1984–1987). It has also outyielded Rayong 1 by 9% and 7%, respectively, in root dry matter yield. Hence, this cultivar can be used both for early and for 12 month harvest. It was released by the Department of Agriculture

Table 4. Yield data of 5 cassava cultivars and a promising clone, averaged from 53 on-farm trials and tests.

Cultivar	Root yield (t/ha) fresh	dry	Root DM content (%)	Root starch content (%)	Total plant weight (t/ha)	HI
Rayong 1	22.39	6.93	30.68	16.72	38.60	0.58
Rayong 3	19.03	6.28	34.19	21.73	30.21	0.63
Rayong 60	23.58	7.40	31.52	17.67	37.43	0.63
Rayong 90	23.49	8.36	34.71	22.17	37.28	0.63
Kasetsart 50	24.83	8.51	33.98	21.22	39.41	0.63
*CMR25-105-112	25.50	8.70	33.71	20.85	39.84	0.64

* a promising clone selected from 27-77-10 x Rayong 3.

on September 30, 1987.

Rayong 90 was a hybrid production at RAY-FCRC of CMC 76 from CIAT with V 43 from Virgin Island in 1978. Selection and multi-location trial were conducted in the research centers and experiment stations of FieldCrops Research Institute since 1983. From 159 trials conducted through 1984 to 1990, Rayong 90 has outyield by 5% in fresh root, and 1% in dry matter yield those of Rayong 1. It has also outyield 18% in fresh root, 21% in starch yield and 20% in root dry matter yield those of Rayong 3. Rayong 90 was released in 1991.

And Kasetsart University has released two cultivars (Table 3):

Sriracha 1 is a selection from a cross made at Sriracha Research Station of Kasetsart University in 1983 between MKU 2-162, a selection from a CIAT hybrid population, and Rayong 1. The fresh root yield of this cultivar is similar to that of Rayong 1 whereas its root starch and dry matter contents are consistently higher than those of Rayong 1. The germination capacity, vegetative vigor and plant type of Sriracha 1 are similar to those of Rayong 1 so that farmers can treat it exactly in the same way as Rayong 1 but obtain higher starch yield.

Kasetsart 50 is a resultant of collaborative research among researchers from 3 institutes; Kasetsart University, Department of Agriculture and CIAT. The cultivar is a selection from the cross between Rayong 1 and Rayong 90 produced in 1984. Kasetsart 50 possesses outstanding germination, fresh, dry and starch yield and, consequently, higher farmers' income. When compared with Rayong 1, KU 50 has 11% fresh root yield, 23% dry root yield higher than those of Rayong 1. It was released in 1992. Promising new clones and future direction.

CMR25-105-112 is selected from the hybrid between 27-77-10, a local selection from a cross made at CIAT by a thai breeder, and Rayong 3 performed at RAY-FCRC in 1982. On-farm evaluation data indicate that this clone is a further improvement over the previously released cultivars (Table 4,5). The data also offer a good demonstration of the step by step process of cassava varietal improvement in yield characters (Table 4,5). Compared with Rayong 1, all the new cultivars are characterized by distinctly higher harvest index (HI) while the

Table 5. Yield data of 5 cassava cultivars and a promising clone as relative to Rayong 1
(average data from 53 trial in 1991-1992)

Cultivar	Root yield		Root DM content	Total plant weight	HI
	fresh	dry			
	----------	----------	%	----------	----------
Rayong 1	100	100	100	100	100
Rayong 3	85	91	111	78	109
Rayong 60	105	107	103	97	109
Rayong 90	105	121	113	96	109
Kasetsart 50	111	123	111	102	109
*CMR 25-105-112	114	126	110	103	110

* a promising clone selected from 27-77-10 x Rayong 3.

improvement over Rayong 1 in other yield components were a gradual process and furhter improvement in total biomass yield (TBY) seems to be much desired.

We suggested that a simultaneous improvement in HI and TBY in these genotype would give additional adaptation to both high and low yielding environments (Kawano, 1990). We also showed that further improvement in HI and TBY were possible (Kawano et al, 1992). This promising clone CMR25-105-112 with higher HI and biomass than Rayong 1 gave higher yield than Rayong 1 in both low and high yielding enveronments throughout its on-farm evaluations. It can grow and survive very well, still giving higher yielding capacity under drought environment or grown in late rainy season. Many more clones endowed with these characters are coming out of the selection pipelines. These seem to indicate the direction of our breeding efforts.

In summary, further improvement of cassava yield and adaptation is imminent by selecting higher biomass and root DM content, while maintaining high HI.

Varietal dissemination

With the overwhelming success of Rayong 1, which coincided with the massive shift of Thai cassava production for human food to industrial processing, virtually all but one, Hanatee for snack cooking, traditional cultivars were wiped out. Rayong 1 occupied more than 99% of the total national cassava acreage until a few years ago. Rayong 3 is now planted in 56,000 to 90,000 ha depending on the sources of estimate (Field Crop Research Institute, 1992; Chainuvat, et al 1993) and the newest cultivars are rapidly catching up. Ironically here in Thailand, the process of modern cultivar diffusion is a process of partially recovering the genetic diversity in production field.

REFERENCES

Chainuvat, C., C. Boonmark and K. Klakhaeng. 1993. The cassava production and extension programe in Thailand. Proc. IV Asian Cassava Research Workshop (Nov, 1993, Trivandrum, India). In press.

CIAT, 1980. Centro Internacional de Agricultura Tropical, Cali, Colombia, Annual Report, 1980. Field Crops Research Institute. 1992. Cassava Research Annual Reports 1976-1992. Field Crops Research Institute, Department of Agriculture, Bangkok, Thailand. (in Thai)

Hahn, S.K., E.R. Terry, K. Leuschner, I.O. Akobundu, C. Okoli and R. Lal. 1979. Cassava Improvement in Africa. Field Crop Res. 2:193-226.

Jennings, D.L. and F.W.Martin. 1973. The utilization of cassava variability on an international basis; the report of study group. Paper presented at 3 rd. Symp. Intern. Soc. Trop. Root Crops, Ibadan, Nigeria.

Kawano, K. 1992. CIAT cassava germplasm and its roles in cassava varietal improvement in Asia. *In*: R.H. Howeler (Ed). Cassava Breeding, Agronomy and Utilization Research in Asia.

Proc 3rd. Regional Workshop, Malang, Indonesia. Oct. 22–27, 1990. pp. 170–184.

Kawano, K., P. Daza, A. Amaya, M. Rios and W.M. Goncalres – Fukuda. 1978. Evaluation of cassava germplasm for productivity. Crop Sci. 18:377–380.

Kawano, K., S. Sarakarn. A. Limsila, A. Tongglum, and D. Suparhan. 1990. Cassava cultivar evolution viewed through harvest index and biomass production. *In*: R.H. Howeler (Ed). Proc. 8th Symp. Intern. Soc. Trop. Root Crops. Oct 30–Nov 5, 1988, Bangkok, Thailand. pp. 202–211.

Office of Agricultural Economics. 1992. Agricultural Statistics of Thailand, Crop Year 1992. Office of Agricultural Economics, Ministry of Agriculture and Co–operative, Bangkok, Thailand.

Sinthuprama, S. and C. Thiraporn. 1987. Cassava varietal improvement in Thailand. In Cassava Breeding:A multidisciplinary review, Proc. workshop held in Philippines, 4–7 March, 1985. Clair H.Hershey (Ed). CIAT, Cali, Colombia. 312 p.

Questions and Answers Session 1

S.Sakaguchi(Q): What is the current situation and future plans for using wild species in cassava breeding.

K.Kawano(A): CIAT has not been particularly strong in completeing the collection of wild *Manihot* species. CIAT has so far not felt a strong need to look for desirable genes from wild relatives. An old British cassava breeding program in East Africa was successfully incorporated resistance to African Mosaic disease from *M. glaziori* into common cassava germplasm and IITA inherited these materials and has used them in their breeding program.

M.Nakaghara(Q): You mentioned three methods of preserving cassava. In addition, you mentioned seed preservation. Could you comment further on seed preservation.

K.Kawano(A): In addition to 1. field maintenance,2. in vitro culture maintenance and 3. cryopreservation of cassava germplasm at CIAT we are keeping a large amount of sexual seeds coming mainly from open pollination of many clones. Keeping seeds is an additional safty measure to the three methods mentioned. Genotypes may be lost but most genes are kept by this method.

H. Takagi(Q): In the breeding objectives of CIAT "versatility" is mentioned. Does this mean "multipurpose varieties"?.

K. Kawano(A): "Versatility" means dual purpose for processing and fresh consumption. Breeding is much simpler if it is only for processing. When dual purpose varieties are needed the cassava roots must have a low cyanide content and favorable eating quality, that is usually difficult to achieve. However, we have selected and released Rayong 3 in Thailand and Malang 2 in Indonesia which are basically high starch content cultivars but can also be consumed as fresh boiled cassava as well.

V.Ramantha Rao(Q): Were there differences in volume density in cuttings for planting from a single plant?

M.Oka(A): There is a large difference in volume density of cuttings among varieties. Within the stakes of a variety, the volume density of lower parts

is higher except in the basal part of stakes. According to the results of our experiments, cuttings with high volume density of more than 1 can germinate even under dry soil conditions.

I. Shiotani(Q): Dr. Oka you mentioned the difference in germination among species. Is the difference in emergence of the root prominent?

M. Oka(A): Germination rate can be presented as the survival rate at about 30 days after planting, since germinating cuttings often die within 2 or 3 weeks after planting. It is a characteristics of cassava germination that rooting is earlier than shooting. The shoots (sprouts) which appear on the top part of stakes without rooting cannot survive more than one month.

K. Takayanagi(Q): How do you uproot big cassava roots? It would seem very laborious to harvest by hand. Is there any breeding objective for easy harvesting of cassava roots?

C. Thiraporn(A): Currently, most cassava in Thailand is being harvested by hand. We expect in the future to use machine harvesting. Ease of harvest is a very important breeding objective. Cylindrical uniform roots tend to give a high yield and are relatively easy to harvest.

F.Kikuchi(Q): You mentioned root color as an important breeding objective. I would like to know the importance of this trait?

C.Thiraporn(A): Some starch factories give a lower price for yellow flesh cassava. Cassava for snack chips requires yellow color flesh. Generally speaking white colored flesh is preferred for diverse kinds of processing.

TECHNICAL REPORTS

Session 2

POTATO

Chairmen
Susumu Sakaguchi
Jose L. Bacusmo

Management and Multiplication of Potato in Japan

AKIO SUEMATSU[1]

Abstract

Unlike seed crops such as rice and wheat, tubers are used as seeds in potato cultivation. The tubers are vegetative organs in which various diseases and pests tend to be retained and these pathogens often spread out from tubers as the source of infection causing considerable reduction in the potato yield. It is important to establish a seed potato multiplication and certification program to realize successful use of potato genetic resources.

Introduction

The Japanese climate differs greatly from region to region. This is largely due to the country's length of 3,000 km. The north of Japan isin the sub-frigid zone and the south in the sub-tropical zone. Potatoes are cultivated commercially all of the prefectures in Japan. There are several cropping types of potato cultivation in Japan, and they can mainly be divided into three types including spring, summer and autumn cropping types.

Potato Breeding Programs have been conducted at Hokkaido National Agricultural Experiment Station, Hokkaido Konsen Agricultural Experiment Station and Nagasaki Prefectural Agricultural and Forestry Experiment Station. More than 30 potato varieties which have excellent adaptations and high qualities have been released. New potato varieties have also been introduced from foreign countries by the Potato Breeding Programs or some private enterprises. They differ in time of maturity, yield, appearance, cooking and marketing qualities, and resistance to various diseases and their use for potato cultivation depends on the regions.

The leading potato varieties in Japan in order of popularity are Danshakuimo, May Queen, Benimaru, Noring No.1 and Dejima.

Danshakuimo is one of the most famous potato variety in Japan, and is planted throughout Japan because of its wide adaptation. This variety was introduced in 1905 from America, and its original name in America is Irish Cobbler which is believed to be a bud mutation of Early Rose. Danshakuimo has early maturing habit, and round tuber shape. The tuber has deep eyes, white flesh color and long dormant period. May Queen is a potato variety introduced from Britain in 1917.This variety has excellent cooking quality, and has medium maturing habit

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and shallow eyes. The tuber is long to oblong in shape,and pale yellow in flesh color.

Benimaru which was released in 1938 has elliptic, pale red tuber and shallow eyes and is a potato variety used mainly for starch production. Norin No.1 is a potato variety released in 1943. It has a wide adaptability for several consumption purposes including table use, starch production and processing for potato chips. This variety has some resistance to brown rot and *Fusarium* dry rot.

Dejima is a potato variety that has a high adaptability for the potato cultivation in double cropping region due to an extremely short dormance period. This variety was released in 1971, and became to be a main potato variety in double cropping regions.

About 120,000 ha of the potatoes are grown in Japan, and as much as 250,000 ton of seed potatoes are needed by commercial potato growers. The seed potatoes can be divided into three categories namely – foundation seed, registered seed and certified seed potatoes. The foundation seed potatoes are produced and distributed by the National Center for Seeds and Seedlings of Ministry of Agriculture, Forestry and Fisheries. They are planted and the tubers are harvested to produce the registered seed potatoes. The registered seed potatoes are planted the following year to produce certified seed potatoes which are used for commercial potato cultivation. In 1989 production of foundation, registered and certified seed potatoes was 1,900, 23,000 and 183,000 tons respectively.

Production of foundation seed potato

Unlike seed crops such as rice and wheat, tubers are used as seeds in the potato cultivation. The tubers are vegetative organs in which various diseases and pests tend to be retained and tubers act as a source of infection for these pathogens which can cause considerable loss of yield. Pathogens, particularly, viruses and potato ring rot are latent in tubers, and can not be controlled by chemicals. Therefore, a continuous supply of the healthy, disease free, seed potatoes is necessary. The multiplication rate of the potato is low compared to other crops and the cost of seeds and seedlings to the total production cost is relatively high for potato production. Therefore, it becomes extremely important to establish a seed potato multiplication organization to supply healthy seed potatoes at low prices, and systemic distribution of seed potatoes for commercial potato cultivation is essential to improve potato production.

It was with these points in mind that, the Japanese government established seven Potato Foundation Stock Seeds Farms in northern parts of Japan in 1947, and an additional Foundation Stock Seeds Farm was established in southern Japan in 1960. These Potato Foundation Stock Seed Farms were reorganized as stations of the National Center for Seeds and Seedlings in 1986.

All foundation seed potatoes of current and new varieties are produced in

stations of the National Center for Seeds and Seedlings. The propagation of foundation seed potatoes at the National Center forSeeds and Seedlings first begins with virus free tubers prepared by the meristem culture technique. The first report of successful production of a virus-free potato plant from an infected plant by meristem culture was from research conducted by Yora and Tsuchizaki(1962). Soon after this success, the technique of meristem culture was introduced to produce the virus-free foundation seed potatoes. The first virus-free foundation seed potatoes of potato varieties were obtained at a station of the National Center for Seeds and Seedlings in 1967. Since that time, meristem culture has been used to eradicate potato viruses from almost all potato varieties planted in Japan.

To produce foundation seed potatoes, virus-free potato tubers prepared by meristem culture are planted in a screenhouse to produce pre-basic seed potatoes. The pre-basic seed potatoes are planted in basic seed potato fields the following year to produce basic seed potatoes. Finally, the basic seed potatoes are used to produce the foundation seed potatoes.

The pre-basic seed potatoes of some potato varieties are propagated by in vitro rapid multiplication technique. After virus-free potato plants are produced by meristem culture, they are multiplied by means of in vitro mass tuberization. There are two main steps in the in vitro mass tuberization process, the first process is in vitro layering of plantlets derived from meristem culture on the surface of a medium to multiply the number of shoots. The second process involvesthe transfer of axillary shoots to a medium containing high concentration of sucrose to produce micro-tubers in vitro. These micro-tubers are propagated in the screenhouse to produce the pre-basic seed potatoes.

At the National Center for Seeds and Seedlings, various inspection tests including electron microscopy, serological tests, sap inoculation tests, tuber indexing tests and roguing are performed at each of the propagation stages to ensure high quality seed potatoes. Electron microscopy is used to inspect plantlets derived from tissue culture, and pre-basic seed potato plants. Serological tests are very useful for large-scale testing, and antisera that have a high titer against the main potato viruses and bacterial diseases are produced in the National Center for Seeds and Seedlings and used for the serological testings. ELISA is the most sensitive serological method that is commonly used to detect potato virus infection at the National Center for Seeds and Seedlings. For the inoculation tests, Chenopodium quinoa, *Physalis floridana*, *Gomphrena globosa* and many *Nicotiana* species are used. Although the reactions of the test plants to potato viruses are often not specific, the inoculation test is very sensitive compared with common serological tests for the detection of potato viruses.

It is very important to remove diseased plants as soon as possible during production of the foundation seed potatoes to prevent the spread of virus diseases from virus infected potato plants to healthy ones. Most of the potato varieties planted in Japan react to virus infections with clear symptoms such as mosaic, vein clearing, leaf rolling or necrosis depending on the potato virus and potato variety

combinations. Therefore, symptomatology is a very important element in recognizing virus infected potato plants in the field. At the National Center for Seeds and Seedlings, roguing of diseased plants is carried out more than 10 times during the seed potato growing period until the haulm of the seed potato plants has been destructed artificially. Infections early in the growing season result in symptoms being expressed in the leaves. These potato plants are removed by the roguing after symptom expression. However, later infection sometimes does not result in any symptoms in the haulm, although the developing tubers of the plant many already be infected. Therefore, tuber indexing is performed for post-harvest control of virus infection of the basic seed potatoes, and to predict the virus infection of the foundation seed potatoes. In tuber indexing, one eye of tuber is cut from potato tuber to be tested. The eyes cut from tubers are planted in greenhouse, and resulting young plants can be inspected 4–5 weeks latter, depending on potato varieties and on growing conditions, by visual inspection, inoculation tests or ELISA.

Production of registered and certified seed potatoes

Production of registered seed potatoes and certified seed potatoes are important steps in the seed potato multiplication system to maintain the quality of seed potato. The production of registered seed potatoes is, in principle, operated by the local government. However, in many cases, it is entrusted to seed potato growers who are proficient in techniques such as detection of virus infected plants and virus disease protection needed in seed potato fields. The production of certified seed potatoes is run by individual seed potato growers. There are about 5,600 seed potato growers in Japan, and they belong to regional Seed Potato Growers Co-operative Association. The fields and places used for seed potato production are usually located within the same locality but isolated from commercial potato fields.

The seed growers have to pass field and harvest inspections conducted by Plant Quarantine Officers to sell and transfer their products as seed potato. This seed potato certification program was initiated in 1951. Application inspection forms are sent from individual seed growers before the planting season of the seed potatoes requesting a listing of varieties, classification and source of seed lots, area, field number and location, previous crop history of fields and date of planting. This information is used by the Plant Quarantine Officer to determine eligibility for the inspections.

The field and harvest inspections are carried out on the incidence of 9 potato diseases and pests. In the field inspection, if more than 0.1 percent virus infected potato plants are found during the final field inspection, the seed field is no longer entitled to be the registered or certified seed field. Special emphasis is placed on the occurrence of bacterial ring rot and potato cyst nematode. Bacterial ring rot and potato cyst nematode are so contagious that they have a zero tolerance

at any stage throughout the growing season of seed potatoes. The harvest inspection is conducted especially on the presence or absence of powdery scab, common scab, potato tuber moth and potato cyst nematode. As failure to meet the tolerance is cause for rejection, lack of isolation of the seed potato fields, unsuitable cultural conditions and high aphid population are also cause for the rejection. At the beginning of the seed potato certification program, the rejection rate of seed potatoes was more than 25 percent due to a high incidence of viruses and unsuitable cultural conditions. However, the recent rejection rate of the seed potatoes is less than 1 percent. This certification program of the seed potatoes has been conducted in 11 prefectures which are the main potato producing areas in Japan.

Conclusion

When vegetatively propagated plants like potato are infected with a disease, the pathogen passes from one generation to the next. The entire populations of a variety are infected with the same pathogen, and the yield and quality of the variety gradually decreases over time. In order to ensure the successful use of potato genetic resources, establishment of a propagation and certification system for seed potatoes is needed. Techniques such as meristem tissue culture, rapid in vitro multiplication and virus testing are very important.

References

Clark, M.F.and Adams, A.N. 1977. Characteristics of the microplate method of enzyme-linked immunosorbent assay for the detection of plant viruses. Jour. Gen. Viol. 34:475–483.

Horio, H. 1972. Production of virus-free potatoes by means of meristem culture. Research Bulletin of the National Potato Foundation Stock Seed Farm. No.6, 1–19. (in Japanese).

Horio, H. 1976. Studies on M-mosaic and S-mosaic of potato. Research Bulletin of the National Potato Foundation Stock Seed Farm. No.12, 1–94. (in Japanese).

Kojima, M.,Chou, T. G. and Shikata, E. 1978. Rapid diagnosis of potato leafroll virus by immune electron microscopy. Ann. Phytopath. Soc. Japan. 44:585–590.

Kojima, M.,Takizawa, T.,Uyeda, I. and Shikata, E. 1982. Application of enzyme-linked immunosorbent assay to diagnosis of potato leafroll disease. Ann. Phytopath. Soc. Japan. 48:458–465.

Kojima, M.,Uyeda, I.,Aoki, T. and Shikata, E. 1980. Detection of potato leafroll virus in the potato leaves and sprouts by ELISA. Ann. Phytopath. Soc. Japan. 46:274–277.

Mori, K.,Hayama, F.,Shimomura, T. and Ikegami, Y. 1969. Production of virus-free plants by means of meristem culture. J. Gen. Agr. Expt. Sta. No.13, 45–110. (in Japanese).

National Center for Seeds and Seedlings. 1991. Experiments on necrotic strain of potato virus Y (PVY) in potato cultivars and its control. Research Bulletin of the National Center for Seeds and Seedlings. No.2, 1–64. (in Japanese).

National Center for Seeds and Seedlings. 1993. Study on method of multiplication of potato through micro-tubers produced in vitro. Research Bulletin of the National Center for Seeds and Seedlings. No.3, 1–109. (in Japanese).

Tanaka, T. 1974. Studies on the potato leaf-roll diseases. Research Bulletin of the National Potato Foundation Stock Seed Farm. No.10, 1–116. (in Japanese).

Tanaka, T. 1980. Experiments on resistance to potato virus X, A and Y on potato varieties. Research Bulletin of the National Potato Foundation Stock Seed Farm. No.14, 1–49. (in Japanese).

Uyeda, I.,Kojima, M.,Yomenura, M.,Aoki, T. and Kawada, T. 1984. Application of enzyme–linked immunosorbent assay to a large scale indexing of potato virus X, Potato virus Y, and potato leafroll virus. J. Fac. Agr. Hokkaido Univ. 62:22–35.

Weidemann, H.L. 1988. Importance and control of potato virus YN (PVY N) in seed potato production. Potato Research. 31:85–94.

Yora, K. and Tsuchizaki, T. 1962. The elimination of latent viruses from potatoes of Danshaku variety by use of tissue culture. Ann. Phytopath. Soc. Japan. 27:219–221.

Characterization, Evaluation and Use of Potato in Japan.

MOTOYUKI MORI[1]

Potatoes (*Solanum tuberosum* L.) were introduced to Japan at the beginning of 17th century, but its cultivation did not spread until the end of the 19th century, during the Meiji era. The area of cultivation increased rapidly because potatoes were used as a processing material for starch in the 1900s. As potato is a crop suitable for cool climates, Hokkaido is the main producer of potato[9),11)]. 1991 statistics show that Hokkaido accounted for about 75% of the total production (3,609,200t) and 60% of the total cultivated area (111,840ha) of potatoes in Japan[1)].

From the end of the 19th century to the beginning of the 20th century, a number of American and European varieties were introduced and repeatedly evaluated. After 1902, a national potato breeding program was started to test varieties and select lines. As a result many introduced varieties were selected as recommended varieties. Old introduced varieties such as "Danshakuimo" (Irish Cobbler) and "May Queen" still remains leading varieties for culinary use. In 1916, artificial hybridization was initiated, continuous effort have been made, and a lot of varieties for starch production were bred, such as "Benimaru" and "Norin No.1", these still remain leading varieties. Inter-specific hybridization started in 1939. South American landraces and wild species (*S. demissum, S. chacoence, S. stoloniferum,* etc.) were used as high starch, pest and disease (late bright, Y-virus, cyst-nematode etc.) resistant genes donor. "Konafubuki" is resistant to the Y-virus and "Toyoakari" is resistant to the cyst-nematode, both contain more than 20% starch. In food processing, "Toyoshiro" remains a leading variety was first bred for potato chips, and "Hokkaikogane" was released for frozen fried potatoes[9),11)] (Table 1).

Evaluation of potato germplasm started as a national project in 1985. Although botanical features and agricultural characteristics used in this project are very useful for general use in breeding, it is necessary to evaluate the genetic characteristics for breeding. Potato breeding objective has changed from the yield considerations (productivity, pest and disease resistance etc.) to quality, because of changing consumer's needs. The desired qualities of potato are as follows:[9),12)]

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Table 1. Outline of potato introduction and improvement in Japan

1600s	*First introduction to Japan
1800s	*Many varieties were introduced from North America including: Early Rose, Snow Flake, Green Mountain, American Wonder, Early Beauty of Hebron, etc.
1900s	*Breeding program was started (1902)
1910s	*Artificial crossing was initiated (1918) Irish Cobbler (used as basic breeding material), May Queen
1920s	*Many varieties were introduced from Europe Pepo (male parent of Benimaru), Deodara (male parent of Norin No.1)
1930s	*First hybrid varieties were released (1938) Benimaru, Myojo, Hokkai-shiro *Many and wild relatives were introduced *Inter-specific hybridization was started (1939)
1940s	Norin No.1 (1943) *Establishment of Seed Foundation Stock Farms (1947)
1950s	*Introduction of new American varieties by G.H.Q. (1954) including: Kennebec, Wheeler, etc. Hochprozentige(1956 from Germany, high starch gene donor) Yoraku (1958, derived from inter-specific hybrid) Unzen and Tachibana (1955, for double cropping)
1960s	Rishiri (1960, aneuploid, late blight resistance) Yukijiro (1961, for mashed potato), Bihoro (1969, high starch 25%)
1970s	Dejima(1971, for double cropping), Waseshiro(1974), Toyoshiro(1976, for chips) Tunika(1978, from Germany, cyst-nematode resistance) Nishiyutaka (1988, for double cropping)
1980s	Konafubuki (1981), Hokkaikogane(1981, for fried potatoes) Toyo-akari(1986), Kita-akari(1987)
1990s	Touya and Musamaru (1992), Hokkai No.73, Koniku No.26 and Saikai No.23 (1994)

under line: introduced variety.

a) Post harvest characteristics; good tuber shape, shallow eye depth, tolerance to mechanical damage, greening tolerance, long dormancy, etc.

b) Processing adaptability; high starch content and good starch quality, low reducing sugar content under low temperature storage, no browning after peeling, no blacking after cooking, etc.

c) Cooking quality; good flavor, taste, texture, skin and flesh color, high vitamin C and low glycoalkaloids content, etc..

Some of the quality characteristics have been incorporated into breeding lines, and new varieties. For example, "Kita-akari" has high vitamin C content and good taste, "Touya" has good round shape tuber and low discoloration in the raw and cooked state, "Hokkai No.76" has very low reducing sugar content suitable for chips.

Breeding for specific traits:

(a) Low reducing sugars content[3),5)]

The variety used for potato chips must have low reducing sugar content. High levels of reducing sugars leads to discoloration. A low level of reducing sugars both at the harvest, during long storage and during reconditioning is important. Most cultivars accumulate significant amounts of reducing sugars when stored at temperatures below 7°C.

Genetic stock lines were selected for direct chipping without reconditioning under low storage temperatures. "ND860-2" (the North Dakota State University breeding clone with *S. phureja* in its background) and some lines of *S. tuberosum* ssp. *andigena* (Andigena) were selected, and crossed with common potatoes (Tuberosum) to transfer cold chipping ability i.e. the potato does not accumulate reducing sugars during low temperature storage and will produce acceptably colored chips with little reconditioning.

In 1987, a search began to select parents which were capable of cold chipping. After some preliminary tests, 81 strains of old and new common potato varieties and lines, lines of Andigena and their hybrids were induced in a final evaluation. After tubers had been harvested, they were allowed to cure for one month, then were stored at 8°C for 107 days and 5°C for 137 days. Then they were immediately made into chips in the standard way. In evaluation, the Agtron reading of 25 or over is commercially acceptable for making chips. Andigena and the hybrid group showed more genetic diversity than the common potato group (Figure 1).

Many crosses were made with good materials selected from this test, subsequent selection of progeny families continued. The tubers of selected lines were stored at 6°C for 5 months. They were directly chipped and evaluated. Also sugar content was examined. "Hokkai No.76" and "Shimakei No.561" are progeny of "ND860-2", and "WB86013-17" is progeny of "Andigena(234)", these lines

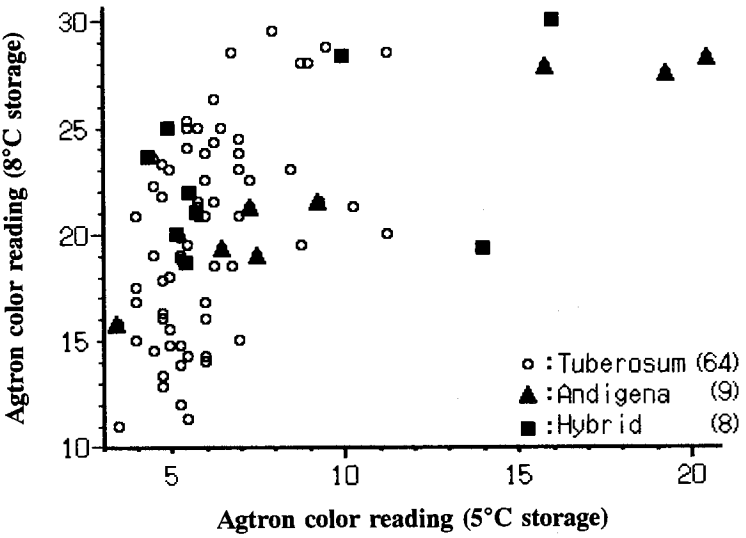

Figure 1. Evaluation of lines with chips color under different storage temperature

Table 2. Cold chipping quality characteristics of varieties stored for 5 months at 6°C

Variety or Breeding lines	Agtron color[1)]	External appearance	Glucose content[2)] (%)
Hokkai No.76	29.3	good	0.6
Shimakei No.561	34.5	excellent	0.5
ND860-2	26.3	medium	0.9
WB86013-17	29.8	good	1.0
Andigena(234)	24.8	medium	0.5
Toyoshiro	11.5	bad	4.5

1) Agtron model 500 (small angle viewer) with green filter standardized at 0 and 90.
2) Sugar analyzer YSI model 27.

possess excellent chipping quality (Table 2).

(b) Low discoloration[6),12)]

Recently there has been an increasing consumption of pre-pealed or cut potatoes. These products are mainly consumed in fast-food restaurants, and sold in take-out food shops or supermarkets. Because of browning after peeling decreases the value of potato products, low discoloration is an important trait for commercial cooking.

There are big varietal differences in browning after peeling. Newly bred varieties belong to the low discoloration group, while Irish Cobbler, a leading variety for culinary use, belongs to the worst group (Figure 2). "Hokkaikogane" is suitable for packaged slicing or cutting, due to its very weak discoloration in the raw and cooked stage, and firmness on cooking. Also Kita-akari which is a very mealy cooking type of potato with a high solids content and weak discoloration is well suited for producing mashed potato salad.

(c) Greening tolerance and glycoalkaloid content[2),4),12)]

Absence of tuber greening is important for marketing. Potato skins change to green when exposed to light and green skins have a bitter taste.

Tubers of 421 genetic stocks and breeding lines were exposed to sunlight for two weeks in the field during September 1992, and much variation for greening was observed (Table 3). Red or purple skin varieties did not become green, but their flesh become green in the same way as other varieties. There is a correlation between skin and flesh greening, but there is no relationship between greening and glycoalkaloid biosynthesis in the potato tubers.

Fortunately, a new breeding line, "Hokkai No.74", has both tolerance to greening and low glycoalkaloid biosynthesis.

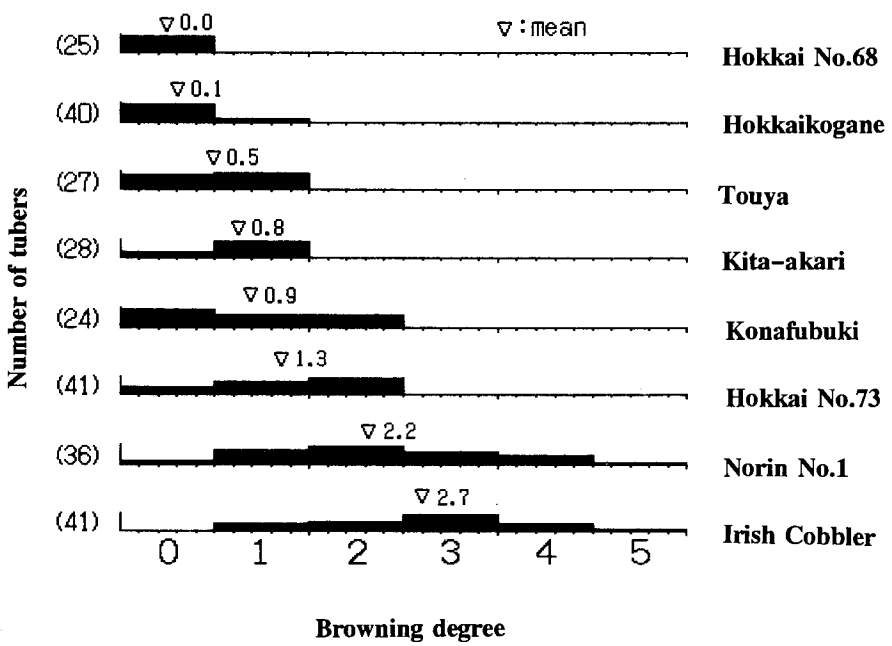

Figure 2. Browning after peeling (cutting) in potato varieties

Table 3. Relationship between skin and flesh of tuber greening in potato varieties for two weeks under sunlight. (r=0.643*)**

		Greening of flesh (degree)						
		0	1	2	3	4	5	Total
Greening of skin (degree)				1				1
	1		21	5	4	1		31
	2		12	44	49	5		110
	3		6	28	96	35		165
	4		1	2	46	50	5	104
	5					4	6	10
Total			41	79	195	95	11	421

Note: White and brown skinned varieties were tested.

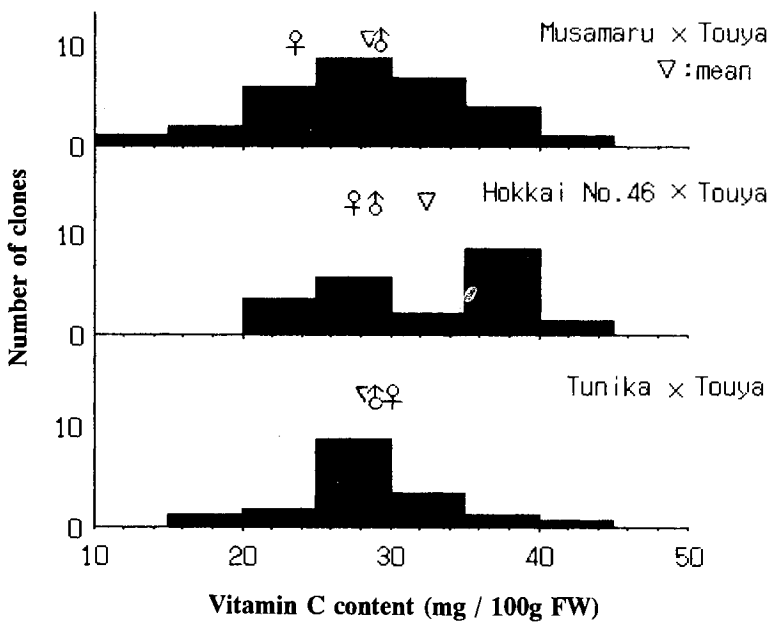

Figure 3. Vitamin C content of tubers in progeny families

(d) Vitamin C content[4),10)]

Vitamin C content of selected parent varieties and progeny families were analyzed. Only L-ascorbic acid in the tuber was analysed by the high performance liquid chromatography (HPLC) method because dehydroascorbic acid is in very small quantities. Sample tubers were harvested on September 2nd 1992, and analyzed on middle of September. From preliminary tests it is known that all parent varieties (23.6–29.8 mg/100gFW) belong to the group with high content of vitamin

C. Only one progeny family was significantly different from other tester. Some clones, which contained 44.0 mg/100gFW, surpassed the vitamin C levels of their parents, but did not have twice the vitamin C content of parents. 44.0 mg/100gFW is the same level as that of "Kita-akari" a variety with the highest vitamin C level (Figure 3). It is presumed therefor, that breeding for high vitamin C content was reached its upper limit.

(e) Phosphorus content in starch[9),10)]

Potato starch is used in many food products. When water is added, upon heating, potato starch gelatinizes at relatively low temperatures, and shows a high viscosity, which is closely connected with Phosphorus content. These characteristics are suitable for traditional foods manufacture such as fish meal sausage, boiled or baked fish paste "Kamaboko" or "Chikuwa", and Japanese noodle "Udon".

Phosphorus content in starch of parent varieties and progeny families were analyzed. Sample tubers were harvested on September 24th 1992.

A significant difference(1%) between two progeny families was found during evaluation. Cross number 90101 aimed to breed for low phosphorus content. Among the progeny families (with a mean of 580ppm), the lowest phosphorus content clone was 387ppm. Cross number 90098 aimed to breed for high phosphorus content, among the progeny families (with a mean of 980ppm) one clone had a phosphorus content of 1201ppm. 387ppm and 1201ppm are probably the limits of phosphorus content in potato starch (Figure 4).

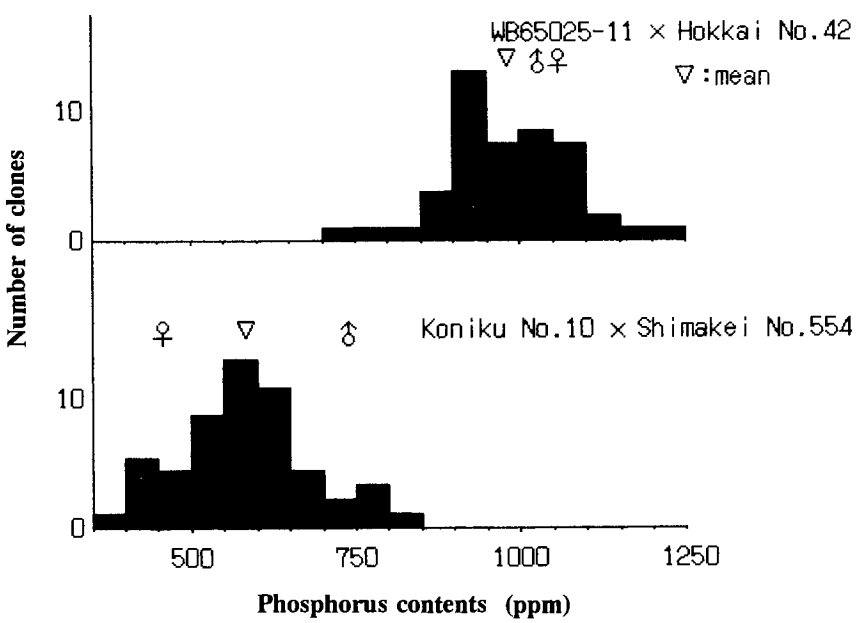

Figure 4. Phosphorus content of tubers in progeny families

(f) Anthocyanin pigments[4),7),8)]

Solanum phureja(Phureja), dihaploid of Tuberosum and Andigena have been used to breed red fleshed potato. Anthocyanin pigment content in tubers was evaluated using the extinction coefficient of extracted juice color. The pigment content increased quickly within two generations, the pigment content increased one hundred times (Figure 5).

Tetraploid species of the Andigena group which has partly pigmented flesh was used in breeding. Within two to three generations, deep pigmented flesh lines (red and blue) were selected (Figure 6).

Diploid lines were superior than tetraploid lines with respect to concentration of pigments. But tetraploid lines have more acceptable yield and agronomic traits.

In the near future, the potatoes with red and purple flesh color will be not only used in table varieties, but also used in food processing, for instance to produce colored potato chips and mashed potato powder. If anthocyanin pigments are more concentrated in fresh, the natural edible pigments can be reasonably collected from residues of potato starch industry.

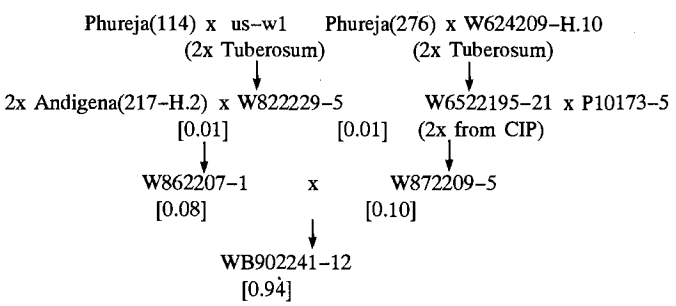

Figure 5. Pedigree of red fresh diploid potato
[ ]: indicate the density of pigment (Extinction coefficient).

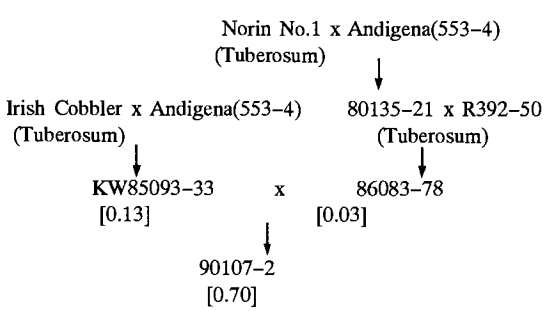

Figure 6. Pedigree of red flesh tetraploid potato
[ ]: indicate the density of pigment (Extinction coefficient).

References

1) Hokkaido Kyodokumiai Tsushinsha (1993): Agriculture in Hokkaido. Hokkaido Kyodokumiai News-agency, Sapporo, Japan, 13.
2) Kimura,T., M.Mori and Y.Umemura (1992): Varietal difference in potato tuber greening. Rep. Hokkaido Branch Crop Sci. Soc. Jpn. & Jpn. Soc. Breed., 33, 40–41 [In Japanese].
3) Mori,M. and S.Nishibe (1989): Evaluation of potato chip color of Solanum clones at different storage temperatures. Rep. Hokkaido Branch Crop Sci. Soc. Jpn. & Jpn. Soc. Breed., 29, 30 [In Japanese].
4) Mori,M., T.Maida G.Ishii and Y.Umemura (1991): Some chemical characteristics in potato breeding – ascorbic acid, anthocyanin and glycoalkaloids –. In Asian Potato Association Proceedings, Bandung Indonesia, 31–35.
5) Mori,M., T.Kita, S.Nishibe and Y.Umemura (1991): Breeding for low reducing sugar clones under low temperature for potato chips. In Abst. 79th Conf. Jpn. Soc. Breed., 266–267 [In Japanese].
6) Mori,M., T.Maida and Y.Umemura (1991): Discoloration of raw potato tuber. 1.Relationship of darkening with variety, tuber size and specific gravity. Rep. Hokkaido Branch Crop Sci. Soc. Jpn. & Jpn. Soc. Breed., 32, 30–31 [In Japanese].
7) Mori,M., T.Maida, Y.Umemura, N.Kusano and T.Sumita (1992): Breeding for high anthocyanin potatoes. (1) The increase of pigments content in diploid hybrid progeny. In Abst. 81th Conf. Jpn. Soc. Breed., 354–355 [In Japanese].
8) Mori,M., Y.Umemura, N.Kusano and T.Sumita (1992): Breeding for high anthocyanin potatoes. (2) The increase of pigments content in tetraploid hybrid progeny. In Abst. 82th Conf. Jpn. Soc. Breed., 482–483 [In Japanese].
9) Mori,M. and Y.Umemura (1992): Current situation of potato processing in Japan. JARQ Vol.26, No.3, 157–164.
10) Mori,M., K.Yamamoto, T.Kimura and G.Ishii (1993): Potato breeding for chemical components. 1.Phosphorus content in starch and vitamin C content. Rep. Hokkaido Branch Crop Sci. Soc. Jpn. & Jpn. Soc. Breed., 34, 112–113 [In Japanese].
11) Nagata,T. and N.Takase (1967): Hokkaido nogyo gijutu kenkyu shi (The history of agricultural technology and research in Hokkaido). Hokkaido Nat. Agr. Exp. Sta., 223–243 [In Japanese].
12) Umemura,Y. (1993): Evaluation of potato germplasm introduced from Russia. Japan–Russia Workshop Gen. Res. Biotech., 105–108.

In vitro Preservation of Potato Genetic Resources in NIAR

TERUO ISHIGE[1]

Abstract

In vitro preservation technology of annual vegetative crops, such as potatoes (*Solanum tuberosum*), has solved the problems associated with field preservation such as high labor costs. This technology can also prevent the deterioration of quality due to diseases. We are conducting a project for establishing a long-term preservation method for potatoes. We have developed a media in which potatoes survive for one year or more without subculturing. In the case of potatoes, we can make microtubers in the test tube. These microtubers have many applications for usage of genetic resources and in cell biology.

Potato lines stored *in vitro*

Genetic resources stored *in vitro* at the Laboratory of Plant Cell Breeding (LPCB) are listed (Table 1). P lines are collected from Potato Breeding Stations and Center for Seeds and Seedlings, MAFF. Ag lines are potato lines transformed by *Agrobacterium tumefaciens*. F lines are somatic hybrid possessing cell selection markers transformed by *A. tumefaciens*. I lines are somatic hybrids without transformed markers. Due to regulation regarding transformed plants, we can not plant Ag lines and F lines in the field . We should keep these materials in closed conditions at present.

Pathogen Elimination

Meristem culture was the first biotechnological approach successfully adopted and applied to obtain virus-free potato stocks. This method is being applied in combination with thermotherapy and chemotherapy to obtain virus-free stocks for further propagation as well as for the production of clean seeds which are planted over large areas. This
method of using disease-free stocks has resulted in an increased yield in many countries. Most potato lines stored *in vitro* at LPBC are virus-free stocks.

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Table 1. Potato lines stored *in vitro* at Laboratory of Plant Cell Breeding

Line	No. of accessions	Genome	Tuberization
P(arental) lines	324(total)		
S. tuberosum	242	4x	Yes
S. tuberosum wild species	45	2x	Yes
S. acaule	13	2x	Yes
S. brevidens	6	2x	No
S. nigrum	3	3x	No
S. photeinocarpum	2	2x	No
S. bulbocastanum	2	2x	Yes
S. peruvianum	2	2x	No
S. pinnatisectum	1	2x	No
S. verrucosum	1	2x	No
S. morelliforme	1	2x	Yes
S. etuberosum	1	2x	Yes
S. muricatum	1	2x	Yes
S. chacoense	1	2x	No
S. megistacrolobum	1	2x	Yes
S. phureja	1	2x	Yes
S. cardiophllum	1	2x	Yes
Ag(robacterium transformed) lines	1024(total)	2x,3x,4x	Yes, No
F(used with markers) lines	120(total)	4x,6x,8x	Yes
I(oa) lines	110(total)	4x,6x,8x	Yes

Micro-propagation

Potatoes are conventionally propagated through tubers. Using totipotency of cells, *in vitro* technology has been applied to produce plantlets on a large scale. Three *in vitro* approaches are generally applied for potato propagation/multiplication: (1) culture of nodes; (2) microtuber formation; and (3) somaclones and gametoclones through callus or protoplast.

Meristem derived virus-free plants are cut into small segments with nodes (including a leaf and an axillary bud), and cultured. The rate of growth and multiplication is faster in liquid media compared to agar medium.

The *in vitro* production of microtubers is another approach which can be applied to the potato seed industry and storage of genetic resources. The microtubers weigh between 10-40 mg each and have two or more eyes. They have the advantage over test-tube plants in that they can be produced in large numbers irrespective of the season, can be easily stored, packed and shipped with less injury.

In vitro conservation of genetic resources

To maintain potato clones, the germplasm is traditionally conserved through

tubers, which have to be grown and multiplied every year. This method is not only time consuming, labour-intensive and expensive, but, above all, the material is exposed to hostile environments and the hazards of pests and pathogens which may result in the total loss of the germplasm. This problem has encouraged attempts to develop *in vitro* methods of conservation.

On normal growth medium, *in vitro* plants have to be transferred frequently to fresh medium, a transfer process that is very labour-intensive. Therefore, methods to reduce the growth rate have been studied. Growth limitation could be obtained by adding inhibitors, reducing the energy source, lowering the incubation temperature or applying osmotic stress.

We are conducting a project to establish a long-term preservation method for potatoes. As a result of these studies and experiments, the following facts have so far been observed. For potatoes, 39 lines of 13 species and 6 somatic hybrids survived for one year or more without subculture at 20°C on R1 medium mainly consisting of MS medium containing 0.5% sucrose and 4% mannitol.

Considerable difference was observed in the survival and health among different lines. When cultured in the medium for long-term preservation, abnormal plants were observed in a number of the lines used. This problem remains to be solved for the preservation of vegetatively propagated crops.

Transport of genetic resources

Potatoes germplasm preserved *in vitro* have applications: among them are *in vitro* application as a material of tissue culture, direct cultivation in the field and distribution to users. There is the need to develop preservation methods suited to these various uses, taking into account the cost involved. In the case of potatoes, we can make microtubers in the test tube. Microtubers have certain advantages over the test-tube plants for storage and exchange; they can withstand longer periods in the dark, and also changes in outside temperature better. They can be easily transported in small bottle to various destinations, stored, planted and multiplied. For successful *in vitro* propagation and distribution, the plantlets transferred from the test tube to the soil require special care. For example, adaptation to low humidity is critical, especially since the roots that have developed *in vitro* are often not very efficient in the soil. Potato tubers produced *in vitro* adapt easily to low humidity when transferred to the soil. The *in vitro* storage and exchange of germplasm ensures the supply of virus-free materials, and it reduces the chances of dissemination of other diseases which normally occur through the conventional method of exchange by tubers.

Application to cell biology

Somaclonal variation, may be due to such factors as endomitosis, polyploidy, aneuploidy, gene amplification, somatic crossing-over, transposable

elements, sister chromatid exchange, or cryptic changes associated with chromosomal rearrangement. The potato appears prone to such variation. We developed 4,000 lines regenerated from discs and protoplasts, and made microtuber of these lines. These microtubers were planted in the field and tested their field performance at the Potato Breeding Station in Hokkaido Agricultural Experiment Station. Extensive phenotypic variation in potato plants regenerated from protoplasts, and tuber discs were observed. The plants showed differences in height, size, dormancy and yield of tubers. The induction of genetic variability and the selection of desirable somaclonal variants would increase the pool of germplasm for use in potato breeding program. This would facilitate the early release of new commercial varieties.

Somatic hybridization through the fusion of protoplasts is now a more or less routine technique in many crops. In potato a number of reports are available on the somatic protoplast fusion. This could be a powerful tool for the induction of genetic variability in this corp. We are conducting a project to fuse protoplasts between diploid potato lines. Somatic hybrids which showed hybrid vigor have been obtained.

Microtuber from these somatic hybrids were planted in the field and tested for agronomic characters.

Genetic Stability

Genetic variation due to chromosomal rearrangements can occur in tissue culture. A correlation exits between the time plant material is grown as callus and the probability for chromosomal change. The use of axillary buds as a base for multiplication reduces the chance of genetic variation.

The best method for long term conservation of potatoes will be cryopreservation in liquid nitrogen, but this methods is not yet applicable for a large collection.

References

R. Aida, F. Takaiwa, T. Imai and T. Ishige. (1991) Analysis of distribution and diversity of patatin promoters in Solanum species by using the polymerase chain reaction technique Japan.J.Breed., 41:511–515

T. Imai, R. Aida and T. Ishige. (1993) High frequency of tetraploidy in *Agrobacterium*–mediated transformants regenerated from tuber discs of diploid potato lines. Plant Cell Reports, 12:299–302

T. Imai, Y. Irikura and T. Ishige. (1992) Studies of the gene expression in a somatic hybrid of dihaploid *Solanum tuberosum* and diploid *S. brevidens* using two–dimensional protein electrophoresis. Plant Cell, Tissue and Organ Culture, 29:115–124

T. Ishige, M. Ohshima and Y. Ohashi. (1991) Transformation of Japanese potato cultivars with the B–glucuronidase gene fused with the promoter of the pathogenesis–related la protein gene of tobacco. Plant Science, 73:67–174

D. P. Rajapakse, T. Imai and T. Ishige. (1991) Analysis of potato microtuber proteins by sodium dodecylsulfate polyacrylamide gel electrophoresis. Potato Research, 34:285–293

Questions and Answers Session 2

S.Sakaguchi(Q): To exchange genetic resources internationally quarantine to eliminate viruses is necessary. An easy and accurate test such as ELISA is good. Are there any viruses for which the ELISA method is not applicable?

A.Suematsu(A): I think that provided one can obtain antibodies, one can use the ELISA method for any virus. At least for potatoes the ELISA test can be used for any virus. However, the concentration of virus affects the test. When the concentration of the virus in the plant is low, they cannot be detected. With this in mind the growth of the plant and timing of the test is crucial.

M. Nakagahra(Q): The National Center for Seeds and Seedlings(NCSS) are preserving many kinds of crop species as well as potatoes. I'd like to know the activities concerned with germplasm conservation for your organisation.

A.Suematsu(A): NCSS is preserving foundation seeds of sugarcane and stock seeds of tea trees but not potato foundation seed. NCSS has four other main functions:

1) DUS testing for the registration of new plant varieties.
2) Quality testing of marketed seeds.
3) Research on seed technology.
4) Multiplication and conservation of plant genetic resources of vegetatively propagated crops.

Shiotani(Q): What species and at what ploidy level, did you use to produce the somatic hybrids mentioned in your presentation? If the parents were tetraploid the somatic hybrids would be octaploid and sterility would be a problem.

T.Ishige(A): We used diploid parents for somatic cell fusion, so the hybrid is tetraploid. In this experiment, our target is to get somatic hybrids which show high heterosis and are tetraploid.

S.Sakaguchi(Q): What problems occur when exchanging *in vitro* genetic resources?

T. Ishige(A): Technically the adaptation of *in vitro* plants to soil is important. For *in vitro* materials, we need reasonable quarantine rules, because these are non-contaminated materials.

S.M.Z.Hasan(Q): You mentioned that no genetic change occurred in your potato tissue culture storage system. How did you confirm this?

T. Ishige(A): Micro-tube culture is very stable, because we don't use any plant hormones. We have a project to confirm the somoclonal change by RFLP analysis.

H. Fujimaki(Q): Among various characteristics of wild species what traits do you think is the most promising for improving Japanese potato cultivars by cell fusion or another means of biotechnology?

T. Ishige(A): Wild species have many good traits, such as resistance to diseases. We can introduce these traits by cell fusion however undesirable traits are introduced too. We have to develop an asymetrical cell fusion system to overcome this problem.

V. Ramanatha Rao(Q): What are the safeguards taken for the release of transgenic plants into the field?

T. Ishige(A): Japan operates a step-wise procedure. We cannot plant transgenic materials directly in the field. First there is a security check in closed conditions. Then we can transfer transgenic plants to semi-open conditions. Finally, we test the transgenic plants in the field. After going through this process we can cultivate transgenic plants in the field.

K.Kawano(Q): Does cell fusion and somatic mutation, which occurs during *in vitro* handling, still offer a bright promise in practical breeding? I am asking this question because at a recent Cassava Biotechnology forum, these technologies were not considered top priority.

T.Ishige(A): Somaclonal variation can be used directly in plant breeding. Somatic hybrids between haploids show hybrid vigor. We need joint projects between plant breeders and tissue culture specialists to realize useful results from these methods.

TECHNICAL REPORTS

Session 3

SWEETPOTATO

Chairmen
Fumio Kikuchi
Truong van Ho

Sweetpotato Genetic Resources in the Philippines

J.L.BACUSMO, V.Z.ACEDO, A.M.MARISCAL and M.Z.ORACION[1]

Sweetpotato is an introduced crop in the Philippines. Although no record exist, it is believed that sweetpotato was first introduced into the Philippines sometime in the 16th century through the "Galleons" that ply the Acapulco – Manila route. It is not known how diverse the ancestral plants were but certainly genotypic variability has tremendously increased since introduction through gene recombination by sexual reproduction, mutation and varietal introduction. Spontaneous germination of true seeds and human selection must be largely responsible for the enormous genotypic variability of sweetpotato present in the Philippines.

Today sweetpotato is an important food crop in the Philippines. Each year more than 130,000 hectares are planted to sweetpotato (Table 1). Per capita consumption of sweetpotato ranged from 10.0 to 24.0 kg. Ninety five percent of sweetpotato are consumed as food. The remaining 5% goes to feed and waste.

As sweetpotato is grown all over the country, farmers in different regions perpetuate varieties that are preferred in their particular locality. Preference to a variety is conditioned by adaptability to local conditions, eating quality and market demand.

Loss of some important varieties do occur usually after drought and as consequence of introduction of more superior varieties.

Table 1. Area planted, volume of production and average yield of sweetpotato in the Philippines, 1986–90

Year	Area Planted (ha)	Volume of Production (MT)	Average Yield (MT/ha)
1986	164,300	777,078	4.7
1987	164,770	800,614	4.9
1988	144,140	843,674	5.1
1989	138,322	660,280	3.19
1990	136,685	668,873	4.66

[1] Professor, Asst. Professor, Assoc.Professor, Philippine Root Crop Research and Training Center, and Associate Professor, Department of Plant Breeding and Ag. Botany, ViSCA, Baybay, Leyte 6521-A, Philippines.

Germplasm Collected

Nationwide collection of sweetpotato germplasm started in 1976 as part of the "Program for the Establishment of a National Root Crop Research and Outreach for the Philippines" which was supported by the International Development Research Centre (IDRC) of Canada and the then Philippine Council for Agricultural Resources Research (PCARR). Under this program, collection trips to the different regions of the country were undertaken to establish a sweetpotato germplasm collection at the Philippine Root Crop Research and Training Center (PRCRTC) at the Visayas State College of Agriculture (ViSCA), Baybay, Leyte. Germplasm from other countries were also obtained through correspondence and personal contact. The number of accessions of *I. batatas* and *I. trifida* x *I. batatas* hybrids in the collection is shown (Table 2).

Aside from PRCRTC, other government agencies such as University of the Philippines at Los Banos (UPLB), Department of Agriculture (DA) and Northern Philippine root Crop Research and Training Center (NPRCRTC), Centro International de la Papa Philippine Regional Office (CIP) and international projects such as Southeast Asian Program for Potato Research and Development (SAPPRAD), also maintain sweetpotato collections for their breeding work. To minimize duplication of efforts, collecting in Luzon area is assigned to NPRCRTC and UPLB, while Visayas and Mindanao is assigned to PRCRTC.

Maintenance

Field Maintenance At PRCRTC, sweetpotato accessions are maintained in one meter quadrats in the field genebank. In each quadrat, 12 cuttings are planted.

Table 2. Number of accessions of *I. batatas* and *I. trifida* x *I. batatas* hybrids in the PRCRTC, UPLB and NPRCRTC germplasm collection

Sources	No of Accessions		
	PRCRTC	UPLB	NPRCRTC
I. batatas		800	653
Philippines	1059		
Taiwan(AVRDC)	80		
U.S.A.	47		
China	25		
Nigeria	25		
Papua New Guinea	17		
Japan	15		
Indonesia	15		
Anonymous	14		
I. trifida x *I. batatas*			
F1	8		
BC1	19		
Total	1324	800	653

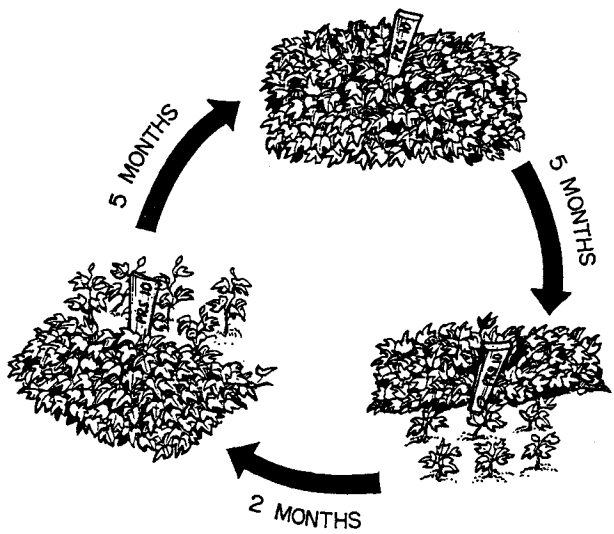

Figure 1. Planting and replanting cycle of sweetpotato germplasm at PRCRTC

Adjacent accessions are separated bby one–meter alleys. Replanting is done annually in the same plots as shown in Fig. 1. Fertilizer application and chemical spraying are kept at the minimum.

At UPLB, sweetpotato accessions are maintained in pots, while the Department of Agriculture and Northern Philippine Root Crop Research and Training Center grow their collections in 4–6 meter rows.

***In vitro* Maintenance of Sweetpotato Germplasm** Backup collection of selected cultivars are kept *in vitro* as the field genebank is exposed to biotic and abiotic risks. PRCRTC established a small tissue culture laboratory for this purpose. Using nodal segments of VSP1 to 6, culture medium formulations consisting of the Murashige and Skoog basic nutrients supplemented with 3% sucrose and different levels of mannitol and sorbitol were studied. The osmotic regulators were used to minimize growth and to prolong tissue maintenance without subculturing.

Results have shown that mannitol at 2% was able to reduce the growth of plantlets compared to the control. However, greater growth reduction was observed at 4% level. Root growth was inhibited or reduces and resulted to the formation of smaller leaves and closer internodes. Plantlets exhibiting a miniature habit. When sorbitol was used, however, a comparable growth rate with the control occured at 2% and growth reduction was only observed at 4%.

Increasing further the levels of mannitol and sorbitol to 8% did not favor desirable growth of tissues. A cauliflower type of growth with callus formation was observed in most of the cultures.

Cultures on 2–4% mannitol and 4% sorbitol were maintained for about a year. When the miniature plantlets were transferred directly to the regeneration medium or the normal growth medium, the roots grew fast and the growing leaves became bigger and the internodes longer. When the plantlets were subcultured using nodal segments and inoculated into the normal growth medium, they produced normal plantlets with no discernible differences from the control plantlets.

At present, 9 selected sweetpotato cultivars, 64 accessions from CIP and 82 embryo cultured hybrids of *I. trifida* x *I. batatas* are maintained in tissue culture. There are plans to conserve Philippine sweetpotato germplasm *in vitro* but at present the Philippine govrnment is not capable to support long term activities of this sort.

***In situ* Conservation** Efforts to promote community based genebanking in the Philippines has been spearheaded by UPWARD (Users Perspective with Agricultural Research and Development). The project is still on it's infancy stage and strategies to convince farmers to initiate and sustain community–based genebanks is not yet defined.

Characterization and Evaluation

Description of the accessions is complete for above–ground parts using the CIP descriptors list for sweetpotato (except for floral characters). Data are stored in the computer for easy retrieval.

Evaluation of the germplasm collection of PRCRTC since 1976 has focused predominantly on yield. Accessions were evaluated in preliminary and replicated yield trials. About 20% of the collection had been evaluated in replicated trials. From these 20% , some high yielding accessions were identified which were used in subsequent breeding works. Other popular farmer varieties such as "Miracle" and "Karinkit" were also utilized as parents. Recently, 50% of the collection was evaluated for yield. Results show that about 75% of the collection gave yields ranging from 1–10 tons/hectare. Some cultivars however gave yields of 156 – 25 tons/hectare (Fig. 2). The variation in skin and flesh color in the collection is shown (Figs. 3 and 4). About 40% of the collection have red skin and about 30% have yellow flesh. Both of these characters are preferred in the market for sweetpotato. Screening for non–sweet varieties, tolerance to acidic soils and tolerance to shade were also done (Tables 3 & 4).

Germplasm Exchange

Within the Philippines, agencies freely exchange sweetpotato germplasm. With agencies outside the country, only "pathogen tested" germplasm materials are accepted. However due to weak quarantine regulations/facilities, "non pathogen tested" germplasm can slip through. Exchange of botanical seeds is virtually unrestricted. Philippines is willing to exchange materials as long as reciprocity is observed.

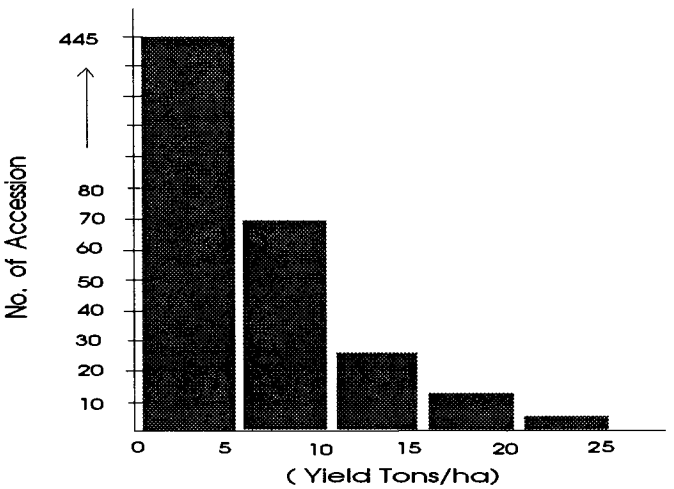

Figure 2. Yield levels of SP germplasm collection (w/o fertilizer)

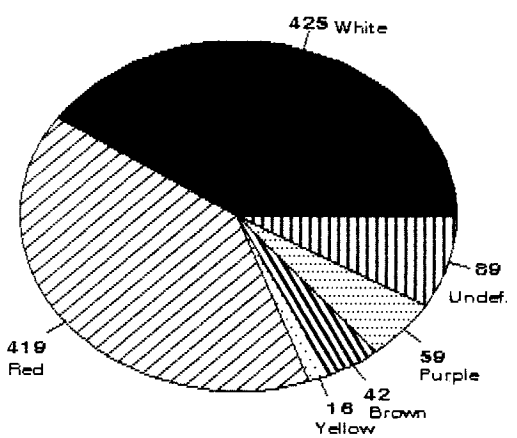

Figure 3. Skin color of sweetpotato germplasm

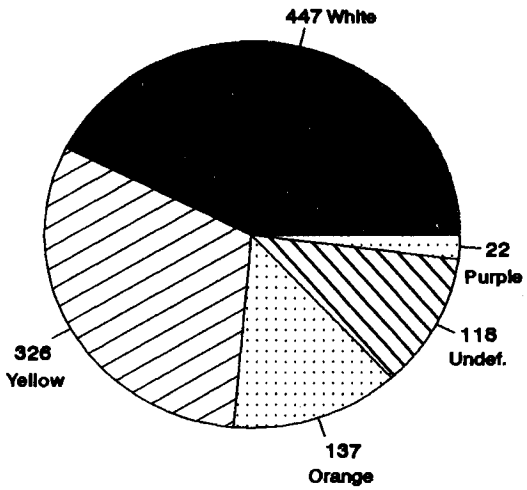

Figure 4. Flesh color distribution of sweetpotato germplasm

Table 3. Yield (ton/ha), weight of herbage (kg/plt) and percent survival of the 10 selected sweetpotato genotypes in single row trial, Matalom, Leyte Philippines 1989

Accessions/ Varieties	Yield (ton/ha)	Herbage (kg/plt)	% Survival
PRS 879	0.88	0.02	15
PRS 882	0.73	0.02	30
PRS 1117	0.66	0.02	50
PRS 1126	0.88	0.03	25
PRS 1128	0.59	0.03	30
PRS 1141	0.73	0.02	15
PRS 1143	0.66	0.02	30
PRS 1159	0.66	0.006	40
PRS 1166	1.76	0.02	10
PRS 1170	1.32	0.04	50
VPS 5(check)	1.65	0.02	20

Table 4. Total yield of sweetpotato accessions under shade, VISCA, 1990

Acc. No	Yield (kg/plot)
PRS 419	13.24
VSP 7	9.62
PRS 111	5.97
PRS 456	4.16
PRS 396	3.97
↓	↓
.	.
.	.
.	.
PRS 526	0.16
PRS 243	0.15
PRS 238	0.15
PRS 285	0.05
PRS 180	0.05

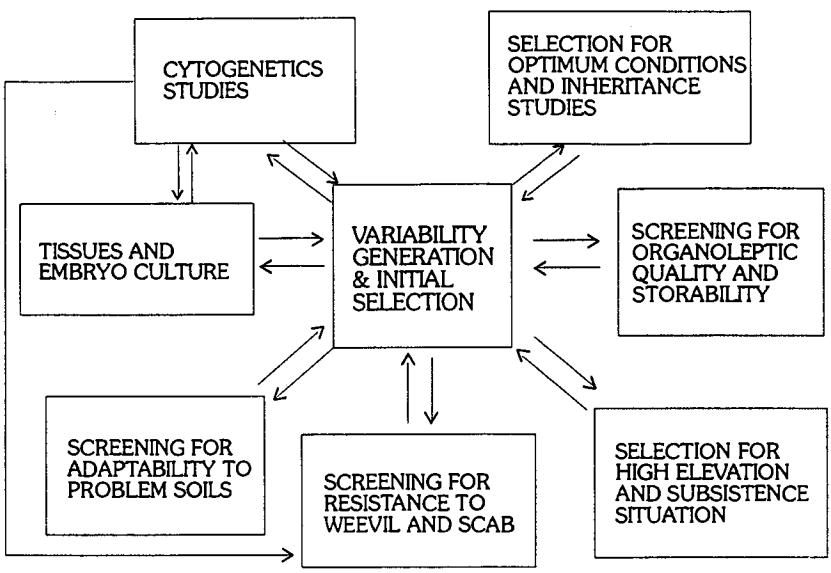

Figure 5. Project structure

Germplasm Use

At PRCRTC, organized breeding effort on sweetpotato started in the late 70's. Interdisciplinary breeding program was later implemented with the support of International Development Research Center (IDRC) (Fig. 5). The breeding

program largely use the polycross method to generating genotypic variations. Briefly, the polycross method as adopted by PRCRTC/ViSCA can be outlined as:

1. Selection of desirable parents
2. Setting up of trellises and planting of parents in mounds
3. Training the sweetpotato in trellises.
4. Collection of open pollinated seeds
5. Germinating the seeds in seed beds
6. Planting terminal cuttings from seedlings followed by strong selection.

Testing of genotypes generated from polycross nurseries and biparental crosses in several locations across the country was also started in the 80's. Promising genotypes from UPLB and DA were also tested under this scheme

Figure 6. Evaluation phases

Table 5. Recommended sweetpotato varieties of the Philippines

Variety	Average Yield (MT/Ha)	Dry Matter	Skin Color	Flesh Color
BNA 51	15.2	–	White	Orange
VSP 1	20.9	26.6	Red	Orange
VSP 2	18.7	33.3	Pink	Orange
VSP 3	17.3	35.4	Red	Yellow
VSP 4	15.7	34.0	White	Yellow Orange
VSP 5	17.2	34.7	Pink	Yellow Purple
VSP 6	19.5	30.6	Red	White
UPL Sp1	16.7	37.0	Red	White
UPL Sp3	17.7	39.0	White	White
UPL Sp 5	13.7	30.0	White	White
BPI Sp1	18.5	26.0	Light Orenge	Orange
BPI Sp2	17.0	31.0	White	Light Yellow
VSP 7	16.46	–	Orange	Orange
Red Wonder	14.0	30.32	Red	Light Yelloow
PSBSp 15	13.83	36.30	Cream	Light Yellow
PSBSp 16	12.16	37.49	White	White
PSBSp 17	17.09	30.12	Red	Yellow

(Figure 6).

To date 17 varieties have been recommended by the Philippine Seed Board (Table 5). These varieties are recommended with yield across testing locations, dry matter and eating/processing qualities as the main criteria.

Screening for Resistance to Weevil and Scab Since 1986 screening for weevil and scab resistance have been going on. A total of 2,152 genotypes were evaluated starting from observational trial. Under field condition, 60 genotypes were rated as moderately resistant or resistant. When screened however using force feeding in pots and in close containers, all genotypes eventually exhibited susceptible reactions (Fig. 7). The results suggest that only low level of resistance are available from the germplasm. This low level of resistance however, may be useful when used in combination with other control measures.

Using Ipomoea Relatives for Sweetpotato Germplasm Enhancement Studies on *Ipomoea* relatives with the ultimate view to their possible use in sweetpotato breeding was started in early to mid–80's. However, the actual wide crosses were achieved only in 1988. The *Ipomoea* relatives used included local and introduced species from various sources. All these *Ipomoea* forms were field grown and only the flowering and vigorous accessions were used in the subsequent crosses under

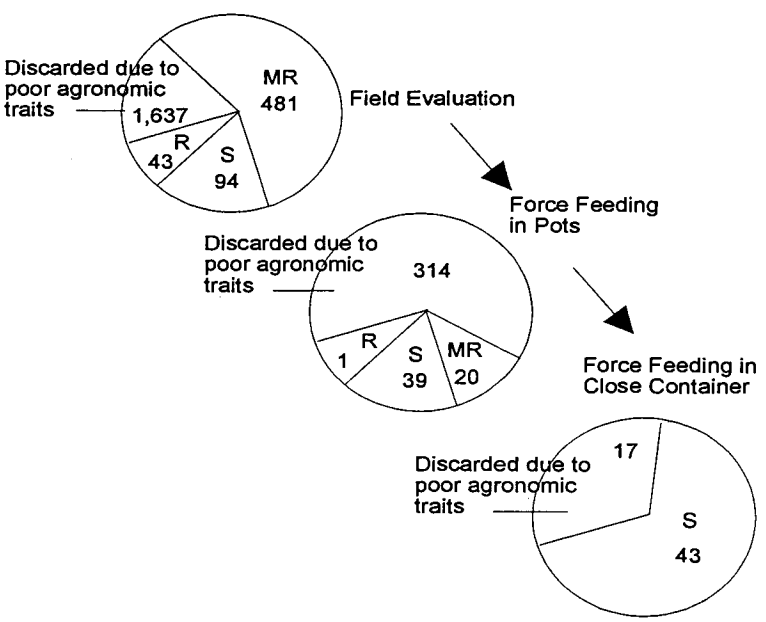

Figure 7. Reactions of genotypes to weevil under different screening procedures

natural conditions. The initial reciprocal cross-compatibility and crossability tests indicated that some cultivars set seeds when used as female in crosses with *I. pes-caprae*, 2x *I. trifida* and 6x *I. trifida* while only the 2x, 4x and 6x *I. trifida* strains set seeds when used as females in crosses with some cultivars. However, all the diploid *Ipomoea* species and the *I. trifida* "species complex" showed evidence of pollen tube growth in stigmas of some cultivars or vice versa, but failed to set seeds. The sporad types and pollen stainability of these *Ipomoea* forms were studied to asses their male/pollen fertility.

Although sweetpotato has successfully been crossed with *I. pes-caprae* and the 2x, 4x and 6x *I. trifida* strains, the main focus of the wide hybridization done so far was between hexaploid sweetpotato cultivars and the hexaploid *I. trifida* as the initial step in broadening the genetic base of cultivated sweetpotato germplasm using wild relatives. Strains of *I. trifida* (6x) from Japan were used in thousands of hand pollinations. A higher seed set was obtained when sweetpotato was used as female, but seed germination was about the same (40%) with seed produced with sweetpotato used as male or female. The F1's have been tested and selections were made based on root number, root weight, root diameter and high dry matter content.

Cytological behavior of some F1 hybrids during meiosis indicated a high degree of bivalent as well as quadrivalent and hexavalent chromosome pairing associations, an indication that chromosomes from the sweetpotato and the 6x *L. trifida* strains were highly homologous. The pairing behaviors suggest that recombination or exchange of genes could take place between these closely related species to broaden the sweetpotato gene pool.

Backcrossing of the F1's to selected sweetpotato cultivars was done resulting to 838 seeds from 104 cross combinations. Percentage germination of BC1 seeds was 30.55% and 40% of these genotypes were selected after field trials for further tests. Field evaluation of the BC1's from *I. trifida* x *I. batatas*, shows that yielding ability can be reconstituted after a single backcrossing. Table 6 shows the yield and reactions to scab and weevil of the BC1's. Though initial results (field screening) indicates resistant reactions to scab and weevil, it is too early to conclude that useful genes for resistance to weevil and scab were obtained from crossing *I. batatas* with *I. trifida*.

Adoption of New Varieties

For the recommended varieties, their adoption is both slow and non symmetrical. In some areas like Bicol, VSP's (ViSCA Sweetpotato) are more widely grown compared to areas such as Leyte and Samar which are closer to PRCRTC.

Among the factors that contribute to this slow adoption of the new varieties are the following.

1. Shortcomings of the new varieties such as in eating quality, storability and adaptability to marginal environment. To increase

Table 6. Number of tubers, yield and reactions to scab & weevil of BC1 *I. trifida* x *I. batatas*

ENTRY	# of tuber/hill	Yield (kg/hill)	Scab (rxn)	Weevil (rxn)
VSP1 x 13-1 P1	2.0	0.12	HR	R
VSP1 x 13-1 P3	1.20	0.06	HR	R
VSP1 x 12-3	0.75	0.01	MR	HR
VSP1 x 24-5 P1	3.10	0.36	HR	R
VSP2 x 12-2	0.75	0.05	HR	R
VSP3 x 12-2 P1	0.25	0.02	HR	R
VSP3 x 13-1	1.40	0.26	HR	R
VSP3 x 13-1 P1	1.09	0.22	HR	R
VSP3 x 13-1 P10	0.67	0.02	R	R
VSP3 x 13-1 P4	1.67	0.05	HR	R
VSP3 x 13-1 P2	0.86	0.03	HR	R
VSP3 x 13-2	0.25	0.01	HR	R
VSP4 x 13-1 P1	5.0	0.25	HR	R
VSP4 x 12-3 P2	0.83	0.09	HR	R
VSP4 x 13-1 P3	1.0	0.03	HR	R
VSP4 x 13-1 P2	1.33	0.06	HR	R
Binotatic x 13-1 P1	0.75	0.10	HR	R
Miracle x 13-1 P1	0.87	0.05	HR	R
VSP2(Susceptible Check)	1.0	0.29	HR	MS
V37-151(Yield Check)	1.93	0.55	HR	MR

chance of adoption, efforts are directed to involving farmers in the selection of potential varieties. This somehow allows farmer criteria to be inputed in the selection of potential varieties. PSBSp15 (Philippine Seed Board Sweetpotato 15), for example is a product of selection involving farmers from the preliminary trial.

2. Limited access of farmers to planting materials of new varieties. Unlike cereals the Philippine government has no program on distribution of sweetpotato cuttings. Moreover distribution of sweetpotato seedpieces is difficult due to : (1) high perishability; (2) bulk; and (3) difficulties in maintaining/multiplying quality seedpieces in the field.

3. Stagnant market of sweetpotato. With nonexpanding market, farmers find no incentive to adopt high yielding varieties in order to increase production.

Nevertheless, some new varieties have started replacing traditional varieties in semi-commercial sweetpotato growing areas. For subsistence farms, it is extremely difficult to assess adoption of new varieties due to the inaccessibility of sweetpotato growers and loss of identity of new varieties from the usual practice of naming/renaming variety according to source.

Conclusion

The sweetpotato in the Philippines exhibits wide genotypic variability. It is not known however, how wide the gene variability is. Government agencies as well as international programs are presently involved in the conservation and breeding efforts on sweetpotato in the Philippines. High yielding varieties of sweetpotato were released by the Philippine Seedboard. Most of these were developed through polycross breeding. Using the wild relative *I. trifida* has also been attempted. Adoption of new varieties released by the Philippine Seedboard remains slow inspite of high yield and other superior traits of new varieties.

The present germplasm collection has yet to be systematically evaluated for important traits in order exploit its full potentials. Problems of continuing and improving present conservation activities on sweetpotato remains in view of diminishing funds for research.

Sweetpotato Genetic Resources and Breeding in Japan

KATSUMI KOMAKI[1]

Sweetpotato can convert solar energy to carbohydrates efficiently and tolerates environmental extremes, such as drought and typhoons, which cause significant losses to upland crop production. Sweetpotato is thought to have been first introduced into Japan in the 1600s. By the middle of the 19th century it had spread throughout Japan, except Hokkaido.(Kobayashi, 1984a) It is one of Japan's most important upland crops, especially in southwestern Japan.

Between five and seven million tons of sweetpotato were produced on 350,000 to 450,000 ha annually between 1945 and 1960. However the acreage and production has been decreasing gradually since then due to the higher price of domestic sweetpotato starch over imported corn starch and changes in Japanese diet. Sweetpotato production in 1992 was approximately 1.2 million tons on 55,000 ha. About 30% is used for starch production, 30% is consumed as a fresh vegetable, and the rest is used as animal feed, farmers' food and material for fermentation products including alcohol and alcoholic beverages.

Domestic sweetpotato starch has been protected for the last 20 years by a policy related to the importation of corn starch. The general tendency toward global free trade of agricultural products may remove protection for sweetpotatoes produced for the starch industry. This could result in a further decrease in sweetpotato production and a decline in upland farming in southwestern Japan, where sweetpotato is an indispensable crop because of low soil fertility, irregular summer rainfall and frequent typhoons.

In such a situation, new demands for sweetpotato have to be developed. Consequently, diverse sweetpotato germplasm is considered important for the development of new sweetpotato products.

The present paper reviews the current status of introduction, conservation, evaluation and use of sweetpotato genetic resources in Japan.

Introduction of genetic resources

Since the first introduction of sweetpotato into Japan a number of exotic genetic resources have been introduced by the National Agriculture Research

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Center(NARC). The origin of these introductions in NARC is shown(Table 1). Initially many accessions were introduced from U.S.A., Taiwan, Philippines and Indonesia. Since the MAFF Gene Bank Project started in 1986, exploration and collection has been conducted in Malaysia, Indonesia and Papua New Gunea for sweetpotato. Introductions include not only cultivars but also wild relatives. In 1956 Nishiyama(1971) explored Mexico and collected a number of wild relatives of sweetpotato including K123 which is a hexaploid type of *Ipomoea trifida*. K221 was collected in Mexico in 1960. This accession was originally called *I. leucantha,* but now it should be identified as a diploid type of *I. trifida*. In addition Kobayashi(1984b), Shiotani(1983), and others collected many accessions of sweetpotato, including *I. trifida*. Species and accessions introduced since 1956 are shown(Table 2).

Introductions coming into Japan must pass through the Plant Protection Office of MAFF. Sweetpotato roots and foliage with a yellow tag issued by Plant Protection Office may enter Japan. The yellow tag is a special permission to introduce plant materials which are basically prohibited to import into Japan by

Table 1 Origin of introductions conserved in NARC

Country	Number	Country	Number
U.S.A.	24	Philippines	7
Brazil	4	Taiwan	4
Mexico	1	Venezuela	3
Papua New Guinea	37	China	7
Malaysia	58	Others	18
Indonesia	43	Unknown	2

Table 2 Wild species closely related to sweetpotato introduced into Japan

Species	Accessions	Remarks
Ipomoea trifida(2x)	7915, 8042, etc.	
(3x)	K222	
(4x)	K300, K500, 7948, etc.	
(6x)	K123, K177	Feral type of *I. batatas*?
I. leucantha	K221	*I. trifida*(2x)?
I. littoralis	K233, etc	Ecotype of *I. trifida*(4x)?
I. triloba	K121, etc	
I. trichocarpa	7934, etc.	
I. tiliacea	K270	
I. gracilis	K134	*I. tiliacea*?

Plant Protection Law. The germplasm issued yellow tag must inspected for virus diseases and some kind of insects by Plant Protection Office. If it does not pass the inspection, it is isolated in the isolation facilities for upland crops in NARC and shoot tip culture is performed. Virus free plants from shoot tip culture can be planted in the open field after approval from the Plant Protection Office.

Genetic resource conservation

The accessions conserved in NARC consist of cultivars registered by MAFF, breeding lines, local cultivars, introductions and hte collections of professor Douglas Yen(Table 3). Genetic resources of sweetpotao are also conserved in Kyushu National Agricultural Experiment Station(KNAES), the National Center for Seeds and Seedlings(NCSS), and National Institute of Agrobiological Resources(NIAR) as shown(Table 4). Approximately 3,500 accessions, including introductions from many countries and breeding lines in Japan, are conserved. Roots are usually stored in storage facilities with a 13 C and 95% RH. However, plants of accessions that produce no storage roots are kept in the greenhouse above 15 C even in winter. Species closely related to sweetpotato are principally

Table 3 Sweetpotato genetic resources in NARC

Source	Accessions
Cultivars registered in MAFF[a)]	61
Breeding lines	398
Local cultivars	275
Introductions	208
Yen's collections	379
Total	1,321

a)Including 17 mutants from these cultivars

Table 4 Number of genetic resources of sweetpotato in Japan(1993)

Organization	Accessions	Propagule
Natl Agric. Res. Ctr.	935	Clone
Kyushu Natl Agric. Expt. Stn.		
in Miyakonojo	918	Clone
in Ibusuki	264	True seed
Natl Ctr. Seeds & Seedlings	969	Clone
Natl Inst. Agrobiol. Resour.	369	True seed
Total	3,455	

conserved as true seeds, but tetraploid and hexaploid types of *I. trifida* which can tolerate growing in pots all year are maintained this way. Since Yen's collection have accessions which do not produce storage roots, hybrid seeds with some cultivars are also conserved in the Gene Bank Facilities of NIAR.

Genetic resources evaluation

Genetic resources are evaluated for a range of traits which includes morphological and physiological characters, tolerance and resistance to biotic and abiotic stresses, and yield and its component(Table 5). In total, 50 morphological and 25 biological descriptors are used for registration of new cultivars, and 30–40 characteristics are evaluated in the organizations responsible to sweetpotato conservation annuall.

Use of sweetpotato genetic resources

1. Sweetpotato cultivars

Genetic resources should be used for breeding from different standpoints in a crop improvement program. Insect and disease resistance, tolerance to environmental extremes, nutritional aspects are usually important traits for breeding. Heterosis is expected from crosses between native cultivars or their progenies and exotic genetic resources. For instance, high yielding cultivars are sometimes developed by using exotic genetic resources, when genetic variation among native breeding materials is limited. 'Koganesengan'(Sakai *et al.*,1967), a leading cultivar for starch production in Japan is related to 'T No. 3' and L–4–5, which were introduced form Indonesia and U.S.A., respectively. Cultivars which have been developed using exotic genetic resources are shown(Table 6).

Table 5 Evaluation of sweetpotato genetic resources

Priority	Characteristics
Primary	Plant type, Twining, Natural flowering, Vine pigmentation, Mature leaf shape, Immature leaf color, Abaxial leaf vein pigmentation, Leaf nectary color, Storage root shape, Storage root color, Storage root flesh color, *etc.*
Secondary	Self– and cross–incompatibility group, Sprouting ability, Storability, Stem rot resistance, Soil rot resistance, Root–knot and root–lesion nematode resistance, *etc.*
Tertiary	Fresh root:Storage root yield, Dry matter content, Starch content, *etc.* Steamed root:Taste, brix(%), blackening, *etc.*

Table 6 Examples of cultivars developed by using exotic genetic resources

Cultivars developed	Exotic genetic resources(Origin)
Koganesengan	L-4-5(U.S.A.), T No. 3(Indonesia)
Minamiyutaka	K123(Mexico), L-4-5, T No. 3
Benihayato	Centennial(U.S.A.), K123
Healthy Red	Caromex(U.S.A.), Nancy Hall(U.S.A.), Tinian(Mexico), L-4-5

2. Wild relatives

Wild relatives are used for specific important traits, such as insect and disease resistance, and for widening the genetic background of cultivated germplasm(Iwanaga, 1987). The wild species that has been used in Japan's breeding program is *I. trifida* which can cross with sweetpotato irrespective polyploidy. K123 reported by Nishiyama as a hexaploid type of *I. trifida* was extensively used in breeding for increased starch production. Although the taxonomic identity of K123 has been questioned(Jones,1967), I call it *I. trifida* in this paper. Hybrids between sweetpotato and K123 were backcrossed to improved cultivars. From BC_2 progenies, Minamiyutaka was selected and released(Ono *et al.*, 1977). Since K123 is resistant to root knot nematode and root lesion nematode, Minamiyutaka is also resistant to those nematodes. In addition, this cultivar shows very high yielding ability.

Most of the newly released cultivars are related to hexaploid types of *I. trifida*. Tetraploid types of *I. trifida* collected in Colombia were used for widening the genetic background of sweetpotato . They are also resistant to root knot and root lesion nematodes. They were crossed with sweetpotato and back-crossed three to four times to improved cultivars. Lines obtained by back-crossing were morphologically and biologically almost the same as sweetpotato(Miyazaki *et al.*, 1984, Chishiki *et al.*, 1985). Diploid types of *I. trifida* were used for the development of a tetraploid type of sweetpotato(Kobayashi and Miyazaki, 1976).

Conclusion

The importance of sweetpotato as a crop can not be estimated solely on the basis of the past or present production and utilization statistics. The use of genetic resources in breeding programs can contribute to the creation of new demands for this important crop. From this standpoint, it is very important to make special efforts to conserve sweetpotato genetic resources and ensure they are evaluated and used. We have to establish *in vitro* conservation and cryoconservation systems to keep and exchange sweetpotato genetic resources safely. It is also important to develop a technique for evaluating the processing quality. Finally, we need to develop techniques, which use new biotechnology techniques, for breeding new

cultivars suitable to meet new demands of sweetpotato.

References

Chishiki, T., Komaki, K. and Miyazaki, T. 1985. Breeding use of wild tetraploid species closely related to sweet potato by continuous backcrossing. 2. Changes of some economic characters as backcrossing advances. Kyushu Agriculture Research 47:56(in Japanese)

Iwanaga, M. 1987. Use of wild germplasm for sweet potato breeding. Pages 199–210 *in* Exploration, maintenance, and utilization of sweet potato genetic resources. Report of the First Sweet Potato Planning Conference. International Potato Center(CIP), Lima, Peru.

Jones, A. 1967. Should Nishiyama's K123 (*Ipomoea trifida*) be designated *I. batatas*? Econ. Bot. 21:163–166

Kobayashi, M. 1984a. Satsumaimo no kita michi(Sweetpotato —where it comes from?—). Kokinshoin, Tokyo, Japan. (in Japanese)

Kobayashi, M. 1984b. The *Ipomoea trifida* complex closely related to sweet potato. Paper presented at Sixth Symp., Intl Soc. Trop. Root Crops, Lima, Peru.

Kobayashi, M. and Miyazaki, T. 1976. Sweet potato breeding using wild related species. Proc. 4th Int. Symp. Trop. Crops 1:53–57

Miyazaki, T., Chishiki, T. and Komaki, K. 1984. Breeding use of wild tetraploid species closely related to sweet potato by continuous backcrossing. 1. Relationship between backcross generations and crossing ability. Kyushu Agriculture Research 46:53 (in Japanese)

Nishiyama, I. 1971. Evolution and domestication of the sweet potato. Bot. Mag. Tokyo 84:377–387.

Ono, T., Marumine, S., Yamakawa, O., Hirosaku, S., Sakamoto, S. and Ide, Y. 1977. A new sweet potato variety, Minamiyutaka. Bull. Kyushu Agric. Expt. Stn. 19:133–150 (in Japanese)

Sakai, K., Marumine, S., Hirosaku, S., Kikukawa, S., Ide, Y. and Shirasaka, S. 1967. On the new ariety of sweet potato, Koganesengan. Bull. Kyushu Agric. Expt. Stn. 13:55–68 (in Japanese)

Shiotani, I. 1983. A survey of habitats of *Ipomoea trifida*, a closely related species to sweet potato. Rep. Plant Germ–plasm Inst. Kyoto Univ. 6:9–27

Maintenance and use of sweetpotato germplasm in China

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Abstract

About 2,000 accessions of sweet potato are maintained in China. These accessions are maintained in an active field genebank at Xuzhou in the north of China and at Ghangzhou in the south. The National Genebank in Beijing maintains *in vitro* plants. In recent years research on sweet potato *in vitro* storage has intensified in all three conservation centers. The main research areas have been meristem culture, plant regeneration and the technical conditions for *in vitro* germplasm storage. This paper reviews the use of sweetpotato germplasm in China in the following areas: germplasm evaluation, local cultivars, introductions, improved varieties, wild relatives, mutants, breeding lines and virus free sweet potato production. Recent research results are also presented.

Introduction

Sweetpotato was introduced into China in the late sixteenth century via two routes: one from Vietnam and Burma to south China (Yunnan and Guangxi provinces) and another from the Philippines to Guangdong and Fujian provinces in southeast China. Thanks to its high yield, nutritional value, wide adaptability to different environments the sweetpotato has been grown in many parts of China, covering most regions of the country. The main production areas have been the Yellow and Yangtze River Basins (Sheng et al., 1987). Currently sweetpotato ranks fourth in China as a food crop after rice, wheat and corn. Sweetpotato is grown annually on six million ha of land(Table 1). China's production in 1990 accounts for 85% of the world total (FAO, 1992).

During the past decade, sweetpotato has increasingly been used as an animal feed and as a raw material for industry. Thus sweetpotato is becoming an industrial crop and it was classified as such in the Eighth-Five-Year National Research Program. In the context of national development for low soil fertility areas in the central and south China, sweetpotato has played an important role in making this area with poor soils productive. Sweetpotato germplasm research has intensified in recent years.

China is in the Asia-Pacific secondary center of origin for sweetpotato. South China is in the tropical and sub-tropical region. Where sweetpotato can

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Table 1. Sweetpotato production in China in 1986

Province	Area ('000 ha)	Production ('000 ton)
Hebei	352	1,125
Jiangsu	275	1,330
Zhejiang	115	557
Anhui	658	2,772
Fujian	217	661
Shandong	4,152	4,003
Henan	783	1,782
Hubei	186	594
Hunan	265	71
Guangdong	579	1,386
Guangxi	237	234
Sichuan	1,230	3,820
Guizhou	101	28
Shaanxi	98	209
Total	9,248	18,572

grow year–round and flower easily in South China. South China has a vast reservoir of sweetpotato germplasm as a result of natural and artifical selection. Landraces cultivated in other areas for decades or hundreds of years also possess desirable characters and also contribute to genetic diversity of the sweetpotato in China. With increasing latitude this diversity decreases. 80% of Chinas sweetpotato genetic diversity is found from the Yangtze River Basin south, while to the north most germplasm is of improved varieties.

International germplasm and information exchange has been improved in recent years with scientists from the International Broad for Plant Genetic Resources (IBPGR), the International Potato Center (CIP), and the Asian Vegetable Research and Development Center (AVRDC) visiting China. In 1987 collaboration between CIP and China was initiated and CIP opened its regional office in Beijing. The contract and collaborative projects between CIP and the Xuzhou Sweetpotato Research Center (XSPRC) have focussed specifically on sweetpotato germplasm evaluation and use and has produced satisfactory results.

Germplasm collecting and maintenance

1. Collecting

Early germplasm collecting started in the 1930's in Taiwan, Guangdong, Sichuan and Jiangsu provinces. This involved introducing new materials and evaluating local varieties. From the 1950's the Government organized two collecting expeditions in the Southeast and Yangtze River Basin and to the north of the Yangtze. A total of 1442 accessions were collected up to 1982, 1096 of which were morphologically characterised and included in the Sweetpotato Variety

Catalog published in 1984 by the XSPRC.

From 1987 to 1990, with funding from CIP the XSPRC organized collecting expeditions to areas north of 46°N in Heilongjiang and south of 28°N in Yunnan and Guizhou provinces. A total of 200 samples were collected from these areas (Wu et al., 1988; Wu and Wang, 1988). Zhaoyuan 15 collected from Heilongjiang and Puer Huangshanyu collected from Yunnan have been used in breeding and production thanks to their high yield and good quality (Wu and Guo, 1990).

Introduction of the sweetpotato via international channels has been continuing. Over 200 sweetpotatoes were introduced from the United States, Japan, the Philippines and other countries. Over 100 were introduced from international institutes like CIP, AVRDC and the International Institute for Tropical Agriculture (IITA). Now the China national sweetpotato collection consists of over 2000 accessions, 184 of which were included in the Annals of Chinese Sweetpotato Varieties edited by XSPRC and publish in 1993.

2. Maintenance

Before the 1970's sweetpotato germplasm was maintained in institutions which also conducted sweetpotato breeding and research. In the 1980's a nationwide germplasm network was taking shape with XSPRC as the leading maintenance center coordinating 23 institutions around the country. Due to differences in agroecological conditions, sweetpotato accessions were maintained nationally in three institutions.

1). Germplasm Nursery at XSPRC maintains, in the field genebank, the accessions from the Yangtze River Basin (and the region to the north) and introductions from Taiwan and international institutions around the world.

2). The sweetpotato germplasm nusery in Guangzhou maintains materials from the southern sweetpotato growing area where sweetpotato is grown as an autumn/winter crop. Guangzhou has a field genebank and maintains germplasm in the form of root and storage organs.

3). The National Genebank in Beijing maintains *in vitro* sweetpotato plants provided by XSPRC and Guangdong Academy of Agricultural Sciences (GAAS) in Guangzhou.

Once the *in vitro* storage system has been completed XSPRC will be responsible for the *in vitro* maintenance currently carried out by the National Genebank. At the moment, around 1000 accessions are maintained in each of these three institutions. A small number of materials are maintained at some breeding institutes.

(1) Field maintenance

This method is technically simple and a viable method(Fernandes et al., 1987; Human, 1987; Takagi, 1987) also evaluation can be done on field grown plants (Yakuwa and Oka, 1987). XSPRC grows about 1400 accessions annually in

the field. These accessions are stored in storage houses with a temperature of 13°C to 15°C and relative humidity of 80% after curing. A storage house for long term roots storage is also being planned for construction. Once completed the roots will be stored for two years to reduce labor and land costs involved in the traditional field maintenance system and minimize the risk of mixing up the accessions and disease infection.

Field maintenance using stem cuttings and storage roots is economically acceptable in China because of its low cost. However, maintained accessions are often subjected to environmental stresses like drought, water logging, frost and also diseases. On the other hand, accessions unable to produce storage roots under natural conditions in the maintaining region cause difficulty in storage and hence maintenance. Mechanical mix-up is another problem in the planting-harvesting-storage cycle (see also Jarret and Florkowski, 1990).

Increasingly severe virus diseases in recent years have also been a threat to field maintenance. Virus free plants produced by meristem tip culture could be infected again when planted in the open field. Data from our nursery shows that 85% of the accessions displayed symptoms typical of virus infection (Table 2). The fact that sweetpotato is clonally propagated also favors virus transmission and accumulation in plants. Some accessions were lost due to virus infection which results in no storage roots being produced. This has been a problem for germplasm conservation for years. Infection could also affect evaluation for yield and disease resistance (Liao et al., 1983; Yang et al., 1991).

(2) *In vitro* maintenance

Sweetpotato plants maintained *in vitro* are usually derived from meristem tip culture and free from virus and other pathogens like fungi, bacteria, nematode and mycoplasm-like organisms and facilitates germplasm exchange and distribution regionally and internationally (Fernadez et al., 1987; IBPGR, 1987; Jarret, 1987;

Table 2. Accessions with symptoms typical of virus infection in germplasm nursery at Xuzhou Sweetpotato research Center during 1982-1989 (1).

Year	No. accessions surveyed	No. accessions with symptoms	Infection rate (%)
1982	530	8	1.5
1983	575	39	6.8
1984	590	42	7.1
1985	590	70	11.7
1986	669	119	17.8
1988	817(2)	580	71.0
1989	1127	958	85.0

1) The first accession found with leaf roll symptoms was Jewel in 1981. Jewel was introduced from the US.

2) Nursery plants were surveyed. Others were surveyed in the field. Data for 1987 is not shown.

Kuo, 1991; Lu and Chen, 1985; Ouyang, 1984). Research initiated in the mid-1980's on tissue culture in China has centered on four area.

a). Meristem tip culture and plant regeneration.

Meristem tip was obtained from field plants or sprouts on the roots in an incubator. Basal MS or 1/2MS was supplemented with plant hormones in different concentrations. Optimum concentration of carbon sources (sucrose and glucose) is 3% and sucrose is better than glucose (Lu et al., 1981). It usually takes two or three months to regenerate new plants (Xin, 1987). Regeneration time could be affected by sterilizing time of explants, concentrations of sterilizing solution, agar quantity added (Chen et al., 1989) and more importantly by hormones and their concentrations (Chen et al., 1989; Tang et al., 1989; Xin, 1987) (Table 3), genotypes used (Table 4), explant size, physiological stage of plants and culture environment (temperature and light) (Xin, 1989a). Merstem tips from apical tips and up to three buds down were found to be easier to regenerate than from other positions. Under optimal conditions, meristem tips with 2–3 primordia can be induced to regeneration for most genotypes.

Culture temperature can range from 28°C to 30°C; growth will be retarded when temperature is below 24°C. When it is above 30°C the meristem tip under culture will turn brown from initial green before it dies (Xin, 1989b). Results from our laboratory indicate that meristem tips excised from sprouts of incubated roots are better for cultures' growth and plant regeneration than those from field plants. In addition, spring is the best season to culture the meristem tip *in vitro*.

Table 3. Effect of hormones on shoot formation from apical meristem tip culture of sweetpotatoes(1)

Basal media	Hormones (mg/l) BA	KT	IAA	Plant regeneration(%)
MS or		2.0	0.5	66–70
1/2 MS	0.5		1.0	85
		0.5	0.2	25
	0.5	0.2		60–70

1) After 7–14 days transfer to 1/2MS.

Table 4. Plant regeneration rate of 30 genotypes cultured on the same medium

Range of regeneration (%)	No. of varieties	Percent
61–100	22	77.3
51– 60	5	16.7
31– 50	2	6.7
11– 30	1	3.3

(3) *In vitro* storage.

There are two methods to maintain *in vitro* cultures: minimal growth and cryopreservation. Regenerated plants were propagated by nodal cuttings and moved to storage room when the plantlet is 3–4 cm. *In vitro* plant growth was controlled by addition of retardants in the media and regulation of light (intens ity and period) and humidity.

Growth retardants added are usually kinetin (KT), abscissic acid (ABA), glyphosate, cycocel (ccc), methyl succinic acid (MSA) and N–dimethyl succinic acid (B9) (Wang et al., 1989; Xin, 1989a; Zhou, 1989). These inhibitors can reduce culture's growth during storage (Table 5) but the effect could carry over to the next subculture, to which no inhibitors were added. Among them ABA can still slow subculture's growth for 3–6 months. Glyphosate treated subcultures show mild chlorosis in the leaves and those in KT treatment could produce callus on the cut surface. High concentration of inhibitors can induce mutation (Xin, 1989c). Mannitol could also be added to produce osmosis in the medium and reduce the roots ability to uptake and hence cultures growth. As a monosaccharide derivative, mannitol is better than sucrose in this respect. It has been reported that with a concentration of 10g/l of mannitol survival of *in vitro* plants was 69.9% after one year's storage (Xin, 1989a).

Lower temperatures (16–18°C) is a simple way to control *in vitro* plant growth. It is a convenient method for maintenance, especially when combined with growth inhibitors. Optimal light conditions with an intensity of 1000 lux in 8 hours daily and humidity of 50–60% (RH). When RH is over 65% contamination can occur due to favorable humidity for fungi spores and bacteria in the air. In our experience, use of tin foil as seals allows both gas exchange and moisture retention and prevents contamination.

c) Genetic stabilty.

Callus formation should be minimal to avoid genetic variation. However, with the time of maintenance *in vitro* variation can more easily occur, no matter what media are used (Ng and Dodds, 1987). Sweetpotatoes stored in media with

Table 5. Effects of five growth inhibitors on *in vitro* survival of sweetpotatoes on MS medium

Growth inhibitors	Conc. (mg/l)	No. of vars. tested	Survival after one years in storage (%)
ABA(Abscissic acid)	1	10	85.5
Glyphosate	1	10	84.8
KT(Kinetin)	10	20	71.3
ccc(Cycocel)	100	10	37.7
ccc(Cycocel)	500	10	89.4
Mannitol	10,000	20	69.9
CK	MS only	20	51.5

Table 6. Effect of growth inhibitors on vine color of Xushu 18

Growth inhibitor	Conc. (mg/l)	Root yield (g/plant)	Vine color
KT	6	420	Purplish red
	10	450	Green
Mannitol	15,000	410	Purplish red
	30,000	100	Green
ABA	1	230	Purplish red
	10	75	Green
CK	MS only	380	Purplish red

Note: Plant was cultured on MS medium. Data were gathered in the field where *in vitro* plants were transplanted. Per plant root yield was averaged over five plants.

KT, mannitol and ABA for one year showed slowed apical growth and shorter vines one month after transplanting in the field. Plant growth becomes normal three months later (Xin, 1989c). At high concentrations, growth retardants can cause morphologically changes. Xushu 18 treated with high dose of the inhibitors have a green vine compared with the original color, purple (Table 6). However, some variation is temporary since treated plants may return to normal after one growth cycle, especially for the colors of leaf, vine, skin and flesh of sweetpotatoes treated with mannitol (Wang et al., 1989). Other authors also suggested that these types of variation are temporary and not heritable. It is safer to add 0.5–1.0% mannitol (w/v) in maintenance media to minimize the possibility of morphological or genetic modifications.

d) Maintenance and management.

Attention should be paid to the following:

a) the storage room should be thoroughly sterilized before use by fumigating the room with potassium permanganate mixed with methanol.

b)Relative humidity should be controlled at 50–60% especially during the summer

c) The room should be periodically ventillated to allow air exchange with the outside in order to reduce carbon dioxide release by dark respiration and ethylene.

d) subculture materials that are already maintained sufficiently long and that do not grow well.

e) Maintained materials should be arranged in such an order that checking and recording can be conveniently undertaken.

Germplasm evaluation

Evaluation of germplasm is important for production and breeding. We

have evaluated germplasm based on yield, quality (dry matter, starch content, soluable sugar, crude protein, crude fibre, vitamin C and carotene), disease and pest resistance (to root rot, black rot, stem nematode and root-knot nematode in the north and to bacterial wilt, stem rot and weevil in the south), stress tolerance (drought, cold, salt excess moisture) and storability.

Evaluation has identified a number of accessions with desirable characters. Some of them are :

a) high-yield whose storage root yield approximates or exceeds the local control: Xushu 18, Fengshoubai, Nongdahong, Yubebai and Pengwei.

b) High dry matter content: based on results from 547 accessions evaluated nationally 23.9% have a DM content over 30%. Examples are Manicunxiang, Yangaofen, Lizixiang, Benikomachi, L-4-5.

c) Good quality: Lizixiang, Yanshu 3, 51-16 and Beijing 553 have a good eating quality while Centenial, Caromax, Dananfu, Yizi 138 and Beijing 284 have a high carotene content.

d) Huabei 256, Hebei 351, Liaoshu 205 and Shaashu 1 have good germinability, which is important in the north where planting materials are obtained from propagules sprouted from bedded storage roots.

e)Early maturity: Huabei 52-45, Jishu 872 and Ningyan Sanshiri Zao. This is important to permit multiple cropping.

Accessions resistant to pests and diseases were also identified:
a)Black rot: Xiaobaiteng, Jiagou Dazi and Tiexianteng;
b)Root rot: Xushu 18, Xu 236 and Licunhuang;
c)Stem nematode: Yanshu 6, Qingnong 8 and Jishu 10;
d)Root-knot nematode: Suxian Xiaohuaye,Qingnong 2 and Hongtou;
e) Bacterial wilt: Huabai 48, Xiangnong Huangpi and Yongshu 2;
f) Stem rot: Yanshu 5, Honghong 1 Peiwei;
g) Sweetpotato weevil: Huabei 117, Biaoxinhong and Tainung 31.

Accessions tolerant to environmental stresses are:
a) drought tolerance: Tiedingfan, Beijing 553, Nongdahong and Jishu 2;
b) cold: Dongshu, Huihongzao, Jiucaizhong and Yanshu;
c) salt: Hongshashu, Baipi, Liushiri, Shaanshu 1 and Lushu 1;
d) excess moisture: Niaoyaoli, Baigu Qilong and Yubeibai;
e) good storability: Zhoushu 13, Tainung 27, Lizixiang and Xindazi.

Germplasm Use.

1) Local varieties.

Four hundred years of cultivation has produced a diversity of sweetpotatoes through natural and artifical selection. These landraces are adapted to the local environment and are grown for their disease resistance and good quality. They

have also contributed to many successful breeding programs. Landraces like Yubeibai and Pengwei from Guangdong, Hengjin from Taiwan Xiaowuchi from Fujian conferred high-yield and drought tolerance genes to improve varieties Fengshu 1, Fengshoubai, Ningshu 1 and Yanchihong. Mancunxiang of Guangxi, Hongpi and Hongxin of Zhejiang, Xiaobaiteng from Jiangsu and Xijiaozhong from Beijing have helped improve dry matter(DM) content in Shijiazhuang 419, DM and germinability in Honghong 1, DM and eating quality in Yan 78-384 and sweetness in Huabei 166 (Sheng et al., 1987). Xushu 18, accounting for over 50% of sweetpotato production area nationally have the genetic background of Anhui local variety, Jiagou Dazi. Likewise, Lushu 5 and Mianfen 1 bred in Shandong and Sichuan has genes from Pengwei (a Guangdong local variety) and Suxian Xiaohuaye (an Anhui local), respectively (Wu et al., 1993).

Some other local varieties with superior characters are:

a) Guangdong's Baigu Qilong and Xiaoshengzhong which are resistant to root rot, a disease that never occurs in Guangdong;

b) Zhejiang's Tieding fan which is highly tolerant to drought;

c) Guangdong's Fenghuangfu Zhong which has high dry matter content of 38-40% when grow locally;

d) Hubei's Dabaishao which is highly tolerant to salt (Guo et al., 1993).

2) Introduced germplasm.

This germplasm has contributed to the diversity of China's sweetpotato genetic resources. Okinawa 100 from Japan and Nancy Hall from the US still account for over 14% of the total sweetpotato production area. Okinawa 100 is grown around the country and has been used as a parent for 41 improved varieties while Nancy Hall was used as a parent for 33 varieties. Crosses between the two have resulted in the release of 31 official varieties (Lu, 1990). Newly-released varieties Nanshu 88 and Lushu 3 were selected from progeny of America Red, Yi 306 and Sushu 2 from Minamiyutaka.

High carotene germplasm from the USA and AVRDC like Caromex, Painter, NC 345, Centenial and AIS 0122-2 have produced some good crosses with progenies of good quality. Clones with high anthocyanin have been selected from crosses between Yaamkawa Murasaki from Japan and Rosa from Brazil, which could be a way to diversify the use of sweetpotato in China.

3) Improved varieties and breeding lines.

Many officially released varieties are selected from parents which themselves were the result of genetic improvement. They are agronomically well accepted and usually used as parent material again. National breeding programs have about 30 combinations of this nature. Thirty-one varieties released in the past ten years were from improved parents. Some improved varieties are used as parents because they can easily flower in the north, like Qinshu 2, Xiangyanghung, Gaozi 1 and Hebei 351.

Many superior varieties produced from breeding are maintained as part of the germplasm collection and are later used as parents. Nationally we harvest hundreds of thousands of hybrid seeds and a good number of advanced materials from those seeds have been used in sweetpotato improvement. The high-starch content Mianfen 1 was selected in a cross between two advanced clones 79-14 and 79-96 (Bi et al.,1988). Advanced line 77-98 produced Jishu 2, a variety with high DM and resistance to black rot (Wang,1988).

4) Wild relatives of sweetpotato.

Wild relatives of the sweetpotato are important sources of genes for disease resistance and quality. After release of Minamiyutaka from *I. trifida* in Japan, Chinese scientists have also incorporated K123 (*I. trifida*) in their breeding programs and have used the progeny as parental materials. Clones selected from such crosses like Guangshu 80-117 and Jinshu 83-91 are resistant.to bacterial wilt and tolerant to cold in addition to having good storage ability (Li et al., 1988). B 58-5 as selected in Jiangsu Academy of Agricultrural Sciences (AAS) from (wild relative X sweetpotato) X sweetpotato backcrosses is highly resistant to root rot and has a dry matter content of 32-36%(Zhang et al. 1987).Shandong AAS also selected seven clones using a wild relative as a parent, which was highly resistant to stem nematode (Chang et al.,1993). As a new variety bred by Zhejiang AAS, Zheshu 2 is a descendant of a Uganda morning glory.

5) Mutation.

Bud sporting in sweetpotato usually occurs under natural conditions. Better clones can be selected from such mutation. Xu 77-6 resulted from a sport in Xushu 18 and has a more vigorous growth, higher yield and better quality than the original Xushu 18. From mutations of Minkang 329 which is resistant to bacterial wilt, Minkang 330 was selected, which also has resistance to stem rot and high yield (Zhang and Chen,1990).

Induced mutations are often used for germplasm enhancement. Beijing Agricultural University (BAU) applied electron beams onto sweetpotato true seeds and found in the offspring some individuals with increased DM (Li et al., 1988). They also irradiated with Cobalt 60, the shoot tips of Xushu 18 which is susceptible to black rot and obtained two Xushu 18 lines with resistance to the disease (Lu et al., 1987). Other workers also applied fast neutron on true seeds and were able to select lines with high starch content and resistance to black rot (Cui, 1987). Those materials can be used in production and breeding.

6) Virus free Sweetpotato production.

This work has just started using sweetpotato plants regenerated from meristem tip culture. Field virus surveys indicate that there are two primary viruses in China: Sweetpotato Feathery Mosaic Virus (SPFMV) and Sweet Potato Latent

Virus (SPLV). Sweetpotato virus elimination can produce significantly higher yield and much better looking storage roots (Yang et al., 1991).

Sweetpotato germplasm has been used mostly in genetic improvement of the crop. More extensive research is warranted to ensure full use is made of the conserved germplasm. International exchange has been limited by some factors. Introduction of sweetpotatoes from other countries especially from South America, the primary center of origin will prove necessary for the crop's future in China. An improved quarantine system necessary. Biochemical and physiological evaluation of germplasm should be on the research agenda and the best germplasm should be recommended to either farmers or breeders. Interdisciplinary research will be another step forward for sweetpotato germplasm research. These will make the sweetpotato more versatile for human and industrial use.

References

Bi, C.X. and M.B. Peng. 1988. High starch content sweetpotato variety "Mianfen 1". Chinese Sweetpotato Journal 2: 124–125 (in Chinese)

Chang, C.X., Q.M. Wang and J.J. Wang. 1993. Preliminary study on resistance to root knot nematode in sweetpotato germplasm in Shandong province. Chinese Sweetpotato Journal 5–6:14–16 (in Chinese with English summary)

Chen, Y.D., X.J. Zhang and Z.X. Fang. 1989. The methods of meristem tip culture of sweetpotato. Pages 27–31 *in* A Treatise on Storage of Crop Germplasm Resources. Academic Book & Periodical Press, Beijing, China (in Chinese with English summary)

Cui, G.Q. 1987. Mutation breeding using fast neutron attacking on adventitious bud from hypocotyl. Chinese Sweetpotato Journal 1: 93–95 (in Chinese with English summary)

Dodds, J.H. 1987. Review of *in vitro* propagation and maintenance of sweetpotato germplasm. Pages 185–192 *in* Exploration, Maintenance and Utilization of Sweetpotato Genetic Resources. International Potato Center, Lima, Peru

FAO Basic Foodstuffs Service/Commodities & Trade Division. 1992. The World Sweetpotato Economy. FAO, Rome, Italy 35p

Fernandez, G.C.J., J.H. Lu and Y.K. Huang. 1987. Status of sweetpotato collections maintained at AVRDC. Pages 129–140 *fin* Exploration, Maintenance and Utilization of Sweetpotato Genetic Resources. International Potato Center, Lima, Peru

Guo, X.D., J.Y. Wu and L.X. Zhu. 1993. Evaluation for salt tolerance in sweetpotato germplasm nursery. Journal of Alkaline Land Use 2:36–41 (in Chinese)

Human, Z. 1987. Current status on the maintenance of sweetpotato germplasm. Pages 101–120 *in* Exploration, Maintenance and Utilization of Sweetpotato Genetic Resources. International Potato Center, Lima, Peru

IBPGR. 1987. Meristem–tip culture and virus indexing of sweetpotato. IBPGR, Rome, Italy 46p

Jarret, R.L. 1987. U.S. sweetpotato repository. Pages 121–128 *in* Exploration, Maintenance and utilization of Sweetpotato Genetic Resources. International Potato Center, Lima, Peru

Jarret, R.L. and W.J. Florkowski. 1990. *In vitro* active vs. field genebank maintenance of sweetpotato germplasm: major costs and considerations. Hortscience 25(2):141–146

Kuo,G.C. 1991. Conservation and distribution of sweetpotato germplasm. Pages ??–?? in *In vitro* methods for Conservation of Plant Genetic Resources. J.H.Dodds (ed). Chapman and Hall, London

Li, W.J., Y.Y. Zhang and S.Y. Lu. 1988. Preliminary study on sweetpotato radiated by electron ray. Chinese Sweetpotato Journal 2:16–18 (in Chinese)

Li, X.Z. and Z.S. Wu. 1988. Use of *Ipomea trifida* (K 123) in sweetpotato breeding. Chinese Sweetpotato Journal 2:48–50 (in Chinese)

Liao, C.H., H.S. Tsay and Y.C. Lu. 1982. Studies on eradication of SPV–A and SPV–N virus from infected sweetpotato. J. Agric. Res. China 31 (3):239–245 (in Chinese with English summary)

Lu, G.Q. 1990. Pedigree of some improved Chinese sweetpotato varieties. Chinese Sweetpotato Journal 4:26–29 (in Chinese)

Lu, S.Y., C.G. Wu, W.J. Li and Q.H. Fang. 1987. Radiating sweetpotato with Co 60 produced resistant mutant. Chinese Sweetpotato Journal 1:172 (in Chinese)

Lu, X.H. and Y.C. Chen 1985. Studies for obtainment of sweetpotato mycoplasm like organism free seedlings by shoot tip culture method and its available identification. Acta Agronomica Sinica 11 (3): 191–197 (in Chinese with English summary)

Lu, Z.X., M.S. Wang and J.G. Dong. 1981. The influence of carbon sources on formation and growth of root tuber callus of sweetpotato (*Ipomea batatas* Lam.). Acta Phytophysiologia Sinica 7 (2):105–111 (in Chinese with English summary)

Ng, S.Y. and J.H. Dodds. 1987. *In vitro* methods for pathogen elimination and international distribution of sweetpotato germplasm. in Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, p.323–329, International Potato Center, Lima, Peru

Ouyang, S., R.S. Wang and X.Y. Zhang. 1984. Sweetpotato meristem–tip culture and elimination of dwarf pathogen. J. Fujian Agric. Sci. & Tech. 2:19 (in Chinese)

Sheng, J.L., Y.H. Wang and Q.H. Xue. 1987. Sweetpotato research and production in China. Chinese Sweetpotato Journal 1:1–5 (in Chinese)

Takagi, H. 1987. Sweetpotato collections in Papua New Guinea. Page 129–140 *in* Exploration, Maintenance and Utilization of Sweetpotato. International Potato Center, Lima, Peru

Tang, J., Y.H. Wang, X.D. Guo and J.Y. Wu. 1989. Meristem–tip culture of sweetpotato. Pages 32–36 in A Treatise on Storage of Crop Germplasm Resources. Academic Book & Periodical Press, Beijing, China (in Chinese with English summary)

Wang, S.F. 1988. New sweetpotato variety, Jishu 2. Chinese Sweetpotato Journal 2:50 (in Chinese)

Wang, Y.H., J. Tang, X.D. Guo, J.Y. Sun and J.Y. Wu. 1989. Preliminary study on genetic stability of sweetpotato (*Ipomea batatas* Lam.) maintained *in vitro*. Pages 204–208 in A treatise on Storage of Crop Germplasm Resources. Academic Book and Periodical Press, Beijing, China (in Chinese with English summary)

Wu, J.Y., X.D. Guo and Y.H. Wang. 1988. Sweetpotato collection and production survey in Yunnan Province. Chinese Sweetpotato Journal 2:1–4 (in Chinese)

Wu, J.Y. and Y.H. Wang. 1988. Sweetpotato collection and production survey in Heilongjiang Province. Chinese Sweetpotato Journal 2:5–7 (in Chinese)

Wu, J.Y. and X.D. Guo. 1990. Some superior local sweet potato cultivars. Chinese Sweetpotato Journal 4:156–157 (in Chinese)

Wu, J.Y., G.Q. Lu, J.L. Sheng and B.F. Song. 1993. Progress on sweetpotato germplasm research in China. Chinese Sweetpotato Journal 5–6:3–7 (in Chinese with English summary)

Xin, S.Y. 1985. Maintaining sweetpotato germplasms by tissue culture. Crop Genetic Resources 3:24–26 (in Chinese)

Xin, S.Y. 1987. Sweetpotato meristem–tip culture and *in vitro* storage. Crop Genetic Resources.3:24–26 (in Chinese)

Xin, S.Y. 1989a. Technology and conditions for germplasm preservation of sweetpotato (*Ipomea batatas* Lam.). Pages 2–9 *in* A Treatise on Storage of Crop Germplasm Resources. Academic Book & Periodical Press, Beijing, China (in Chinese with English summary)

Xin, S.Y. 1989c. Effects of chemicals on the preservation of sweetpotato germplasm. Pages 10–15 *in* A Treatise on Storage of Crop Germplasm resources. Academic Book and Periodical Press, Beijing, China (in Chinese with English summary)

Xin, S.Y. 1989b. Meristem culture of sweetpotato. Pages 27–31 *in* A Treatise on Storage of Crop Germplasm Resources. Academic Book & Periodical Press, Beijing, China (in Chinese with English summary)

Yakuwa, H. and S. Oka. 1987. Maintenance of clonally propagated crop germplasms by *in vitro* methods. Agriculture and Horticulture 62(12):1343–1347. (in Japanese)

Yang, Y.J., J.Y. Xing and C.L. Zhang 1990. Survey on sweetpotato virus diseases. J. Jiangsu Agric. Sci. 2:33–34 (in Chinese)

Yang, Y.J., J.Y. Xing, J.Y. Wu, J. Tang and X.D. Guo. 1991. Yield increase of virus–free sweetpotatoes. J. Jiangsu Agric. Sci. 4:38–39 (in Chinese)

Zhang, L.S. and Q.H. Chen. 1990. New sweetpotato resistant to bacterial wilt, Minkang 330. Chinese Sweetpotato Journal 4:147–148 (in Chinese)

Zhang, L.Y., P.L. Xu and R.L. Qui 1987. Collection and utilization of wild relatives of sweetpotato. Chinese Sweetpotato Journal 1:26–29 (in Chinese)

Zhou, M.D. 1989. The effects of methyl succinic acid on growth and preservation of plantlet of sweetpotato *in vitro*. Pages 17–20 *in* A Treatise on Storage of Crop Germplasm Resources. Academic Book & Periodical Press, Beijing, China (in Chinese with English summary)

The Use of Sweetpotato Genetic Resources in Breeding in Japan

OSAMU YAMAKAWA[1]

Abstract

The use of genetic resources in sweetpotato breeding started with domestic accessions, and then involved introduced cultivars and wild relatives. Initially these materials were crossed directly to each other. In the next stage of breeding parental lines with high inbreeding coefficients were produced by selfing, full-sib or half-sib crossing. These lines with different origins and high combining ability were crossed one by one to find high heterosis. Wild relatives were back-crossed to elite cultivars several times to get storage root formation before attempting a breeding program. Recently the polycross method has been adopted using this method many accessions are crossed simultaneously. To use this system widely, it is necessary for cultivars to flower or to develop grafted stocks which results in flowering.

1. History of Sweetpotato Breeding in Japan

It is said that sweetpotato was introduced to Japan about 400 years ago. The maximum acreage of sweetpotato (*Ipomoea batatas* LAM.) was 450,000 ha in 1950, but it began to decrease in 1965 and the acreage in 1993 was only 55,100 ha. Farmers selection started at the same time as farmers first grew the crop, but there are no records of sweetpotato selection before the end of 19th century.

Sakai (1989) classified sweetpotato breeding in Japan since 1890 into five periods:

The first period from 1890 to 1912 involved the breeding of the promising cultivars by farmers, who collected domestic or foreign cultivars or spontaneous mutants and selected the best cultivars from these materials. During this period "Beniaka", "Genji" and "Sichifuku" were released.

The second period from 1913 to 1936 was the start of systematic breeding, which was supported by the government. During this period various domestic cultivars were crossed and "Okinawa No.100", an important cultivar, was released.

The third phase of sweetpotato breeding, from 1937 to 1956, involved the establishment and development of a breeding system or network, in which the relationship between each experimental stations was clarified. During this period 20 registered cultivars were released, among which "Gokokuimo", "Norin No.1",

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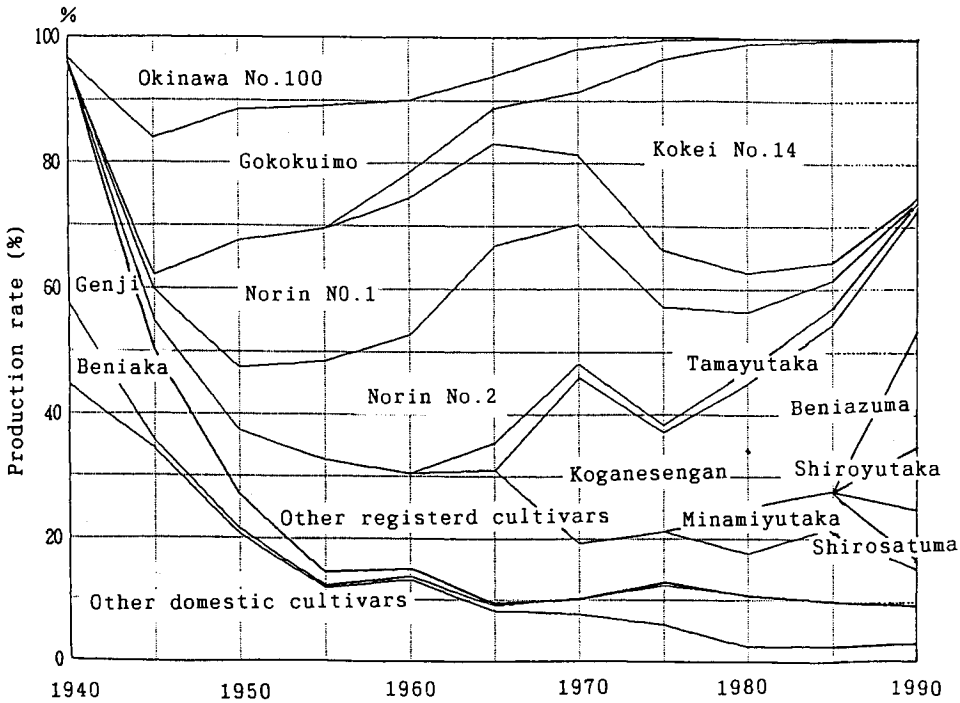

Figure 1. Production rate of acreage per each sweetpotato cultivars

"Norin No.2" and "Kokei No.14" are the most famous ones. The most important registered cultivars ("Okinawa No.100", "Gokokuimo", "Norin No.1" and "Norin No.2") occupied 70% of the cultivated acreage by the end of this period (Fig.1).

During the fourth period from 1957 to 1974, most attention was paid to the improvement of breeding methods and using the foreign genetic resources. "Tamayutaka", "Ariakeimo" and "Satsumaaka" were released in the beginning of this period as a result of breeding in the former period. However breeding efficiency decreased gradually due to the narrow genetic background leading to inbreeding depression. There were only five ancestors of the leading cultivars grown at that time. These were "Shichifuku", "Choshu", "Genki", and "Yoshida", "Benikawa" (Sakai, 1965). Therefore many introduced cultivars and wild relatives were introduced into crossing programs to broaden the genetic base. "Koganesengan" and "Minamiyutaka" were released as the results of using introduced germplasm (Fig.2).

The fifth period from 1975 to the present the sweetpotato breeding focussed on breeding cultivars for new foods and sweetpotatoes which require little labor inputs. "Benihayato" (Sakamoto et al., 1987) with high carotenoid content and

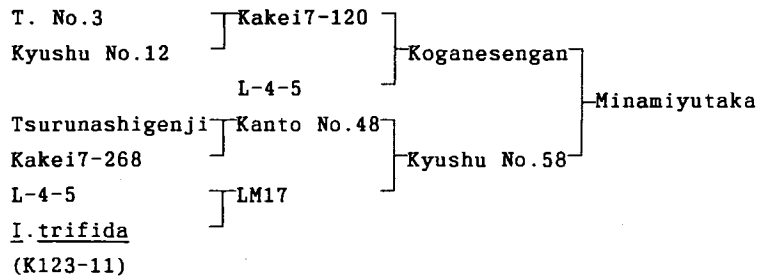

Figure 2. The pedigree of "Minamiyutaka" derived from a wild species (*Ipomea trifida*, 6x)

Table 1. Caroteniod and polyphenol content of "Benihayato" (1984)

NO.Cultivars	Dry matter content(%)	Caroteniod content(mg%)	Polyphenol content(mg%)
1 Benihayato	27.3	12.9	76.5
2 Kokei No.14	32.1	0.3	42.2
3 Koganesengan	34.4	0.3	39.5
4 Hayatoimo	28.3	3.0	94.0
Carrot(cont.)	-	12.3	-

Table 2. Beta-amilase activity and maltose content of "Satsumahikari" before and after cooking (1983-85)

Cultivars	Dry matter content(%)	Beta-amilase activity(I.U./ml)	Maltose content(%) Before	After
Satsumahikari	31.0	0.11	0.6	0.6
Kokei No.14	32.1	950.0	1.3	11.5
Koganesengan	34.4	1090.0	0.8	11.1
Benikomachi	35.0	1100.0	2.0	10.9
Beniazuma	37.5	1220.0	0.7	12.8

"Satsumahikari" (Kukimura et al., 1989) with low maltose have been released (Tables 1 and 2). "Naeshirazu" (Shikata, 1976) was released for direct planting as occurs with potato. "Beniazuma" and "High Starch" (Tarumoto et al., 1989) were released for table use and starch industry, respectively. There is recent interest in developing low starch cultivars with high color pigment, which could be used as a substitute for as potato and carrot. For this introduced genetic resources will be very useful, because they generally have low starch and low sugar content.

2. Inbreeding Method for Using Genetic Resources

Since Sakai (1964) showed that starch content is mainly governed by polygenes with additive effects and root yield by genes with non-additive effects, the most common breeding method in 1970,s used inbred lines with high starch and test combining ability. Domestic and introduced cultivars were inbred by selfing or sib-crossing. According to Yunoue (1967) and Yoshida (1986), both seed setting rate and plant vigor decreased rapidly when the inbreeding coefficient became close to 0.2. From my own experience, inbreeding depression made it difficult to maintain inbred lines and hybrid seed set between inbred was sometimes impossible.

The most successful cultivar bred by this inbreeding procedure is "Shiroyutaka" (Sakamoto, 1987) for the starch industry. Its maternal parent has "Kanto No.33" three times in its ancestory before its grandparents generation. "Beniazuma" and "Fusabeni" released for table use have grandparent as an inbred line. "High Starch" with the highest starch content, one of the great grandparents is an inbred line.

Yamakawa et al. (1977) crossed inbred lines from a sib-crossed series derived from different origins (domestic, introduced and wild) with several testers which has no relationship with crossed partners, and compared the progeny means for dry matter content and root yield among crosses. The results showed that improvement of dry matter content by inbreeding was not clear and the decrease of root yield by inbreeding depression could not always be recovered by heterosis. The inbreeding method have some success but is not used now.

3. Backcrossing Method for Using Wild Relatives

The use of wild relatives of sweetpotato in sweetpotato breeding started one year after Nishiyama introduced one accession (*Ipomoea trifida* DON.) from Mexico to Japan in 1956 (Nishiyama, 1963). Sweet potatoes are usually used as recurrent parents in backcrossing with wild relatives. Undesirable traits of wild relatives were eliminated by repeated backcrossing and useful traits accumulated by selection. In the first backcross the progenies still showed the wild traits such as slender twining stem. But in the second backcross their morphological traits were almost similar to those of sweetpotato (Sakamoto 1970).

Yamakawa and Sakamoto (1978) studied the number of backcrosses and practical traits like root yield and dry matter content using several F1, B1 and B2 lines derived from two triploid and hexaploid accessions of *I. trifida*, K223 (3x) and K123 (6x). The F1 hybrid lines had the highest root yield, but the lowest dry matter content. Progeny tests showed that the combining ability of root yield and dry matter content improved from F1 to B2 generation (Fig.3). From these results, it is recommended that more than two backcrosses should be undertaken along with the selection for root yield and dry matter content.

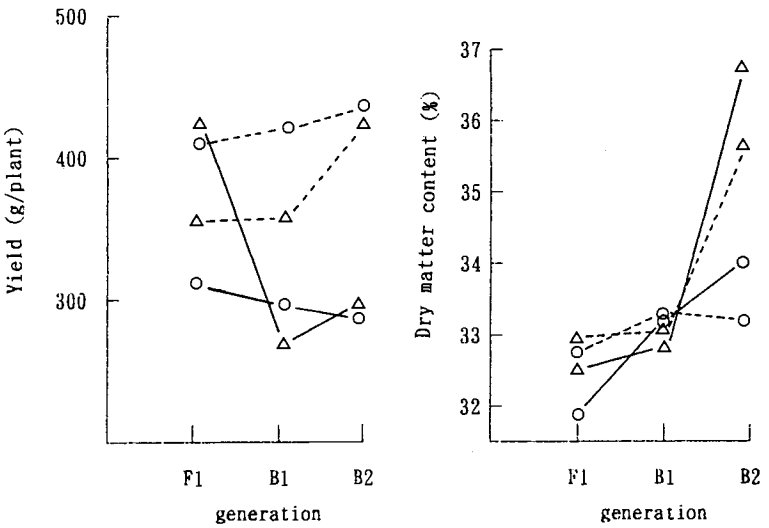

Figure 3. Relationship between the times of backcrossing and the practical traits when sweetpotato was backcross to *I. trifida* (6x and 3x).

I. trifida (6x) series: *I. trifida* (3x) series
shows parental lines: shows progeny means

As a result of backcrossing during the last 20 years, excellent parental lines "LM17" (F1 hybrid between K123 and "L-4-5") and "Kyushu No.58" (B1 generation of "LM17") were developed. "Minamiyutaka", which belongs to B2 generation of "Kyushu No.58", was released for the starch industry. This variety has a 1/8 kinship relationship with *I. trifida* (6x) in its pedigree. "Minamiyutaka" was grown 5,500 ha in 1978. At present "Shiroyutaka" and "Shirosatsuma" have replaced this cultivar, but "Minamiyutaka" is still a very valuable cultivar with strong resistance to nematodes which is thought to have been inherited from *I. trifida*. Most cultivars except "Siroyutaka" have "LM17" or an other F1 hybrid with *I. trifida* (6x) as an ancestor. Wild species introduced by Nishiyama have been playing an important role in sweetpotato breeding in Japan. However, to date only *I. trifida* (6x) has lead to useful results.

4. New breeding methods for Using Genetic Resources

Simple single crosses between unrelated or weakly related parents so that the the weaknesses and strengths of each parent are complemented is frequently used. Yosida (1986) calculated inbreeding coefficients of all single crosses contained in the combining ability tests from 1961 to 1984 and showed that single crosses with smaller inbreeding coefficient than 0.1 would have higher yielding than those with larger inbreeding coefficient than 0.2. About 90% of all breeding lines

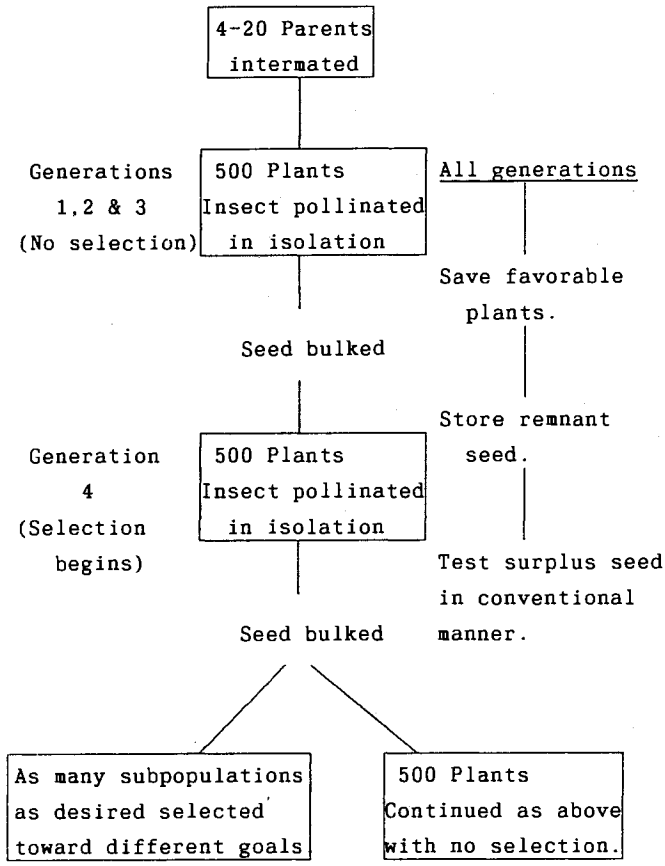

Figure 4. Breeding procedure for sweetpotatoes proposed by Jones (1965).
Four generations without selection are necessary to establish a randomly interbreeding base population. In following generations, the base population may be altered toward horticultural goals by selection.

with "Kyushu No." have an inbreeding coefficient of less than 0.1 (Yoshida 1985).

Recurrent selection in sweetpotato breeding was first proposed by Jones (1965) (Fig. 4). In this procedure, selection should be avoided in the early generations in order to increase the frequency of effective gene recombination. Shikata (1980) tried mass selection for skin color and root yield after four generations of random mating. After three cycles of mass selection the skin color converged to the desired objective and root yield tended to increase.

Yamakawa and Sakamoto (1980) proposed another procedure by using the polycross method with naturally flowering lines (Fig.5). The individual selection within half-sib families selected using the combining ability test took the place of

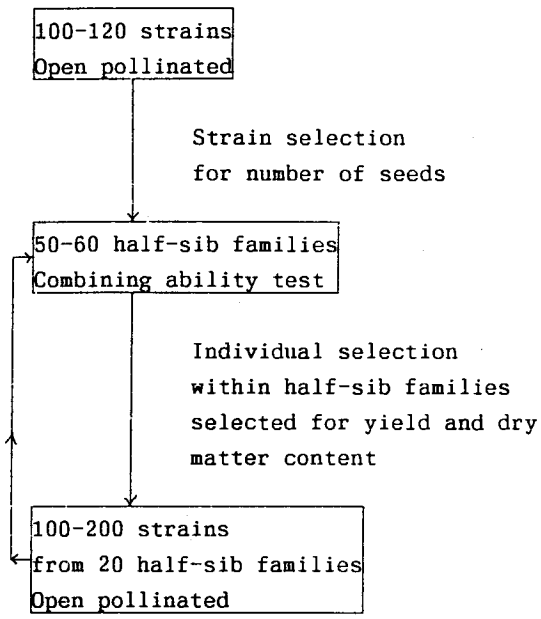

Figure 5. Breeding program in sweetpotato for breeding synthetic cultivars adapted to true seed planting (Yamakawa and Sakamoto, 1980)

simpler mass selection. After two cycles of selection the root yield under true seed planting culture increased by some 15% per cycle (Yamakawa and Sakamoto 1987)

Shiga (1984) proposed reciprocal recurrent selection using polycross and parental line selection without using progeny test (Fig.6). Katayama et al. (1991) crossed two groups of the parental lines selected after three cycles of polycrossing within each group (domestic and introduced), and concluded that progenies from single crosses have smaller coefficients of variation for root yield and dry matter content than those from polycrossing, but they have higher means for both traits than those from polycrossing.

Recurrent selection is simpler and more efficient method of using sweetpotato germplasm. However it is not popular in sweetpotato breeding in Japan, because there are no promising naturally flowering lines which is necessary for random mating or polycrossing. In place of using natural flowering lines, it is possible to graft sweetpotato to morning glory (*Pharbitis nil*) to induce flowering. But there are many difficulties in growing this morning glory in uncontrolled conditions. There are about 1,400 germplasm accessions in the Kyushu National Agricultural Experiment Station and a part of them have naturally flowering traits. We are trying to introduce this naturally flowering trait into superior cultivars and to develop good stocks of naturally flowering sweetpotato.

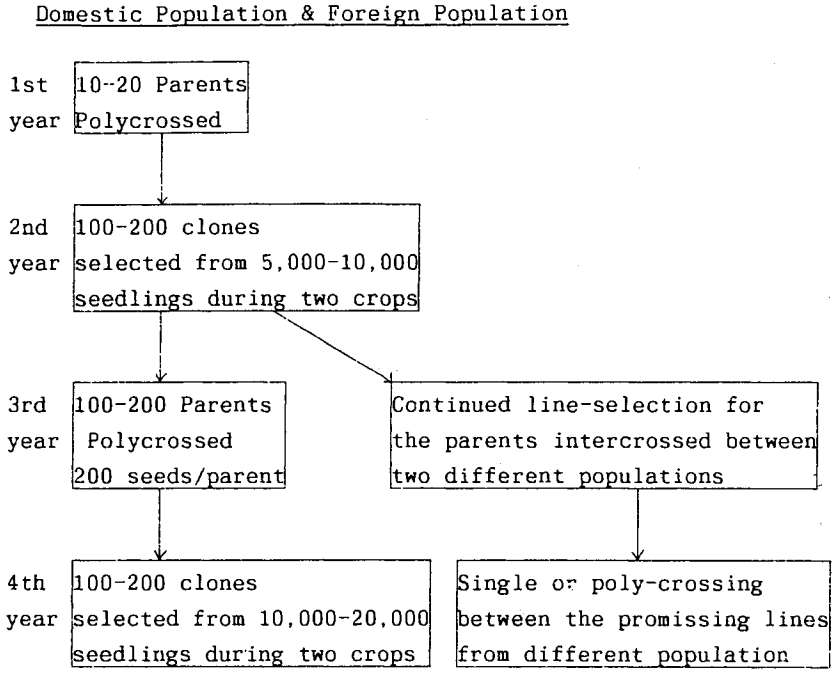

Figure 6. Breeding procedure for sweetpotatoes proposed by Shiga(1984).
In the selection year (2nd and 4th year) there are two selections a year, because two crops per year become possible owing to plastic multing culture.

References

Jones, A. 1965. A proposed breeding procedure for sweetpotato. Crop Sci. 5: 191–192

Katayama, K., Tamiya, S., Tarumoto, I. & Kato, S. 1991. Segregation of yield components in sweetpotato seedlings of single cross and polycross among lines derived from maternal line selection. Japan J. Breed. 41 (Abs.2): 2–3 (in Japanese)

Kukimura, H., Yoshida, T., Komaki, K., Sakamoto, S., Tabuchi, S., Ide, Y. & Osamu, Y. 1989. "Satsumahikari": A new sweetpotato cultivar. Bull. Kyushu Natl. Agr. Exp. Stn. 25 (3): 225–250 (in Japanese)

Nishiyama, I. 1963. The origin of the sweetpotato plant. Pages 111–128 in J. Barrau (ed.) Symposium, plants and the immigrations of pacific people.

Ono, T., Marumine, S., Yamakawa, O., Hirosaki, S., Sakamoto, S. & Ide, Y. 1977. "A new sweetpotato variety "Minamiyutaka". Bull. Kyushu Agr. Exp. Stn. 19 (2): 133–150 (in Japanese)

Sakai, K. 1964. Studies on the enlargement of variations and the improvement of selection methods in sweetpotato breeding. Bull Kyushu Agr. Exp. Stn. 9 (3): 247–397 (in Japanese)

Sakai, K. 1965. Present and future of breeding the sweetpotato cultivars with high yielding and high starch content. Agr. Tech. 20: 124–128

Sakai, K., Marumine, S., Horosaki, S., Kikukawa, S., Ide, Y. & Shirasaka, S. 1967. On the new

variety of sweetpotato "Koganesengan". Bull. Kyushu Agr. Exp. Stn. 13 (1,2): 55–68 (in Japanese)

Sakai, K. 1989. Sweetpotato breeding: Its history and direction. Agr. Res. 2: 29–42 (in Japanese)

Sakamoto, S. 1970. Utilization of related species on breeding of sweetpotato in Japan. JARQ 5: 1–4

Sakamoto, S., Marumine, S., Ide, Y., Yamakawa, O., Kukimura, H., Yoshida, T. & Tabuchi, S. 1987. "Benihayato": A new sweetpotato cultivar registered. Kyushu Agr. Exp. Stn. 24 (3): 255–277 (in Japanese)

Sakamoto, S., Marumine, S., Ide, Y., Yamakawa, O., Kukimura, H., Yoshida, T. & Tabuchi, S. 1987. "Shiroyutaka": A new sweetpotato cultivar registered. Bull. Kyushu Natl. Agr. Exp. Stn. 24 (3): 279–305 (in Japanese)

Shiga, T. 1984. New method of sweetpotato breeding using polycross and parental line selection. Ann. Report of Natl. Agr. Res. Cent. 1: 84–89 (in Japanese)

Shikata, S. 1976. Breeding of sweetpotato adapted to direct planting and method of direct planting culture. JARQ. 10: 174–177

Shikata, S. 1980. Utilization of random mating populations in sweetpotato breeding. Bull. Chugoku Natl. Agr. Exp. Stn. (A) 28:1–48

Tarumoto, I., Shiga., Sakamoto, S., Ishikawa, H., Kato, S., Takemata, T. & Umemura, M. 1989. New sweetpotato cultivar "Hi–starch". Bull. Natl. Agr. Res. Cent. 15: 15–29 (in Japanese)

Yamakawa, O. & Ono, T. 1977. The effect of inbreeding on the parental ability in sweetpotato breeding. Japan J. Breed. 27 (Abs.2): 236–237 (in Japanese)

Yamakawa, O. and Sakamoto, S. 1978. Studies on use of interspecific hybrid between *Ipomoea batatas* and *I. trifida*. Japan J. Breed. 27 (Abs.2): 6–7 (in Japanese)

Yamakawa, O. & Sakamoto, S. 1980. Studies on breeding sweetpotato varieties to true seed planting. I. Flowering habit, seed–setting and adaptability of natural flowering population to true seed planting. Japan J. Breed. 30: 151–160 (in Japanese)

Yamakawa, O. & Sakamoto, S.1987. Response to selection of natural flowering population for adaptability to true seed planting in sweetpotato. Japan J. Breed. 37: 66–74 (in Japanese)

Yoshida, T. 1985. Inbreeding coefficients of breeding lines in sweetpotato. Japan J. Breed. 35: 464–468 (in Japanese)

Yoshida, T. 1986. Inbreeding coefficients and yield in sweetpotato. Japan J. Breed. 36: 409–415 (in Japanese)

Yunoue, T. 1967. The fifteen year's history of agricultural research in Kyushu. Kyushu Agr. Exp. Stn. Japan. 153–156 (in Japanese)

Sweetpotato Cultivars Bred for High Yield and High Starch Content in Japan

SHINJIRO KATO[1]

Introduction

Breeding sweetpotatoes for high yield and high starch content has been conducted at National Agriculture Research Center in Japan. This program started in 1967 by selecting germplasm for use as parental lines. The parental lines are characterized by high starch content and multiple disease resistance, and these characteristics have an additive gene effect. After selection of parental lines, general and specific combining ability are examined. Three cultivars have been successfully developed during the last decade.

The cultivar 'Shirosatsuma'

'Shirosatsuma' was registered as Norin 39 in 1986. It was selected at the National Agriculture Research Center (NARC) from a cross made in 1977 between CS69136–2 and Tamayutaka. The female parent, CS69136–2 selected as a parental line at NARC, is characterized by the high starch content and multiple disease resistance. The male parent, Tamayutaka was bred as a new variety for industrial use at NARC in 1960, is characterized by high yield, good storability and medium starch content.

The main characteristics of 'Shirosatsuma' are as follows:

1) The color of the uppermost expanded leaf is light brown, other leaves are dark green and the leaves heart shapeed with many small lobes at the leaf edge. The stem and internodes are green. The skin color of the tuberous root is light yellowish white, flesh color is white and the root shape is short, fusiform and large.
2) The sprouting ability is excellent. Compared with the leading variety 'Koganesengan' the tuberous root enlarge later. The roots store well.
3) The starch content was equivalent to 'Koganesengan'. Tuberous roots yield was 17% higher, and crude starch yield was 18% higher than 'Koganesengan' in Oosumi branch of Kagoshima Agricultural Experiment Station.

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4) 'Shirosatsuma' is resistant to root knot nematode and black rot, and moderately resistant to soil rot and root lesion nematode. However it is susceptible to stem rot.

The cultivar 'Hi-starch'

'Hi-starch' was registered as Norin 41 in 1988. 'Hi-starch' was selected at NARC from a cross made in 1978 between CS7279-19G and CS69136-33. Both parents, selected as parental lines at NARC, are characterized by high starch content.

The main characteristics of 'Hi-starch' are as follows:

1) The color of the uppermost expanded leaf is light green and other leaves are green and have a shallow single incision. The stem and internodes are green. The tuberous root is long and has pinky-light brown skin color. The flesh color of the root is light yellowish white.
2) The sprouting ability is moderately low. Compared with 'Koganesengan' tubers enlarge a bit earlier. The roots have poor storage ability as those of 'Koganesengan'.
3) The starch content is extremely high, approximately 30%, whereas 'Koganesengan' has about 25%. The starch yield was 12% higher in performance trials compared with 'Koganesengan' in Oosumi branch of Kagoshima Agricultural Experiment Station.
4) Whiteness and stickiness of starch and frequency distribution of starch grains appeared to be improved, and the components of starch quality were less influenced by culture conditions compared with 'Koganesengan'.
5) 'Hi-starch' is resistant to root knot nematode, and moderately resistant to stem rot and soil rot. It is susceptible to black rot and root lesion nematode.

The new cultivar 'Kanto 106'

'Kanto 106' will be registered as Norin No. in 1994. It was selected at NARC from a cross made 1986 between Koganesengan and Hi-starch. The female parent, Koganesengan bred at Kyushu Agricultural Experiment Station, is characterized by the high yield and high starch content. The male parent, Hi-starch bred as a variety for starch production at NARC in 1988, is a cultivar characterized by the very high starch content.

The main characteristics of 'Kanto 106' are as follows:

1) The color of the uppermost expanded leaf is green and other leaves are green and have a shallow single incision. The color of the stem and internodes is green. The flesh color of the root is yellowish white. The tuberous root is long spindle and has yellowish white skin color.

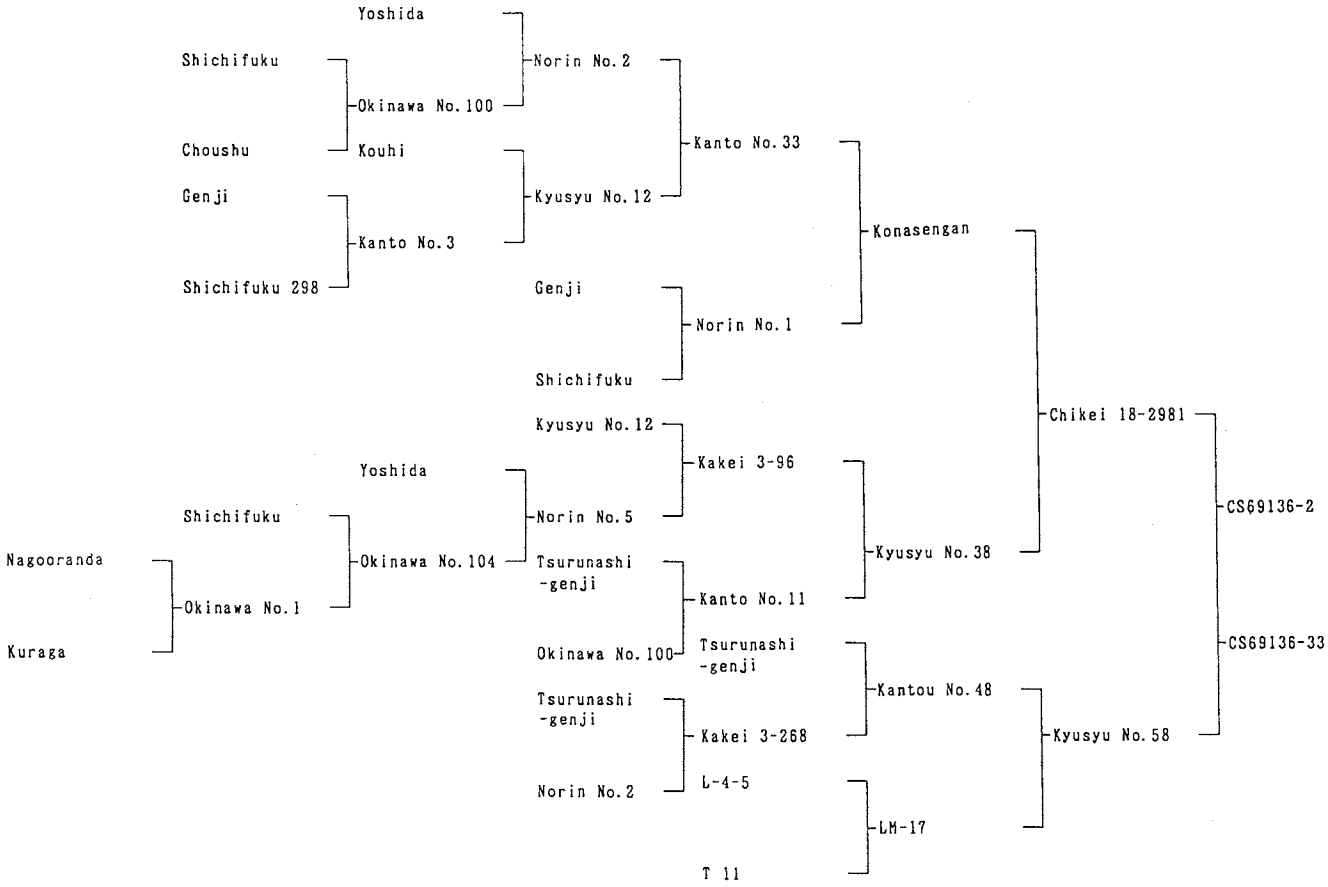

Fig.1 The pedigree chart of the parental lines of CS69136-2 and CS69136-33.

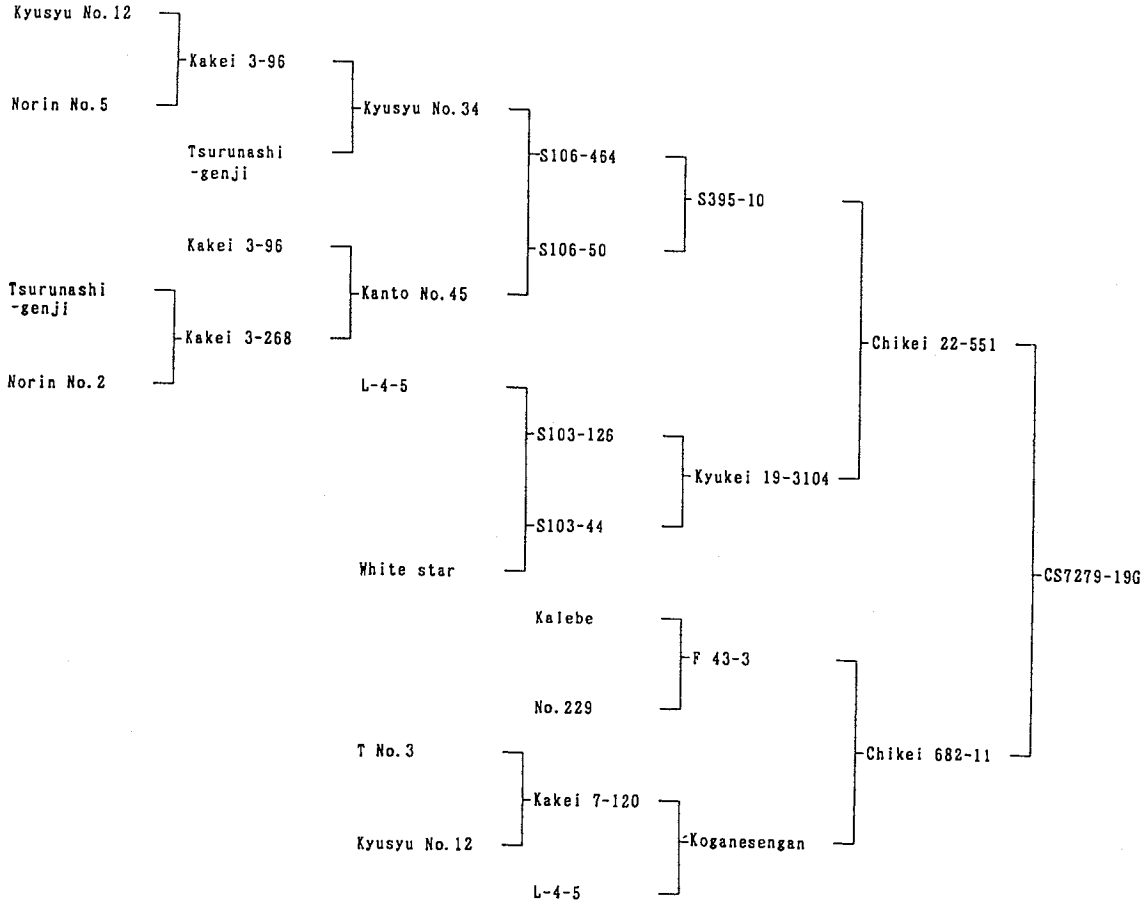

Fig.2 The pedigree chart of the parental lines of CS7279-19G.

2) The sprouting ability is intermediately. Tuberous habit is of the moderately earlier enlarging type compared with that of 'Koganesengan'. The roots show low storage ability as those of 'Koganesengan'.
3) The starch content of 'Kanto 106' was higher than 'Koganesengan', and as high as 'Hi-starch'. The crude starch yield was 23% higher than 'Koganesengan' in performance trials at Oosumi branch of Kagoshima Agricultural Experiment Station.
4) 'Kanto 106' is moderately resistant to stem rot 5 starch content of tuberous root in grafts.

When Hi-starch was used as a grafting stock, regardless of scion, the starch content was higher than those of other grafts. When Koganesengan was used as stocks, the starch content was second highest. In the case of Okinawa 100 stocks, the value was lower than those of other grafts, regardless of scion type. Consequently it is believed that the high starch content of Hi-starch was controlled by stock characteristics. Similarly dry root weight of Hi-starch stock grafts were higher than other stock grafts, regardless of scion type. From the graft experiment, root yield and starch content are believed to be affected by sink more than source.

Table 1 Starch content (%) in grafted sweetpotato.

Stocks	Scions							
	Hi-starch	Koganesengan	Tsurusengan	Norin No.1	Tamayutaka	Okinawa No.100	mean	s.d.
Hi-starch	24.6	21.5	24.8	23.4	22.1	23.0	23.2	1.3
Koganesengan	18.9	18.6	20.0	17.7	20.7	18.5	19.1	1.1
Tsurusengan	16.6	15.6	19.6	15.6	15.1	19.0	16.9	1.9
Norin No.1	17.4	15.8	16.4	15.3	16.3	15.3	16.1	0.8
Tamayutaka	15.7	16.8	16.8	15.8	16.0	14.2	15.9	1.0
Okinawa No.100	13.2	12.9	13.8	12.5	13.7	13.3	13.2	0.5
Mean	17.8	16.9	18.6	16.7	17.3	17.2	17.4	
s.d.	3.8	2.9	3.8	3.7	3.3	3.6		

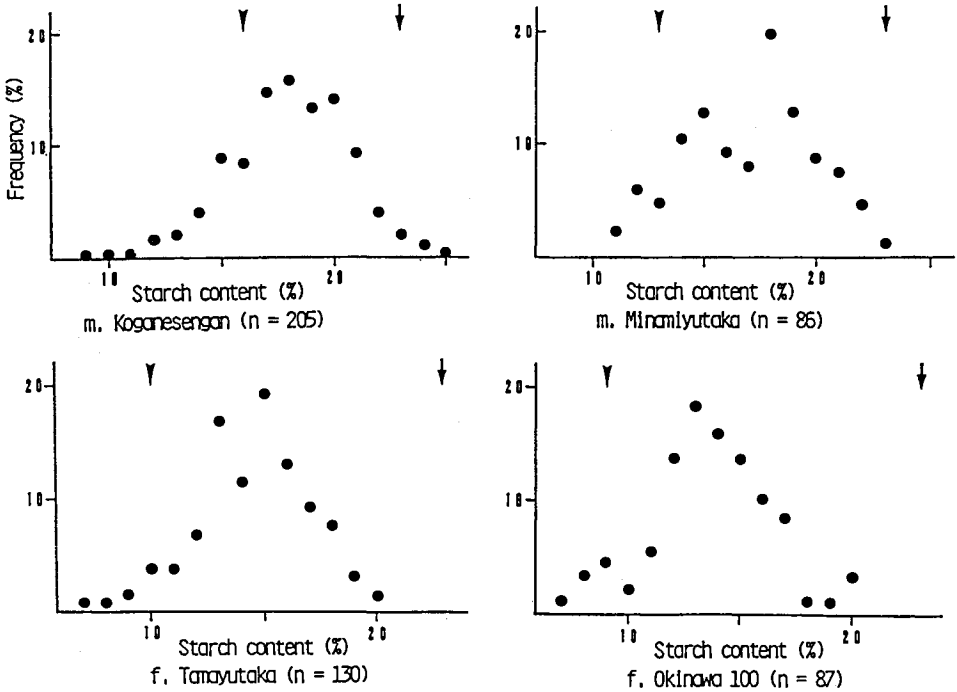

Fig. 3 Frequency distributions for starch content in each of F_1 population.
note) ↓ : Starch content of Hi-starch, ▼ : Starch content of the other parent.

m.=male f.=female

Inheritance mode of starch contents

In order to improve the starch content (SC) efficiently, it is important to know its mode of inheritance, particularly when using varieties recently improved for high SC and yield. Crosses were made between Hi-starch (the common parent) and other cultivars. In the cross between Hi-starch (very high SC) and Koganesengan (high SC), overdominance was observed in the both directions and the SC values exceeded that of the parents, and SC showed a normal distribution. In crosses between Hi-starch and Minamiyutaka (high SC) overdominance was observed in one direction. SC values of the lower SC parent of Minamiyutaka was exceeded, and the distribution was also normal. In the crosses between Hi-starch and Tamayutaka (low SC) and between Hi-starch and Okinawa 100 (very low SC), overdominance was observed in one direction with the SC values of the progeny exceeding only the lower SC parents, Tamayutaka and Okinawa 100, and the distribution was normal. However, the segregated individuals having the highest SC value in the F_1 generation did not reach the SC values of the higher cross parent,Hi-starch. From the above results of frequency distribution and the direction of overdominance, it is considered that the inheritance of starch content in the

above combinations of sweetpotato cultivars is controlled mainly by additive polygenic effects and partly by the dominant effects inducing the lower values of the starch contents. Under the above inheritance mode of the starch content mentioned, it is suggested that both of parents should have high starch content in order to breed varieties with high starch content.

References

Sakamoto, S., T. Shiga, H. Ishikawa, S. Kato, T. Takemata, M. Umehara and T.Ando, 1989. New sweet potato cultivar "Shirosatsuma", Bull. Natl. Agric. Res. Cent., 15:1–13 (in Japanese)

Tarumoto, I., T. Shiga, T. Sakamoto, H. Ishikawa, S. Kato, T. Takemata, M. Umemura, 1989. New sweet potato cultivar "Hi-starch", Bull. Natl. Agric. Res. Cent., 15:15–29 (in Japanese)

Tarumoto, I., H. Ishikawa, S. Kato, 1990. Inheritance mode of starch contents in *Ipomoea batatas*. Newsl. Natl. Agric. Res. Cent. 7:7–11

Questions and Answers in Session 3

H.Takagi(Q): Dr. Bacusmo, you mentioned sweetpotato tends to have profuse flowering in the Philippines. When you keep your germplasm collections in the field at the same place over several years, do you have any problems with voluntary seedlings?

J.L.Bacusmo(A): We periodically clean and replant parts of the 1 meter square plot. In this way we eliminate "volunteers".

M.Djazuli(Q): Do you have any advice regarding keeping vines alive during exploration? Sometimes during a collecting trip it is necessary to keep material alive for a month or more.

J.L.Bacusmo(A): In the tropics when you put a large number of cuttings in a bundle rotting can occur in the middle of the bundle and if not bundled they tend to dry up. In our experience wrapping the bottom portion of the cuttings with moistened newspaper will allow us to keep the cuttings from dehydration and rotting for 2 weeks.

I.Tarumoto)Q): In your presentation, Dr. Bacusmo, you mentioned that yield was the primary objective. Do you have any special reason for this?

J.L. Bacusmo(A): In the Philippines consumers and farmers have a range of requirements. Some consumers eat sweetpotato as a snack food while others eat sweetpotato because they have no other choice. Some farmers grow sweetpotato for the market while some grow it as a security crop. Due to this diversity of needs we choose to focus firstly on breeding for improved yield since this is the major criteria farmers use for chooseing a variety. This does not mean that quality improvement is not also important it must also accompany yield improvement.

I.Shiotani(Q): Dr. Bacusmo you used the wild species *Ipomea pescaprae*. Does this species have traits beneficial to sweetpotato, for example weevil resistance?

J.L.Bacusmo(A): We would like to think there are beneficial genes in *I. pescaprae* such as weevil resistance. In one meeting however Dr. Talekar of AVRDC showed a picture of sweetpotato weevil infesting stems of *Ipomea*

pescaprae. *I. pescaprae*, however, may have genes for tolerance to salinity as it naturally grows on the coast line in the Philippines.

S.C.Halus(Q): Given the large number of accessions of sweetpotato available in various collections and the trend towards breeding for specific biochemical traits, is there any effort to develop more rapid and reliable methods such as *in vitro* or combined *in vitro*/biochemical tests?

K.Komaki(A): We have no specific techniques to evaluate specific biochemical traits *in vitro*. However, we have just started to evaluate the resistance of sweetpotato to *Fusarium* wilt *in vitro*. Hopefully we will get some good results from this experiment.

M.Oka(Q): Is there any possibility to use the tetraploid breeding material for your sweetpotato breeding?

K.Komaki(A): The yield of the tetraploid sweetpotato is high, but the starch content is lower than hexaploid sweetpotato cultivars. In addition, it seems that tetraploid sweetpotato is susceptible to virus diseases. Thus, the possibility for breeding with these materials is not high.

M.Mori(Q): In potato, some high pigmented lines have poor or somewhat bitter taste depending on the line. Is the taste of sweetpotato also affected by high concentration of anthocyanin. Does anthocyanin affect discoloration after cooking.

K.Komaki(A): Lines containing much anthocyanin usually taste bitter in sweetpotato too. Anthocyanin is an end product of polyphenol synthesis and polyphenol sometimes acts as a substance inducing bitterness. I think that polyphenol might affect the taste in high anthocyanin cultivars. Blackening after cooking is not related to the taste.

H.Tauagi(Q): Non-sweet sweetpotato varieties could attract the interest of breeders in the tropics. I've heard that low B-amylase is a recessive character. Since sweetpotato is hexaploid. I think enormous effort should be made to select for this trait. Could you tell us how you could incorporate selection for this trait in your breeding program?

O.Yamakawa(A): In the cross between non-sweet and sweet types of sweetpotato, there is the chance of getting a small percentage of nonsweet lines. The

number is not so small as to discourage breeders from developing non-sweet cultivars.

K.Okuno(Q): You mentioned B-amylase free cultivars developed in your program. Is there any relationship between B-amylase activity and longevity of the roots in storage?

O.Yamakawa(A): Until now we have not found any relationship. There will be some relationship between storage ability and A-amylase which tends to increase during storage.

V.Ramanatha Rao(Q): What is the significance of maltose content in sweetpotato breeding? How long can the tubers of sweetpotato be stored at 13°C?

O.Yamakawa(A): We are trying to use sweetpotato in cooking in a similar way to potato which has no maltose after steaming. In Japan we can store sweetpotato in the store house from November to the next April at a temperature of between 13 and 15°C.

Y.Takahata(Q): What is the chance of producing a new line with higher starch content?

S.Kato(A): The starch content of Hi-starch was reported as 32.5% at Shizuoka Agriculture Experiment Station. However we think there may have been an error in measuring the starch content because we have only obtained 30% starch content for Hi-starch. Breeding is only likely to increase this slightly in the future.

T.Masuda(Q): To achieve high yield and high starch content in sweetpotato, which is the dominant controlling factor the ability of the source or the sink?

S.Kato(A): In grafting of sweetpotato with small and large sized tuber cultivars, regardless of scion type, photosynthate translocated towards large tubers. So I believe yield is controlled by the sink. Starch content will be controlled by enzyme activity of the sink.

I.Shiotani(Q): How were you able to breed a high yielding variety using Hi-Starch even though it has a low yield?

S.Kato(A): Both parents had high starch content (23–25%) and low yield. These characteristics acted additively. Hi–starch did not have a very high yield. From the cross Koganesengan and Hi–starch we bred Kanto 106 which has a very high starch content and high yield.

TECHNICAL REPORTS

Session 4

TARO AND OTHER ROOT CROPS

Chairmen
Kazuo Kawano
Kenji Takayanagi

Taro Genetic Resources and Utilization in Indonesia

MUHAMAD DJAZULI[1]

Abstract

Taro (*Colocasia esculenta* (L) Schott) is the third most important root crop in Indonesia, after cassava and sweetpotato and it originated in Southeast Asia probably Indonesia. 17 accessions of taro were collected in 1931 from East and Central Java. In the Molluccas 12 accessions are cultivated by farmers, while 4 accessions collected are maintained in *in vitro* culture. 143 accessions were found in Irian Jaya. At BORIF–CRIFC, 19 accessions from Java are maintained in the germplasm collection. Some accessions have been characterized for pre– and post–harvest traits. Recently, 87 accessions were collected on Mentawai island, West Sumatra. Yields of taro range from 6 to 10 t/ha. Taro is cultivated in the lowlands and highlands up to 2.700 m above sea level. Taro is consumed as a staple food in Irian Jaya, the Molluccas, and Mentawai island, West Sumatra. In Java, corms are consumed as chips and steamed corm, while leafy parts are used as vegetables. Recently, taro is thought to have good prospects as an agro–industrial crop in Indonesia.

Introduction

Food diversification has high priority in the agricultural development of Indonesia in order to sustain food self–sufficiency which was achieved in 1984. Increasing population and limited suitable agricultural land has caused farmers to move onto marginal soils with many unfavorable conditions.

Taro or cocoyam (*Colocasia esculenta* (L) Schott) is the third most important root crop in Indonesia after cassava and sweetpotato. As a minor food crops, however, taro received little attention both from policy makers and researchers.

Taro grows best in fertile, heavy and moist soils, however, some cultivars are also tolerant to upland conditions.

Currently, no exact estimates of the harvested area, productivity, and cultivars of taro in Indonesia are available. Therefore, systematic exploration on a national scale should be done. As native crop, taro grows in all parts of the Indonesian archipelago from lowlands to highlands and has various uses.

History

Taro is found wild from India to Southeast Asia, and has spread throughout the tropical world up to the border of the temperate zone. Toward the east the

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plant was spread by Malaysians or Polynesians to all the islands of Oceania, including Hawaii and New Zealand. Taro reached China in about 100 BC. The spread of taro to the west is poorly documented. From Southeast Asia, taro was brought to African by Indians or Indonesians around 500 AD (Mauny, 1953 in Leon, 1976).

Colocasia esculenta has been cultivated for a long time and is distributed across the islands of Indonesia. In western part of Indonesia, except Mentawai island, taro is used as a supplementary food, while in the eastern parts, it is used as a staple food together with sweetpotato, sago, and cassava.

Botany and Cultivation System

Taro (*Colocasia esculenta* (L.) Schott) belongs to the genus Colocasia, within the monocotyledonous family Araceae. This crop is classified into two groups: the dasheen type (*Colocasia esculenta* (L.) Schott var. *esculenta*) which is characterized by larger corm and small cormels and the eddoe type (*Colocasia esculenta* (L.) Schott var. *antiquorum*) which is characterized by larger cormels and small corm. In Indonesia, the dasheen type is more common than the eddoe type. Taro grows best in wet heavy soil with good fertility, adequate humus, and good drainage. Most farmers in Indonesia use lateral bud seedlings as a planting material. They plant with varying spacing between plants. Plant spacing for the large cultivars ranges from 100 x 60 to 150 x 60 cm, while for small cultivars, it ranges from 30 x 45 to 75 x 50 cm (Danimihardja, 1978). Crop duration of taro varies from 5 to 12 months, and it is influenced by genetics and environmental conditions, especially temperature. In Bogor, growing period of taro is between 6 and 9 months.

Productivity of taro varies among accessions and growing conditions. It was reported that average yield of taro in the Biak regency, Irian Jaya is 10.3 ton/ha (Anon., 1990), while the productivity of taro in the highlands of Irian Jaya generally, is much lower due to low temperature and soil fertility. In Bogor, as a production center, taro yields range from 500 to 3000 g/pl. Information of harvested area of taro is limited, however, it was reported that three production centers of taro Biak Rumfor, Bogor, and Mentawai have a harvested area are 573, 115, and 50 ha, respectively.

As a minor of food crops, taro has received little attention both from decision makers and researchers. Only germplasm exploration and agronomic studies have been conducted. Taro is very susceptible to leaf blight disease caused by the fungus *Phytophthora colocasiae*. It was reported that of 10 cultivars tested, all were affected when inoculated with taro leaf blight. This fungus was able to reduce yield by up to 54 % (Soenarto and Tethoal, 1976), and up to 80 % in two locations in Irian Jaya. It was also reported that epidemics of taro leaf blight disease occurred twice in Irian Jaya, the first one occurred in Sorong regency in 1976 (Soenarto and Tethoal, 1976), and the second in Biak island during 1981

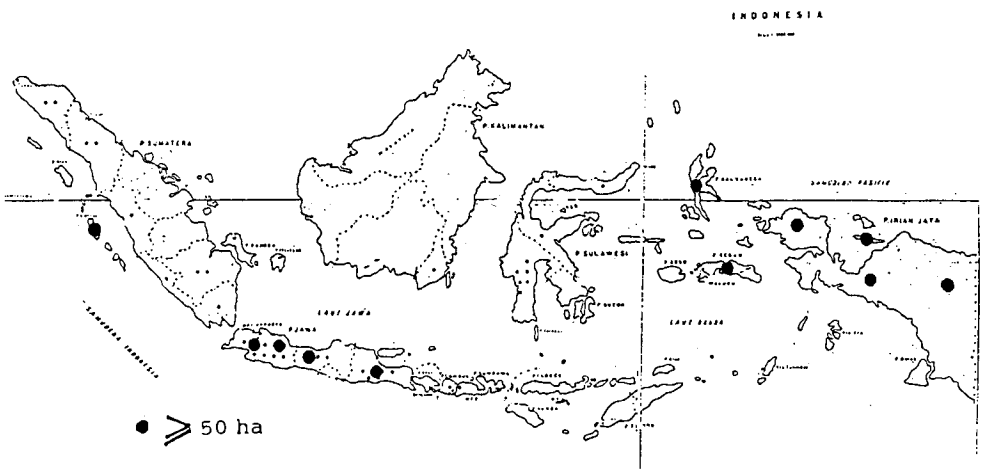

Figure 1. Taro production centers in Indonesia

(Patiasina et al, 1981).

Taro is usually intercropped with other root crops, such as sweet potato in Irian Jaya, it is also a well established as a crop bordering wet rice fields in many agricultural systems.

Distribution

As a native crops of Indonesia, taro is widespread on many islands in Indonesia from Sumatra to Irian Jaya (Western part of Papua) (Fig. 1). Up to the present no systematic exploration of taro was conducted in most production centers in Indonesia. The first taro exploration in Indonesia was made by Osche in 1931. He reported on the use and cultivation of 17 accessions collected from East and Central Java (Danimihardja, 1978).

The diversity of taro in Irian Jaya is relatively high. From some exploration conducted by Cendrawasih University teams, they have found 64 accessions in Sorong regency (Patiasina and Paiki, 1981) and 27 accessions in Manokwari regency (La Achmady, 1983). Matanubun et al (1991) reported that the Center of Root and Tuber Crops Studies (CRTCS)–Cendrawasih University explored the Paniai regency, Irian Jaya, and collected 52 accessions of taro from the three sites (Table 1). In Jayawijaya regency, Irian Jaya it was estimated that more than 20 cultivars of taro grew in the area. Even taro was found at Kuyawage district, Irian Jaya, at an altitude more than 2.700 m see above level and at least five varieties of taro are cultivated.

In Irian Jaya the germplasm collection of taro is maintained both in the farmers field (*in situ*) and in the experimental field of CRTCS–Cendrawasih

Table 1. List of taro accessions collected in Paniai Regency, Irian Jaya Province, 1990

No.	Local Name	Collection site
1.	Medanomo	Moanemani
2.	Pokounomo	Moanemani
3.	Yoni	Moanemani
4.	Agae	Moanemani
5.	Tigiboke	Moanemani
6.	Tabah	Moanemani
7.	Ani makai	Moanemani
8.	Godu	Moanemani
9.	Daino	Moanemani
10.	Degenomo	Moanemani
11.	Pokou	Moanemani
12	Toga	Moanemani
13.	Ibokatota	Moanemani
14.	Tobonume	Moanemani
15.	Wadoya	Moanemani
16.	Degepokou	Moanemani
17.	Badade	Moanemani
18.	Tigoboke	Enarotali
19	Widumani	Enarotali
20.	Agae	Enarotali
21.	Pudo	Enarotali
22.	Bunanomo	Enarotali
23.	Bokome	Enarotali
24.	Kuima	Enarotali
25.	Dadikoge	Enarotali
26.	Muninomo	Enarotali
27.	Oboikigi	Enarotali
28.	Ekinaba	Enarotali
29.	Pagukade	Enarotali
30.	Tugei	Enarotali
31.	Wayuma	Enarotali
32.	NN-1	Enarotali
33.	NN-2	Enarotali
34.	NN-3	Enarotali
35.	NN-4	Enarotali
36.	NN-5	Enarotali
37.	NN-6	Enarotali
38.	Toga	Wagethe
39.	Petege	Wagethe
40.	Pagukoda	Wagethe
41.	Taaba	Wagethe
42.	Koteka	Wagethe
43.	Makadege	Wagethe
44.	Tigiboke	Wagethe
45.	Dedego	Wagethe
46.	NN-1	Wagethe
47.	NN-2	Wagethe
48.	Paame	Wagethe
49.	Widumani	Wagethe
50.	Muninomo	Wagethe
51.	Bunanomo	Wagethe
52.	Tobenue	Wagethe

University (*ex situ*).

An exploration team from Pattimura University, Ambon reported that in Molluccas islands at least 12 varieties were cultivated by farmers, and 4 cultivars among them were maintained by Pattimura University, Ambon in *in vitro* culture (Table 2).

Recently, 87 accessions of taro were found in Mentawai island, West Sumatra by a team from Sukarami Research Institute for Food Crops (SARIF-CRIFC).

As a research institute, Bogor Research Institute for Food Crops (BORIF) has characterized 19 accessions of taro collected from East Java, Central Java, and Yogyakarta provinces (Kartowinoto and Ngatimin, 1993). Two accessions among

Table 2. List of taro accessions collected in Yogyakarta, West Java, East Java, and Central Java provinces

No.	Local Name	Collection site	Color			
			YL[1]	OL	VN	PT
1.	NN-1	Kotagede	g	g	p	p
2.	NN-2	Mangkubumi	g	g	w	g
3.	NN-3	Juwana	g	dg	w	p
4.	NN-4	Playen	g	dg	w	p
5.	Bogor	Bogor	g	dg	w	p
6.	Sutera A	Bogor	g	dg	w	g
7.	Paris	Bogor	g	dg	w	p
8.	Bentul	Malang	g	dg	w	p
9.	Ketan	Bogor	g	g	w	g
10.	Loma	Bogor	g	g	w	p
11.	Sutera B	Bogor	g	g	w	p
12.	Lumbu sawah	Banjarnagara	g	g	w	p
13.	Lumbu ireng	Banjarnagara	g	g	w	p
14.	Lumbu Banten	Banjarnagara	g	g	w	g
15.	Talas salak	Banjarnagara	g	g	w	p
16.	Belitung[2]	Banyumas	g	g	w	g
17.	Sayur buntik	Banyumas	g	g	w	g
18.	Talas gatal	Banyumas	g	g	w	g
19.	Talas sambal[2]	Banyumas	g	g	w	g

[1] YL = Young leaf; OL = Old leaf; VN = Vein; PT = Petiole
g = green; dg = dark green; p = purple; w = white

[2] Eddoe type with larger cormels and small corm.

Table 3. List of taro accessions collected in the Molluccas at Patimura University, Ambon

No.	Local Name	Collection site
1.	Keladi Mai Merah[1]	Rumahkai
2.	Keladi Mentega[1]	Rumahkai
3.	Keladi Toalo[1]	Rumahkai
4.	Keladi Batang Bunga[1]	Rumahkai
5.	Keladi Tenggara	Tihulale

[1] Under in vitro culture

them belong to the eddoe type with larger cormels and small corm (Table 3).

Names of cultivars are usually based on morphological characteristics, taste, color, or origin. For instance, Talas Sutera means Taro (Talas) with fine hair, or silky skin (Sutera). Talas Ketan means taro with a taste like sticky rice (Ketan). Talas Bogor means taro originating from Bogor (Table 3).

Use and Future Prospect of Taro in Indonesia

Both upper and underground part of taro have relatively good carbohydrate, protein, fat, and mineral content (Table 4). Protein content of leaf is much higher

Table 4. The approximate, nutrient and vitamin composition of fresh taro corm

Approximate/ vitamins/nutrient	Unit/100g	1	2	3
Calorie	cal	–	153	98.0
Water	g	75.1	–	73.0
Carbohydrate	g	18.2	37.0	23.7
Protein	g	2.00	1.00	1.90
Sugar	g	1.42	–	–
Ash	g	1.17	–	–
Crude fiber	g	0.80	–	–
Fat	g	0.20	–	0.20
Phosphor	g	–	0.051	0.061
Calsium	g	–	0.026	0.028
Fe	g	–	0.001	0.001
Vitamin C	mg	–	–	4.0
Vitamin B1	mg	–	0.092	0.13
Riboflavin	mg	–	0.030	–
Niacin	mg	–	0.85	–
Thyamin	mg	–	–	4.0
Vitamin A	I.U.	–	–	20.0

1. Payne, et al 1941. In Danumihardja, 1978.
2. Murai et al, 1956 In Plucknett, 1976.
3. Anon. 1989.

than that of corm parts both in wild and edible varieties (Danimihardja and Sastrapradja, 1978).

Taro and potato have a higher alkalinity than cerealia (Watt and Breyer–Brandwijk, 1962). Furthermore, he reported that the people who consumed taro have better and stronger teeth than those of consume sago as a staple food.

In Indonesia, taro is consumed both as a supplementary food and staple foods. In Java, with the highest population, various additional foods are made from taro such as chips, fried or steamed corms, and for other traditional snack foods. In the production center of Bogor farmers and small retailers sell fresh taro around the famous Botanical Garden and other tourist destinations. Accordingly, taro is become a characteristic souvenir food from Bogor.

Taro leaf and petiole are used as a vegetable. Taro is also used as a traditional medicine. Winarno (1990) reported that root extract can be used as a medicine for rheumatism and acne. While extract of leaf can be used for clotting blood, neutralizing snake poison, and as a purgative medicine.

Cultivation of taro close to urban market is more profitable. It was reported that R/C ratio and the net income per capita of taro farmers in Bogor was significantly higher than that from other food crops (Table 5). The comparative advantage of Taro is its low production cost, and a relatively high price.

To increase demand for taro, a diversity of taro products should be developed. Various foods using taro flour have been developed in order to reduce the demand for imported wheat flour. It was reported that Bogor Agricultural University and BORIF succeeded in producing various processing products from

Table 5. Analysis of farming system of several food crops in Bogor, 1990–1991

Commodity	1990		1991	
	Farmers income[1] (Rp .000)	R/C[2]	Farmers income (Rp .000)	R/C
Taro	2.678	2.40	2.617	2.50
Rice	1.120	1.87	1.379	1.99
Maize	676	1.44	583	1.60
Cassava	829	1.66	1.176	1.94
Sweetpotato	704	1.72	1.194	2.10
Peanut	894	1.97	1.483	1.90
Soybean	578	1.50	607	1.30
Mungbean	399	1.47	470	1.32

[1] Production value (including rental land and labour cost) – total production cost
[2] Production value/total production cost

taro such as starch, flour, glucose syrup, cake, and biscuits.

Increasing population in Mentawai island, West Sumatra, the Molluccas and Irian Jaya which consume taro as a staple food, improving productivity, and increasing planting area should be seen as a priority activity.

Conclusion

As a native crops, taro is widespread in Indonesia. In 1931, exploration of taro in Indonesia was pioneered. However, information on genetic resources, production, harvested area, and use of taro in the national research system is still limited.

About 17 taro accessions from East and Central Java, 12 accessions from Molluccas islands, 143 accessions from Irian Jaya, and 87 accession from Mentawai island, West Sumatra have been collected and are maintained as a germplasm collection.

Phytophthora colocasiae is still a main constraint in production.

Taro has a relatively good nutritional value, and various taro products have been developed as supplementary foods. While in the eastern parts of Indonesia especially the Molluccas and Irian Jaya, and Mentawai island, West Sumatra, taro is consumed as a staple food.

Taro has a good prospect as a cash crop in urban areas and as an industrial crop in the future.

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CIP–ESEAP regional.

References

Anonymous 1989. Composition of food material list. Brathara. Jakarta.

Anonym. 1990. Biak Rumfor on statistics. Statistical office. Biak Rumfor.

Danimihardja, S. 1978. Utilization and cultivation of Talas (Colocasia esculenta (L.) Schott). Bulletin of Botanical Gardens. Vol 3. No. 4. pp 101–107.

Kartowinoto, S. and Ngatimin. 1993. Rejuvenation and characterization of Minor root crops germplasm. Progress Report. BORIF, Bogor. 12p.

La Ahmady, 1983. Evaluation of Colocasia sp, Xanthosoma sp, and Alocasia sp germplasm in Manokwari. Fac of agriculture, Cendrawasih University. Manokwari.

Lalopoa, J.R., R.E Wattimena, A. Walsen., and S.H.T. Rahardjo. 1989. Proc. Seminar on Development of tuber crops potential. Fac. Agriculture, Pattimura University–USAID. 95–130

Leon. J. 1976. Origin, evolution, and early dispersal of root and tuber crops. Pages 20–36 Proc. fourth Symp. Inter. Soc. Trop. Root Crops. Cali, Colombia.

Matanubun, H, J. Renwarin, F.A. Paiki, Gunaryo, A. Rochani, and H.T. Dedaida. 1991. First Exploration of root and tuber crops in Paniai and Biak Rumfor regencies, Irian Jaya. Center of Root and Tuber Crops Studies, Cendrawasih University. Manokwari. 47p.

Onwueme, I. C. 1979. The tropical tuber crops ; Yam, Cassava, Sweetpotato, Cocoyam. John Wiley, & Sons. pp 199–267

Patiasina, J.W. and F.A. Paiki, 1981. Exploration of taro and tannia in Ayamaru. Fac. of Agriculture, Cendrawasih University. Manokwari.

Patiasina, J.W., J.P. Karafir, A.M. Killian, and F.A. Paiki, 1981. Preliminary study on disease control of taro leaf blight in Irian Jaya. Fac. of Agriculture, Cendrawasih University. Manokwari.

Plucknett, D.L. 1976. Giant Swamp Taro, a Little known Asia– Pasific food crop. Pages 36–40. Proc. fourth Symp. ISTRIC. Cali, Colombia.

Purseglove, J. W. 1981. Tropical crops : Monocotyledons. Longmans. 5th edition.

Purwanti, H. 1986. Resistance of Taro (Colocasia esculenta) accessions to Bacterial Leaf Blight (Phytophthora colocasiae). Agricultural research. Vol 4:5–7

Soenarto and Y.Tethoal. 1976. Study on epidemic taro disease at Ayamaru district. LPPPM. Manokwari.

Tindall. H.D., 1983. Vegetables in the Tropics. MacMillan Press. London. pp 52–56

Watt, J.M. and M.C. Breyer–Branwijk. 1962. The medicinal and poisonous plant of southern and eastern Africa. E&S Livingstone, London. 1457 p.

Winarno, F.G. 1990. Food chemistry. Bogor Agricultural University. Bogor.

Root and Tuber Crop Genetic Resources in Vietnam

TRUONG VAN HO AND COLLABORATORS[1]

Introduction

Vietnam is rich in Plant genetic Resources, root crops in particular. Root crops play an important role as human food, animal feed, medicines, spices and dyes. Civil and political disturbances in Vietnam have been major factors contributing to genetic erosion of crops (Table 1). The collection and conservation of root crop genetic resources therefore is becoming increasingly urgent.

The Potato and Vegetable research Center (PVRC) of the National Institute of Agricultural Sciences (INSA) is responsible for the National Root and Tuber Crops Project. This project receives financial support from the International development research Center (IDRC), Canada, and the technical advance of the International Potato Center (CIP). It is conducted in collaboration with many institutions in Vietnam and aims to collect, maintain and evaluate root and tuber crop germplasm.

This paper presents the findings of and collecting missions throughout Vietnam during 1992–1993.

Lying between 8°N and 23°N and 102°E and 110°E Vietnam can be divided into 8 agro-ecological regions. The average temperature ranges from 22°C to 27°C. The temperature is lower in the north where the temperature is subtropical with cold winters. The annual rainfall in different ecological regions varies from 1500 mm to 2500 mm. The dry season lasts from November to April and the wet season from May to October. Towards the east lies the sea and in the west the Truong Son mountain range. The terrain is highly varied and slopes down towards the sea. Mountains and hills cover four-fifths of the country. The cultivated area

Table 1. Factors affecting genetic erosion in Vietnam

Enlargement of farms and plantations in the mountainous regions
Pressure from the increasing population
Replacement of indigenous varieties by modern cultivars
Changed cropping patterns
Spontaneous resettlement and migration
Constructions and development
30 years of war

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covers 7 million ha including 4.3 million ha under rice, the rest is under upland crops and perennial plants. The variability in climate, edaphic factors and diversity in farming systems in Vietnam have generated different types of genetic resources for various crops. Collecting root and tuber crops in Vietnam.

Based on their economic importance and scientific significance, root crops, in order of priority to Vietnam, are:- sweetpotato, taro, yam, cassava, Canna and other minor root crops used as medicines, dyes and spices.

The main principles of exploration and collecting were applied based on the crop genetic resources field collecting manual of Hawkes (1980) and the standard passport descriptors recommended by the International Board for Plant Genetic Resources (e.g. IBPGR, 1980; Huaman et al., 1977). Information on varieties and their localities were obtained in the collecting areas from farmers, villagers, local scientists and cadres. Cultural practices and production constraints were also recorded.

During 1992 to 1993 the collecting missions were organised as 10 trips covering the main regions of the country. 100 field days of collecting were carried out in total. The total distance travelled was more than 10,000 km. Itineraries of the collecting missions are shown. The districts where collecting was undertaken is shown (Tables 2). A total of 1208 accessions were collected and of these 518 were sweetpotato, 402 taro, 69 yams, 128 cassava, 33 canna and 58 minor root and tuber crops (Table 3).

Diversity observed

Sweetpotato- *Ipomea batatas* (L.) Poir

Sweet potato was introduced to Vietnam centuries ago, and is widely adapted to all agro-ecological regions. Sweetpotato ranks first among the root crops of Vietnam in terms of growing area with about 400,000 ha and is grown in almost all regions. It is considered a crop of poor farmers because:

a: no other root crop can yield as well as sweetpotato
b: planting and harvesting can be done at any time of the year
C: it does not require much investment unlike rice and maize

It is grown in rotation with rice and upland crops such as maize, beans and vegetables. The most popular varieties, know to exist many decades ago are Lim, Chiem dau, Choi sa, Bi etc. The species *I. digitata, I. hederacea, I. maritina, I. aquatica* of the GENUS *Ipomea* were also collected. But no wild species closely related to the sweetpotato has been found. A total of 518 accessions was collected and are kept at the PVRC. A large amount variation was observed for the type of vine, leaf size, leaf shape and color and storage root characters.

Table 2. Collecting sites of root anf tuber crops

Province	District
Northern Vietnam	
Ha son binh	Ky son, Tan lac, Yen thuy, Hoa Binh
Ha nam ninh	Tam diep, Hoang long, Hoa Lu
Thanh tinh	Nong cong, Thanh thanh, Nhu xuan, Ngoc lac
Nghe tinh	Nghia dan, Tan ky, Con cuong, Anh son, Nam dan, Thach ha, Huong khe, Ky anh
Quang binh	Bo trach, Le ninh
Quang tri	Ben hai, Huong hoa
Thua thien	Huong thuy, Hue, Phu loc
Vinh phu	Doan hung, Thanh hoa
Ha tuyen	Ham yen, Yen son, Bac quang, Vi xuyen, Ha giang
Hoang lien son	Than uyen, Van chan, Mu cang chai, Chan yen
Son la	Yen chau, Mai son, Moc chau, Mai chau, Thuan chau
Lai chau	Tuan giao, Muong lay, Phong tho, Dien bien
Bac thai	Phu thong, Bach thong, Phu luong, Ba be
Cao bang	Hoa an, ha quang, Nguyen binh, Quang hoa, Thach an
Lang son	Huu lung, Van lang, Loc binh, Dinh lap, Cao loc
Ha bac	Lang giang, Luc ngan, Yen the, Que vo, Son dong, Tien son, Viet yen
Quang ninh	Hoanh bo, Tien yen, Quang ha, Hai ninh, Yen hung, Cam pha, Dong trieu
Hai hung	Chi linh
Hai phong	Thuy nguyen
Hanoi	Hanoi
Thai binh	Vu thu, Thai thuy, Thai binh
Southern Vietnam	
Quang nam	Que son, Hoa vang, Thang binh, Dien ban
Quang ngai	Duc pho, Mo duc, Son tinh
Binh dinh	Hoai an, Hoai nhon, Phu cat, Phu my
Phu yen	Tuy hoa
Khanh hoa	Cam ranh, Van ninh, Dien khanh
Thuan hai	Ham thuan nam, Ham tan, Duc linh
Gia lai-kon tum	Mang vang, Cho so, Le trung, Cho ban, Chu se
Dac lac	Eakar, Buon Ma Thuat
Lam dong	Duc trong
Song be	Thuan an, Thu dau mot
Tay ninh	Chau thanh, Go dau, Hoa thanh, Trang bang
Dong nai	Long thanh, Tan phu, Long khanh, Thong nhat, Xuan loc
TP. Ho Chi Minh	Thu duc, Cu chi, Go vap, Hoc mon
Long an	Ben luc, Tan an
Dong thap	Thanh hung
An giang	Tri ton
Tien giang	Chau thanh, Tam hung
Ben tre	Thanh phu, Mo cay
Chu long	Chau thanh
Hau giang	
Kien giang	
Minh hai	

Table 3. Root crops collected in Vietnam during 1992–93

Crop	Northern provinces	Southern provinces	Total
Sweetpotato	174	344	518
Taro	337	65	402
Yam	64	5	69
Cassava	45	83	128
Canna	33	–	33
Other tuber crops	–	–	58
Total			1208

Table 4. Araceae accessions collected and their uses

Botanical name	No. of accessions	Part used	Remarks
Colocasia sp.	290	Tuber, leaf, petiole	Human and animal food
Xanthosoma sp.	80	Tuber, petiole	Human and animal food
Alocasia macrorrhiza	15	Tuber, petiole	Animal food, medicine
Amorphophallus sp.	7	Tuber, stalk	Human and animal food, medicine
Cyrtosperma chamissonis	4	All parts	Animal food
Schizocasia reqnieri	3	All parts	Ornamental
Lasia spinosa	1	Tuber	Medicine
Typhonium divaricatum	2	Tuber	Medicine
Total	402		

Taro

Taro is used as a collective word for general edible aroids– Alocassia, *Colocasia, Cyrtosperma, Xanthosoma*, but it is also applied to each of the aroids separately. There is no data on taro growing area and production but taro is grown in almost all regions in areas ranging from 5 m to 1,800 m and many different agro–environmental conditions. Up to now no research on taro varietal improvement or cultural practices has been conducted in Vietnam (Table 4). Among the species collected, *C. esculenta, C. antiquorum, X. sagittifolium* and *A. campanulayus* are grown as food crops. Son la, Ha bac and Quang ninh provinces are the principal provinces growing *C. esculenta*. Other taro's are not used as human food because they contain an irritating agent of varying amounts in the leaf, petiole or corm. This group can be grown under a wide range of hydrological regimes from flooded fields to rainfed upland conditions. Wild relatives occurred along roadsides and forest margins, mostly in shaded area in Tuyen quang and Cao bang provinces. Some varieties produce a large edible main corm with few cormels; others produce a small or medium sized main corm that often may be inedible because of the acridity and a large number of small edible cormels. Wide variation with respect to shape and color of corms, leaf, plant height was observed.

Yam– *Dioscorea alata, D. esculenta*

A total collection of 69 samples of both wild and cultivated forms were found distributed throughout Vietnam (Table 5). Almost all are climbing plants and most of them have thin stems, and storage organs under the soil surface. *D. bulbifera* grows large tubers in the axils of leaves. Phu tho and Tuyen quang provinces have a considerable area under *D. esculenta* cultivation. While Quang ninh, Ha bac provinces grow *D. alata* on a larger scale. In the south, *D. alata* is

Table 5. Yam species (*Dioscorea* sp.) collected

Botanical name	No. of samples	Remarks
D. alata	47	The principal yam species, tuber have many forms
D. esculenta	17	Only found in cultivation, no bitter forms
D. bulbifera	1	Edible aerial tubers
D. hispida	2	Grows wild. Used as insecticide and medicine
D. persimilis	2	Imported food, traditional medicine
D. cirrhosa	2	Dye
D. deltoidea	1	Introduced. Medicinal plant
D. floribunda	1	Introduced. Medicinal plant
Total	69	

found of economic importance in Long an and Tien giang provinces. Apart from the two species mentioned above, there are a range of the useful *Dioscorea* species. *D. cirrhosa* is used as a traditional dye, *D. perimilis* is used as food and medicine, *D. hispida* is used as a medicine. The different types of yams and their many properties are well known to local people. Large amounts are gathered from the wild when local people want them. During collecting *D. floribunda* and *D. deltoidea* were found which are thought to be new introductions. Large variation in leaf shape, leaf lobe number, cross section of the stem, flash color and tuber shape were observed. Farmers always name a yam according to the shape of the tuber.

Cassava– *Manihot esculenta* Crantz

Cassava was introduced to Vietnam more than one century ago and became an important source of human food all over the country, especially in the highlands. Cassava is often grown on sloping and hilly land some of which have ben severely eroded so the soil is very poor. But people continue to plant this crop because in highly infertile soils no other crop will grow. The area cultivated to this crop is approximately 350,000 ha with annual production of about 3 million tons of fleshly roots. Production is concentrated in the northern mountainous region, the south central coastal region and the southeastern region.

At least 40 cultivars are believed to be planted throughout the country of which Canh nong in the north and Gon in the south are considered to be the oldest. Two cultivars, Mi trang and Vinh phu are widely grown in nearly all cassava producing regions.

In recent years, with the assistance of the International Center for Tropical Agriculture (CIAT) and other scientific institutions, the Hung Loc Agriculture research center and Agricultural institute no 3 have undertaken cassava varietal

improvement with promising results. The making of dry chips, starch (wet and dry), alcohol, maltose, noodles and cakes are long-standing traditional techniques used by farmers in some locations, such as Hoa binh, Vinh phu, Ha tay, Thua thien, Hue, Dong nai, and Kong tum.

Edible Canna. *Canna edulis* Ker.

This species originates from South America where it is known as achira in the Andes. The plant is a perennial and a robust herb. The rhizomes are large and up to 60 cm long, and much branched. There is variation in the shape of the rhizomes, as well as in the composition of the rhizome. 6 groups of *Canna* can be distinguished:

Tall plants with broad violet leaves
Tall plants with narrow violet leaves
Short plants with narrow violet leaves
Tall plants with broad green leaves
Tall plants with narrow green leaves
Short plants with narrow green leaves

A total of 33 accessions of Canna spp. have been collected. Among them, 5 have beautiful leaves and flowers and are used as ornamental plants and two varieties are used in traditional medicine.

Edible *Canna* is grown on an estimated 30,000 ha, producing 300,000 tons of fleshly rhizomes. A long duration crop, *Canna* is usually grown in monoculture, but sometimes it is mixed with other crops. Processing centers having noodles as the main product are found in the large scale Canna growing areas of Hanoi, Hue and Dong nai provinces.

Other minor root and tuber crops – dyes, spices, medicinal plants.

Root and tuber crops as sources of dyes, spices or traditional medicines are listed (Table 6). Their distribution is scattered in all regions. Some varieties are planted mainly in home gardens for home consumption. Some usually grow wild and people gather them in the forest when needed. Some times they are very rare. Most samples collected belong to the Zingiberaceae family. It is difficult to define which species should be included as spices or medicinal plants, but they are all locally used as a source of dyes, spices or medicines.

Conclusions and recommendations

This paper reports the first systematic collecting missions concentrating on root and tuber crops in Vietnam. Information on distribution, diversity of natural habitats and genetic diversity was obtained.

The considerable number of samples, collected indicates that rich diversity of root germplasm exists in Vietnam. Some species belonging to the Araceae,

Table 6. Other minor tuber crops in Vietnam

Botanical name	No. of samples	Use
Curcuma longa	4	dy; sp; me
Curcuma sp.	3	dy; sp; me
Zingiber officinale	12	sp; me
Zingiber jerumbet	4	sp; me
Alpinia officinarum	9	sp
Alpinia galanga	3	sp
Kaempferia galanga	2	me
Kaempferia sp.	2	me
Stemonia tuberosa	1	me
Maranta arundinacea	4	me
Pueraria thomsoni	3	me
Pueraria sp.	1	af
Stephania rotunda	2	me
Pachyrrhizus erosus	8	me
Total		

Notes: dy–dyes; sp–spices; me–medicine; af–animal food

Zingiberaceae and Dioscoreaceae are native to Vietnam.

More detailed exploration and collection should be organised and aimed at particular species in remote areas where variability is known to exist.

References

Hawkes, J.G. 1980. Crop genetic resources field collection manual. IBPGR/EUCARPIA 37pp.

Huaman, Z., J.T. Williams, W. Salhuana and L. Vicente. 1977. Descriptors for the cultivated potato. IBPGR Rome, Italy 44 pp.

IBPGR. 1980. Descriptors for yam (*Dioscorea* sp.) IBPGR, Rome, Italy.

Characterization and Phylogeny of Taro Genetic Resources in Japan

MASASHI HIRAI[1]

Introduction

Although wild taro(*Colocasia esculenta* var. *aquatilis*) is reported in the Ryukyu islands of Japan, cultivated taro did not become domesticated in Japan, and is believed to have been introduced to Japan from tropical areas through China. The beginning of rice cultivation has long been thought of as the beginning of agriculture itself in Japan. However, some Japanese anthropologists recently pointed out that taro has possibly been cultivated from late Jomon period(10th century B.C.), far before the beginning of rice cultivation (Sasaki 1986).

Taro has always been a main crop in shifting cultivation in Japan, and taro is sometimes especially important in local ceremonies. Therefore, knowledge of the origin of taro cultivation and cultivars are important to elucidate the origin of Japanese agriculture.

In Japan taro is not a staple food, but is used as a vegetable. Cormels are mainly used for cooking, but sometimes petioles are used as vegetable. Taro is cultivated in upland fields on main islands of Japan, but in the Ryukyu islands, some cultivars are cultivated on pond fields. Japan produces about 300,000 tons per year, but the production is now slightly decreasing.

Taro Cultivars in Japan

Kumazawa(1956) recorded 194 cultivars, and those were classified into 22 groups. Analyzing 80 cultivars, Hirai *et al.*(1989) reported 9 morphological groups. Major groups are as follows:

Eguimo group: Triploid. Distinct in its deep green petioles. Sprouts earlier than other cultivars. Cold-hardy. Flowers under natural condition in Japan. Produces many cormels having smooth flesh. Only cormels are used as food. Main corms are slightly acrid.

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Ishikawa-wase group: Triploid. Distinct in dark colored fringe of the petiole. Produces many spherical cormels. Cormels are smooth in texture and early maturing. Cultivated in Osaka and neighbouring areas of Japan. One of the most economically important groups.

Dodare group: Triploid. Produces many cylindrical cormels having a smooth flesh. Mainly cultivated in the eastern region of Japan. One of the most important groups for taro production. Hasubaimo group, which is distinct in its horizontally lifted leaf laminae, may classified in a sub-group of the Dodare group.

Akame group: Triploid. Distinct in its reddish anthocyanin pigment in petioles and buds. Produces large spherical cormels. Texture is intermediate. Both corms and cormels are used as food. Mainly cultivated in Kyushu. Less cold-hardy than the other triploid cultivars. Cultivars named "Serebesu" are classified in this group.

Tonoimo group: Diploid. Petioles are dark-purple brown. Produces many shrimp-shaped cormels, when cultivated well. Sometimes produces slender spindle-shaped cormels, when poorly fertilized. Flesh texture is hard and powdery. Less cold hardy than most of triploids. Cultivated in Kyoto and the surrounding areas and used for traditional cooking in Kyoto. It is sometimes named "Ebiimo".

Yatsugashira group: Diploid. Many buds sprout from a single corm (Fig. 2), and the corms grow into irregular shape. Cultivated mainly for petiole production as a vegetable. Acridity in the petiole is low. The other characters are the same as those of Tonoimo group.

Taimo group: Not yet characterized in NIVOT. Produces large main corm and a few cormels. Cultivated on pond field in the Ryukyu islands south in Japan. Main corms are boiled, mashed and used for traditional cooking in the Ryukyu islands. Possibly related to cultivars on Lanyu Island, East of Taiwan Island.

The variation in corm protein

Analysing 80 cultivars using non-denatured polyacrylamide gel electrophoresis, only 8 patterns were found in corm storage protein. Three of the 8 were found in minor cultivars, Binroshin, Takenokoimo, and Migashiki (Hirai *et al*, 1989)(Fig. 1). Therefore most of the Japanese cultivars of taro were classified into 5 protein patterns, which suggests very low genetic diversity.

In natural conditions in Japan taro cannot produce seeds. Only cultivars in the Eguimo group can flower under cultural conditions, but cannot produce seeds because of low temperatures in autumn. These 5 groups may be of clonal origin.

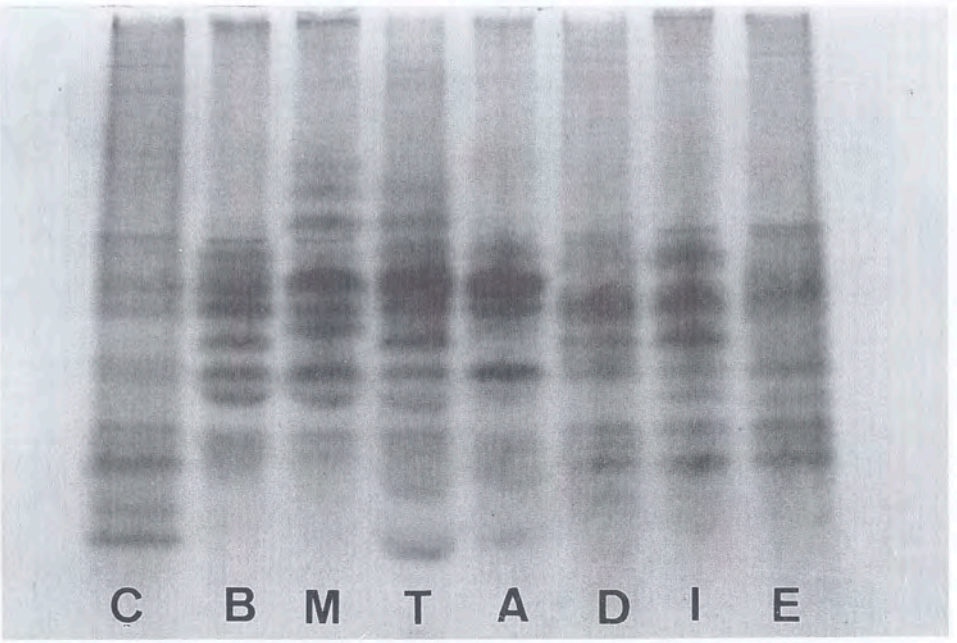

Figure 1. Electrophoretic pattern of corm protein.
C: Takenokoimo, B; Binroshin, M: Migashiki, T:Ebiimo(Tonoimo group), A: Serebesu(Akame group), D: Dodare(Dodare group), I:Ishikawa-wase-maru (Ishikawa -wase group), E:Eguimo(Eguimo group)

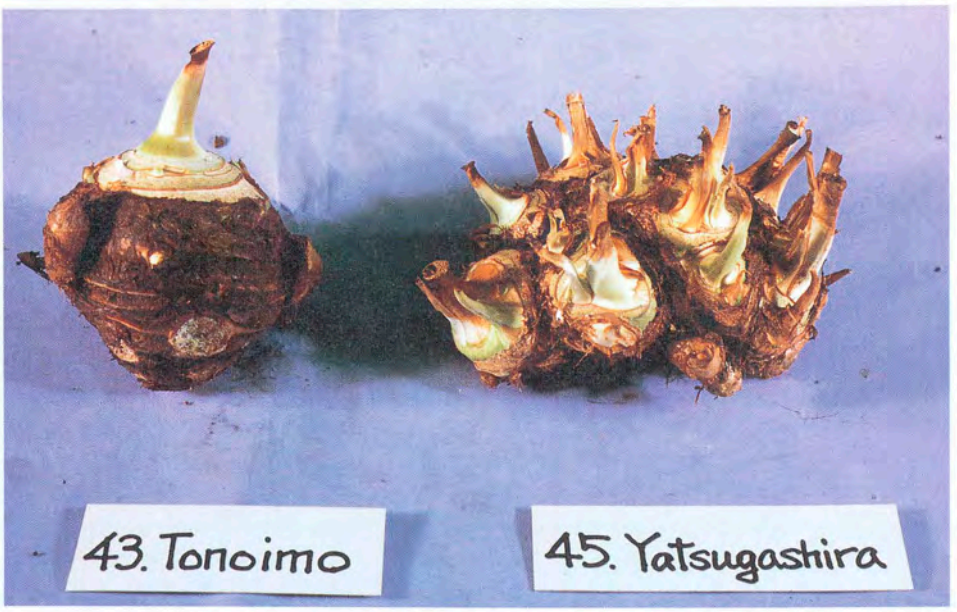

Figure 2. Corms of Tonoimo(left) and Yatsugashira(Right).

Within groups, minor differences in color or shape were also recorded. Many local cultivars may originate by mutation.

A total of 40 morphological characters were scored on the 80 cultivars. A dendrogram based on 40 morphological characters coincided well the results of the protein analysis and horticultural classification (Kumazawa et al. 1956). The results of morphological and protein analyses lead to the following hypotheses on the origin of Japanese taro cultivars.

Ishikawa-wase was not recorded in the old literature, and is thought to have originated in Osaka prefecture in the 19th century. This cultivar has the same protein pattern as Kurojiku, an old cultivar recorded in the 18th century. Shoot tip culture of Ishikawa-wase sometimes results in mutants having dark-colored petioles, which is common to Kurojiku. These mutants are less productive than Ishikawa-wase. Ishikawa-wase may have originated from the Kurojiku group by mutation, the mutant being selected and propagated by farmers because of the productivity and earlier production of the tubers. The mutation during tissue culture could be a back mutation.

Yatsugashira showed a protein pattern common to that of Tonoimo. Injection of gibberellic acid to the meristem of Tonoimo sometimes resulted in a change in growth habit as seen in Yatsugashira. Gibberellic acid may activate lateral meristems, and the resulting growth of many petioles. These findings suggest that Yatsugashira originated from Tonoimo by mutation, and the mutation includes the change in hormonal metabolism (Fig. 2).

DNA analysis

The spacer region of ribosomal DNA is reported highly to be variable, and has been used to understand genetic relationships of species and cultivars. A spacer fragment of taro cloned by Dr. P.Matthews was used to elucidate the relationships between taro cultivars. Taro total DNA was digested with Taq I, separated by electrophoresis, blotted to a membrane and probed with the spacer fragment. A 2.8 kb fragment, which has been found in wild diploid taro in Queensland, Australia (P. Matthews, 1990), was also found in Japanese diploid cultivars. The same fragment was also found in wild taro (var. *aquatilis*) in Okinawa (Fig. 4 and 5). While major triploid cultivars in Japan, Eguimo, Dodare, and Ishikawa-wase had no 2.8 kb band (Matthews *et al.* 1992)(Fig. 3). The pattern for mitochondrial DNA (ATPase α) also suggests a genetic difference between diploid and triploid cultivars. Therefore the diploid cultivars and the triploid cultivars are different not only at ploidy level, but also in genetic background.

Some of the triploids showed genetic similarity with both triploid and diploid lines. The Akame group exhibited 2.8 kb bands and larger and smaller bands. Shogatsuman, a minor cultivar collected from Amami Island, Southern Japan, showed 2.8 kb, 3.4 kb and the smallar bands (Matthews et al.1992)(Fig. 3). These cultivars may have been derived from crosses with tropical diploids and

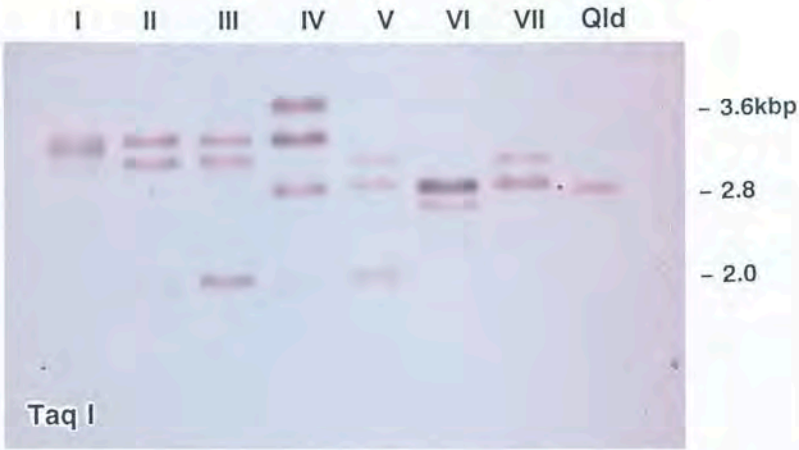

Figure 3. Ribosomal DNA pattern of Japanese cultivars and an Australian wild taro.

Total DNA of taro was digested with Taq I, separated with gel electrophoresis and probed with the spacer fragment of taro ribosomal DNA. For patterns I–VII, the variety names were (I) Eguimo, (II) Wase-kohasubaimo, (III) Ishikawa-wase maru, (IV) Daikichi, (V) Shogatsuman-amami, (VI) Yatsugashira and (VII) Okinawa-aokuki. The Queensland (Qld) pattern was from wild *C. esculenta* var. *aquatilis*.

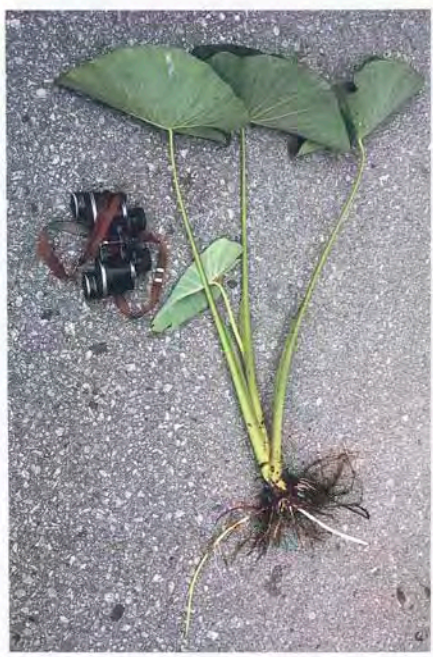

Figure 4. Wild taro(*Colocasia esculenta* Schott var. *aquatilis*) in Okanawa Island showing long slender stolons.

Figure 5. Wild taros growing on river bank, Kunigami village of Okinawa Island. Larger leaves are *Alocasia macrorhiza*.

ancestors of the temperate triploid. The flesh texture of the corms and cold-sensitivity of Akame are intermediate between the diploid cultivars and most of the triploid cultivars, and support this assumption.

Origin of diploid cultivars

The diploid cultivars may have originated in the tropical lowlands, where var. *aquatilis* is very common and has broad genetic diversity. The variation in Okinawa and northern part of Australia seems very low, possibly because these areas are the margins of the natural distribution. People selected non acrid and tuber-producing taro for cultivation. These cultivars are not cold-hardy, and it is difficult for them to become major cultivars in the temperate zone.

Origin of triploid cultivars

Japanese triploids have smaller bands around 2.0 kb and larger bands around 3.4 kb in the DNA analysis. Some Nepalese taro in our collection in NIVOT showed similar bands. Most of the triploid cultivars in Japan have common mitochondrial DNA to Nepalese ones. The origin of the triploid cultivars may be the mountainous region in Nepal, Yunnan in China and neighbouring areas adjacent to the lowlands. The triploids are more cold-hardy than the diploids. The triploid

cultivars were introduced to Japan from Southern China with tea, mandarin oranges, and the other crops along with the cultural technique of shift planting (Sasaki 1971).

References

Sasaki, K. 1971. Inasaku Izen (The agriculture before rice cultivation). Nippon Hoso Shuppan Kyokai, Tokyo, pp. 316.(in Japanese)

Kumazawa, S., K. Niuchi and F. Honda 1956. Classification of taro varieties in Japan. J. Japan. Soc. Hortic. Sci., 25:1–10.(in Japanese)

Matthews, P., Y. Matsushita, T. Sato and M. Hirai 1992. Ribosomal and mitochondrial DNA variation in Japanese taro(*Colocasia esculenta* L. Schott). Japan. J. Breed., 42: 825–833.

Hirai, M., T. Sato and K. Takayanagi 1989 Classification of Japanese cultivars of taro(*Colocasia esculenta* (L.) Schott) based on electrophoretic pattern of the tuber proteins and morphological characters. Japan. J. Breed., 39: 307–317.

Matthews, P. 1990. "The origins, dispersal and domestication of taro" PhD thesis, The Australian National University. Canberra.

(Comment)

Observations on yam cultivation in Papua New Guinea.

HIDEKAZU TOYOHARA[1]

It is regretable that Mr. W.L.Akus was unable to attend this workshop to present his paper on genetic diversity of yams in Papua New Guinea. In his absence I will relate to the workshop some of my own observations in Papua New Guinea during 3 field surveys in 1991, 1992 and 1993.

Yams (*Dioscorea* spp.) are one of the most important crops in Papua New Guinea, especially in the low lands such as Central, Madang, East Sepik, and Milne Bay provinces which have seasonal or heavy year round precipitation. The major species of yam cultivated in Papua New Guinea are *D. alata* and *D. esculenta*. Other *Dioscorea* species are also cultivated *D. bulbifera*, *D. nummularia*, *D. pentaphylla* and *D. hispida*. In the Nuku area of Sandaun province at an altitude

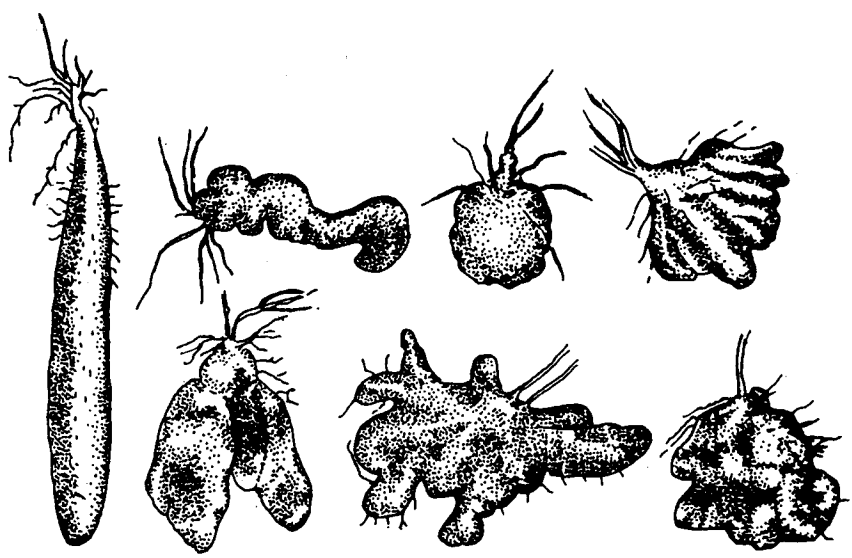

Figure 1. Tubers of the greater yam (*Dioscorea alata*) grow in many different shapes and sizes. Some are shown here.

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Sakuragaoka, Setagaya, Tokyo 156, Japan

of about 300m I have under taken field surveys. In this region people engage in shifting cultivation.

On sloping land people do not cut all the trees since some are usful as a support for yam vines. Taro (*Xanthosoma* sp.) and banana are planted on areas with a steep slope to avoid soil erosion and yam is cultivated on gentle slopes.

Yam is commonly planted on ridges. There are many types of yam and different types are planted in different areas. Yams with long tubers are more often planted on steeper land than cultivars with round tubers. In the Nuku area *D. alata*

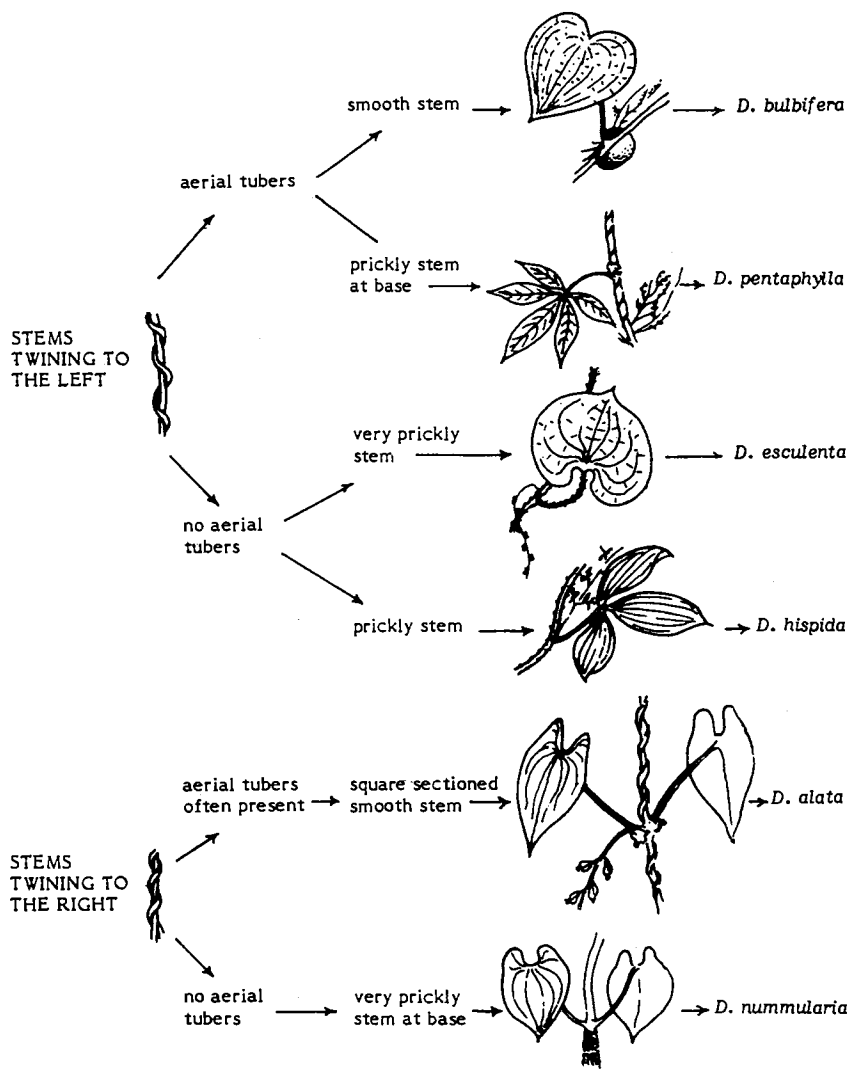

Figure 2. A simple key to identify the main yam species in Papua New Guinea

is called Nani and *D. esculenta* is called Bache. We have examined about 70 cultivars of of *D. alata* and 35 cultivars of *D. esculenta* on one farm. According to Laloki Plant Introduction and Horticultural Station, 118 cultivars of *D. alata* and 83 cultivars of *D. esculenta* can be found in Milne Bay Province. Papua New Guinea is thus a very rich area for yam genetic resources.

Local people give names to yams based on the morphology of above ground parts and roots, texture and where the yam originated. Local people have a rich knowledge yams and some people can identify yams at a glance. Since yams are eaten every day it seems that they grow many cultivars to provide some variation to their meals.

Yam is usually cooked with coconut milk but sometimes they are baked. Yams are used as a daily food and also at times of special celebration such as during thanksgiving ceremonies and marriage.

After yams are harvested they are divided into two groups. One to eat immediately the other group is stored.

Finally I would like to propose that further research and development on yam cultivation and processing should be undertaken.

Questions and Answers in Session 4

M.Hirai(Q): What is the scientific name of snake gourd?

H.V.Truong(A): *Dioscorea hispida.*

M.Hirai(Q): In Indonesia do you have any varieties with side corms?

M.Djazuli(A): So far I have not seen any. However, characterization of recent collections from Mentawai island is not yet complete.

M.Morishita(Q): What are the differences between taro on Mentawai and Irian Jaya, Indonesia.

M.Djazuli(A): Since the collections from Mentawai are not yet characterised I cannot say yet. I would expect considerable differences considering the differences which exist between these areas agro–ecologically.

K. Takayanagi(Q): Taro cultivation in Indonesia may be subsistence and in some areas may be for commercial production. Which parts of the country grow taro commercially.

M.Djazuli(A): Production centers in Java grow taro as a cash crop.

J.L.Bacusmo(Q): Is there any breeding of taro in Indonesia?

M.Djazuli(A): No.

J.L.Bacusmo(Q): Do you have *Xanthosoma*, *Macrorrhiza*, *Cytosperma* and other minor aroids in Indonesia?

M.Djazuli(A): During our exploration in Central Sulawesi, Central and West Java we found some minor aroids and these accessions we planted in Bogor as part of the germplasm collection.

I.Tarumoto(Q): In your presentation you showed three kinds of cultivation system. The broader system you showed, would that be for producing seed corms for the next planting?

M.Djazuli(A): No. Cultivation of taro on rice field bunds is for corm production not seed corm production.

V.Ramanatha Rao(Q): Is it appropriate to use protein patterns to study intraspecific diversity?

M.Hirai(A): Taro is probably outcrossing and has broad genetic variation even at the intra-specific level. Protein banding patterns are effective to detect this diversity.

I.Shiotani(Q): How many times can mutations occur to differentiate the pattern of two proteins?

M.Hirai:(A) At the moment I can not answer. We already cloned two cDNA storage protein genes. In the near future I will be able to answer your question.

T.Yamada(Q): You discussed triploid taro. How did it become triploid?

M.Hirai(A): This is not known. We have not found tetraploid taro even in the Nepal collection.

D.Vaughan(Q): Do weedy taros exist and if so how do they differ from wild relatives of taro?

M.Hirai(A): I don't think weedy taros exist in either Okinawa or Australia. I do not know about other regions.

K.Kikuchi(Q): Are there any particular morphological differences between the triploid and diploid cultivars.

M.Hirai(A): Yes diploid taros produce a single large main corm and triploids have many side corms.

K.Kikuchi(Q):Would you please explain the breeding of taro in Japan?

M.Hirai(A): Only a few prefectural research stations have some breeding of taro. However this is a very small effort.

GENERAL DISCUSSION

Chairmen
V. Ramanatha Rao
Itaru Shiotani

General Discussion

K. Kawano(Q): Given that the CGIAR Centers can take care of, by and large, all aspects of germplasm management in major crops, what would be the long term role of IBPGR?

V. Ramanatha Rao(A): Based on the needs expressed by the national programs, IPGRI will assist in genetic conservation of root and tuber crops in any way it can. It will highlight the need for complementary strategies for conservation, develop appropriate methodologies and guidelines for this purpose. Its level of support will, however, depend on the donors support for the issues that have been raised during the meeting.

K. Kawano(Q): In the wake of "intellectual property right"(IPR) concerns mainly from the developed countries and so-called "germplasm nationalisn" on the part of developing countries in the tropics. Can you explain where IBPGR stands in these topics? Can IBPGR contribute to sorting out the possible conflict?

V. Ramanatha Rao(A): National sovereignity on genetic resources is not limiting the exchange of germplasm. It may lead to some amount of control, but a country is free to evolve its own regulations. However, IPGRI will continue to promote free exchange of germplasm. Coming to IPR, IPGRI, along with the other CG centers does not recognise IPR of plant genetic resources. IPGRI has an internal taskforce to follow the international scene and can play an advisory role to national programs, if requested.

I. Shiotani(Q): You mentioned about 100 root and tuber species belonging to 22 genera which are used for various purposes in subsistence economies. Dr. Truong also mentioned 58 useful minor root crops in Vietnam. I suppose that there are quite alot of these plants that are wild and semi-cultivated as well as the cultigens.

I am very interested in these species. In the near future, germplasm to be used for crop improvement will be extended to the remote species through methods of DNA manipulation. Does IBPGR have a project to collect and publish information on these natural resources including wild relatives of major root and tuber crops?

V. Ramanatha Rao(A): There are numerous root and tuber crops that are used by people in developing countries as indicated earlier by me and Dr. Ho Truong. Information on some of them will be covered under a German supported IPGRI project on 'neglected crops'. Efforts also will be made to gather information on other useful species. As far as possible information on wild relatives will also be gathered.

M. Oka(Q): Weevil causes serious damage on sweet potato in Asian countries including the south western islands of Japan.
Is there any specific genetic resources showing weevil resistance. If there are not, can we find such materials from the many genetic resources kept at agricultural institutes around the world? How about an international research network system for finding weevil resistance?

J. L. Bacusma(A): Our work in the Philippines has not revealed any weevil resistant materials. AVRDC has done much more work on this topic.

K. Komaki(A): As far as I am aware AVRDC has not been successful in finding weevil resistance. It is my opinion that weevil resistance will not be found since it would be very difficult to protect the whole edible tuber from the weevil.

M. Nakagahra(Q): Safe, cost effective and simple methods to conserve root and tuber crops is very important. What kinds of efforts are being made to develop such systems for different crops and in different countries.

C. Thiraporn(A): In Thailand our cassava collection is maintained in the field and *in vitro*.

J. L. Bacusmo(A): In the Philippines we maintain most of our germplasm in the field or in pots. A little is also conserved in vitro.

T. Ishige(A): We are concerned mainly with the maintenance of a working collection of about 2000 lines. Since this is research material not a genetic resources collection we have our own interests in mind when maintaining this collection and can thus find the resources to do so. This may not always the case for those maintaining large germplasm collections.

M. Djazuli(A): Our collection of taro is not so large so we can maintain in the

field. However resources to evaluate the material are limited and we will face problems maintaining the collection if it grows much bigger.

D. A. Vaughan(Q): I would like to ask about in-situ on farm conservation of root and tuber crops. In-situ (on farm) conservation seems to offer a useful means of conservation of root and tuber crops:
Would Professor Shiotani comment on whether there is any possibility for promoting on farm conservation of traditional varieties in Japan where many tradional varieties apparently grow in isolated pockets as his paper indicated?.
Could Professor Bacusmo comment on work being conducted on in situ conservation efforts in the Philippines and its practicability?

I. Shiotani(A): Replacement of many traditional varieties occurred in a short period of time during the 1950's and early 1960's. Progress and loss comes together. I could quote a Japanese proverb 'lucky and unlucky are twisted in a thread'. The best way to keep diversity on the farm is to stop breeding efforts but this is hardly practical. Local agricultural activity is most important to keep genetic diversity on the farm. We need to look for new breeding systems which maintain genetic diversity in local agriculture.

J. L. Bacusmo(A): This is a difficult question. In the Philippines there is a CIP project called UPWARD which started a project on 'memory banking' that is a project to record information on varieties in farmers memories. The project consisted of asking lots of questions to farmers understand their genetic resources better and to help get a lead in evaluating varieties. Breeders and a social scientist were involved in this project. The project progressed into a community based genebank project in the hope of convincing people to do something with there own genetic resources. This project may be difficult to sustain because sweet potato is not an indigenous crop to the Philippines and it is an economic crop only of use if the price for it in the market is good. The concept of in-situ conservation is to compliment ex-situ efforts. Giving communities the opportunity to plant different varieties of a crop in a kind of gene reserve is a good idea. In situ conservation might be sucessful in the Philippines for indigenous crops and wild relatives of crops, such as wild yams, for which their forest habitat can be protected.

J.L.Bacusmo(Q): Can you explain Japanese principles regarding germplasm exchange of sweet potato.

M. Nakagahra(A): Japan freely exchanges germplasm with other countries. Requests for germplasm in the MAFF genebank system should be addressed to the Director General of NIAR(Kannondai 2-1-2, Tsukuba, Ibaraki, Japan. Fax: +81-298-38-7408). He can then direct the request to the appropriate researcher to respond.

The only 'germplasm' which cannot be released immediatly are recently registered varieties for which a period of 4 to 5 years after registration are not distributed from the genebank system of Japan. The reason for this is that these varieties are initially protected by the Japanese law of seed and seedlings.

WORKSHOP SUMMARY

V. Ramanatha Rao

Summary

V. RAMANATHA RAO[1]

From the technical papers that were presented on various crops I would highlight the following issues which emerged from the last two days of discussion as being important:

– there are considerable gaps in the collections for many crops. Taro, for example, is poorly collected in the area it is considered most diverse and still no tetraploid taro has been found according to Dr. Hirai. Eco–geographic and ethnobotanical studies to identify areas rich in genetic diversity are needed. Dr. Truong indicated much more can be learnt about root and tuber crops in Vietnam from such an approach.

– strategies and methods for characterisation and evaluation need to be improved. Wild relatives of root and tuber crops need to be a part of this process. The importance of finding good sources of resistance to the sweet potato weevil was highlighted by several participants.

– documentation needs of different countries and institutions are at various levels of development and need improvement. In this regard, IBPGR has recently produced software and self teaching manuals (genebank management system) which might go some way to helping satisfy this need.

– at present nearly all the focus of attention regarding root and tuber crops is on the "big three" namely the potato, cassava and sweet potato. Only limited efforts are directed towards taro and yams. While many minor, but locally very important, root and tuber species, to borrow the words of Dr. Kawano, "appear doomed to extinction" unless appropriate action is taken.

– much research is needed in developing conservation methods, particularly to make them cost effective. Clearly the conservation methods which may be appropriate in one country may not be in another. For example, a reliable cryopreservation system may be possible in Japan, however in countries where the needed supplies are not readily available alternative approaches may be necessary.

[1] International Board of Plant Genetic Resources,
Asia Pacific Oceania Office, Singapore

– a complementary conservation strategy is essential for root and tuber crops. *In situ* conservation, by which I include on–farm conservation, offers real possibilities for many root and tuber crops. Many minor root and tuber crops are either semi–domesticated or wild and their habitats could be protected. For conservation of farmers varieties, it was pointed out by Dr. Bacusmo that *in situ* conservation could be effective. However, he indicated, it is best to focus on a species which is indigenous to a locality and not introduced. Additionally, the felt need by farmers to maintain diversity is an important consideration for the success of *in situ* conservation

– the poor knowledge on the ancestry of many root and tuber crops highlights the need for more attention to be paid to wild species. This seems particularly important in the 1990's when biotechnology permits somatic hybridization , as discussed by Dr. Ishige, and other means of using distant relatives of crops.

– ready exchange of root and tuber crops is hampered by the need for careful attention to quarantine procedures. Movement of cassava from Africa to South America is restricted due to quarantine concerns, as pointed out by Dr. Kawano. Safe means of overcoming some of these problems are needed so that useful germplasm is available to people worldwide. Efforts of IBPGR in developing guidelines for the safe movement of germplasm are directed towards this goal.

This workshop has highlighted how dependent countries are on one another for plant germplasm. The pedigree charts shown by several speakers from Japan for different crops illustrated this point well. So there is a need for increased collaboration assisted by international and regional agencies. Japan, with its scientific expertise and leading economic development, is in a position to assist in various collaborative ventures in the region both by expanding work on strategic research as well as by contributing necessary funds to promote work on the issues of conservation and use of root and tuber crops in the region.

As far as I know, international institutes operating in the region are sincere in their efforts and will definitely do whatever they can to assist the national programs. With further assistance from donors, it should be possible to do more in this area. It is also essential to increase allocations on the so called neglected or locally important species as they play a major role in subsistence agriculture. It should also be possible to encourage "green marketing" for such products so that cultivation of these could be expanded and diversity be maintained on the farm.

To conclude, the two days deliberations have been very useful in exchanging information and ideas. I hope this will also lead to increased collaboration work on root and tuber crops.

CLOSING REMARKS

Masahiro Nakagahra

Closing Remarks

MASAHIRO NAKAGAHRA[1]

Thank you very much Dr. Rao and Dr. Shiotani for your excellent summary of the discussion.

We have now come to the end of all the sessions. On behalf of the organizing committee of the workshop, I should deliver a few words.

First of all, I would like to thank all the chairpersons, speakers, and other participants for their valuable contributions. I would also like to express our thanks to the cooperating institutes, NARC, JIRCAS and FTRS in Tsukuba for helping to organize this workshop successfully. I am thankful to Agriculture, Forestry and Fisheries Research Council for providing us with full financial support for this workshop.

The MAFF International Workshop on Genetic Resources aims at promoting research exchange and collaboration on the development of technologies and global strategies for conservation and use of genetic resources in national programs and the international research institutions. The subject of root and tuber crops was the first focus during this workshop to learn about the present status in this area.

Dr. Rao mentioned yesterday that he often considers the Science of Genetic Resources as the Science of Crisis. We hope by increased commitment to conserving genetic resources the crisis will lessen.

We prepared a program consisting of keynote addresses and four technical sessions. In keynote addresses, "The Role of international organizations in root and tuber crops conservation" and "The Utilization of root and tuber crop genetic resources in Japan" were presented. Technical sessions dealt with present status and current research topics on root and tuber crops genetic resources, in which 14 reports were presented. In general discussion, the importance of in situ and in vitro conservation were highlighted, of cooperation among countries and international organizations in overcoming quarantine problems in transportation of genetic resources, exploration, exchange of materials and information.

Thus, during this workshop, we shared a great deal of information on root and tuber crop genetic resources. We understand that these genetic resources are playing an important role in food production for millions of peoples in the world.

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[1] Genetic Resources Coordinater, National Institute of Agrobiological Resources (NIAR), Tsukuba, Ibaraki 305, Japan

This workshop is small scale and a first, but I anticipate that by continuing these efforts in the future, we will contribute to further promotion of exchange and strengthen of research collaboration in conserving genetic resources.

On behalf of all the members of the organizing committee, I wish to express our sincere gratitude to all of you who have so actively participated in this workshop to make it such a success. I thank you, all the distinguished guests and participants again, for their active participation and cooperation. I would like to extend my best wishes to all of you for your work in your countries and organizations. I and all the staff members of Tsukuba institutions are looking forward to seeing you again in the future.

We will have one more day for a field workshop tomorrow. Now I have the duty and the honor to declare the Indoor-workshop closed.

Thank you very much for your kind cooperation.

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JIRCAS: Japan International Research Center for Agricultural Sciences
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