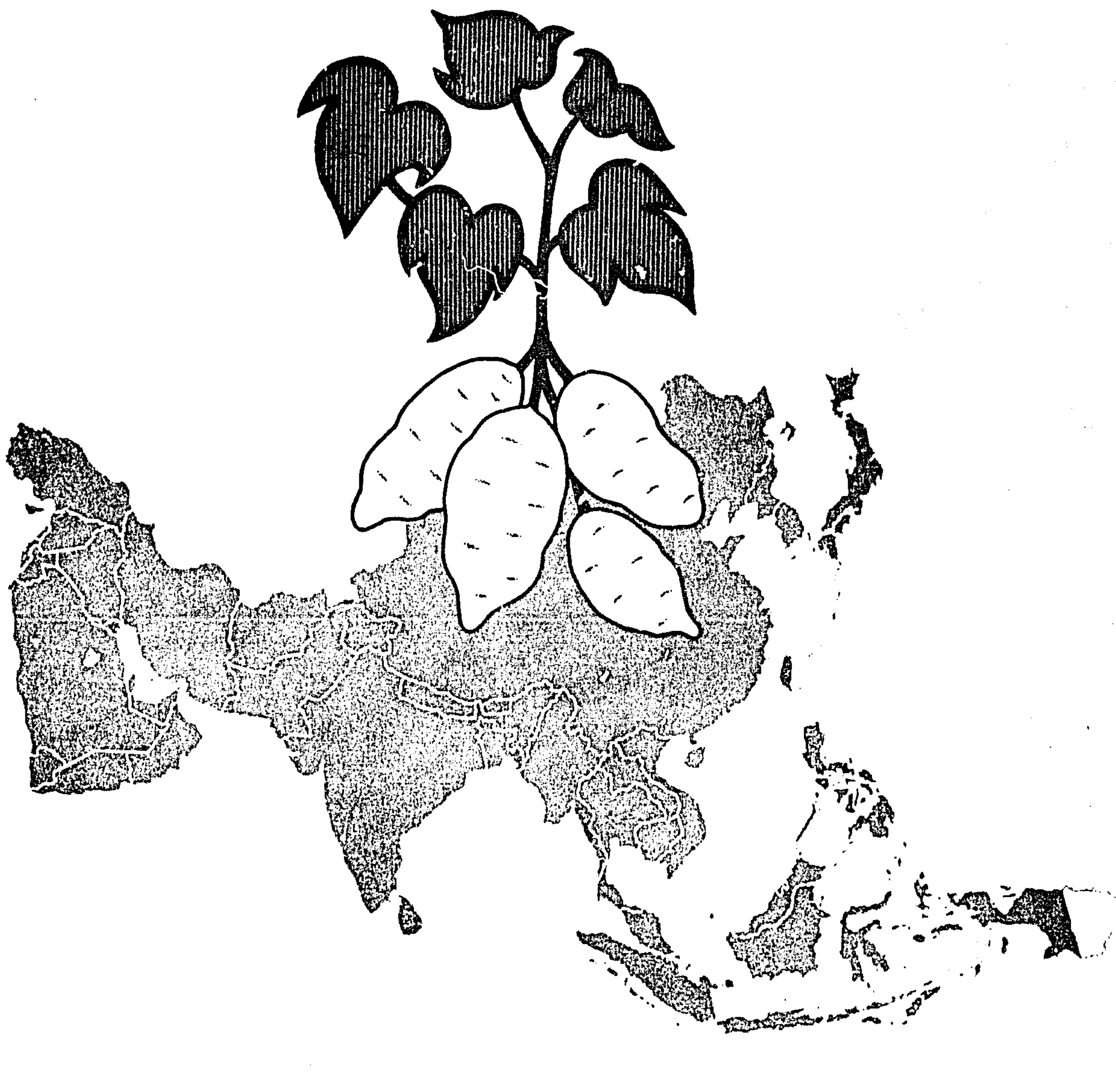
IMPROVEMENT OF SWEET POTATO (*Ipomoea batatas*) IN ASIA

Report of the "Workshop on Sweet Potato Improvement in Asia", held at ICAR, Trivandrum, India, and jointly sponsored by the International Potato Center (CIP), the Indian Council of Agricultural Research (ICAR), and the Central Tuber Crops Research Institute (CTCRI), October 24-28, 1988.



INTERNATIONAL POTATO CENTER (CIP)

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CIP RESEARCH AND TRANSFER PROGRAM

Primo Accatino[1]

Mr. Ragkavan, Honorable Minister of Agriculture of the State of Kerala, India.
Dr. Rao, Special Director General of the Indian Council of Agricultural Research.
Dr. Chadha, Deputy Director General of the Indian Council of Agricultural Research.
Dr. Nayar, Director General of the Central Tuber Crop Research Institute at Trivandrum.
Scientists and research managers of international and national institutions attending the workshop.
Scientists from CIP, members of the press, ladies and gentlemen.

First of all on behalf of the Director General of CIP and its staff, I would like to thank and acknowledge the host institutions of this workshop: The Central Tuber Crop Institute at Trivandrum, and the Indian Council of Agricultural Research for this excellent collaboration in the organization of this workshop.

I have planned my presentation on CIP research and transfer program on the basis of the major objectives of the workshop, which are:

1. To gather knowledge of the sweet potato situation in the countries of Asia in terms of production, utilization, constraints, research and technology transfer activities, international collaboration and needs for improvement.

2. To inform the participants of CIP sweet potato research activities and linkages already established with international and national research institutions.

3. To develop plans for collaboration in research and technology transfer between the countries research institutions and CIP to initiate collaborative research and training projects based on mutual agreements on national and CIP capabilities and resources and to identify opportunities for research contracts on topics of mutual interest where also resources are shared for their implementation.

4. To discuss possible network activities for research, training and technology transfer among the countries and CIP where the members institutions pool their physical and human resources for directions, implementation, evaluation and funding. The budgeting and the decision making process is executed by the institutions members of the network.

In accordance with the above major objectives, I would like to present the research and technology transfer program of CIP with some details on the organization and strategies with the purpose of facilitating the up coming decisions on collaborative activities that might develop between CIP and National Sweet Potato Research Programs attending this workshop.

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CIP is one of the 13 international agricultural research centers sponsored by the Consultative Group on International Agricultural Research - CGIAR. CIP collaborates with research and development agencies throughout the world to achieve two basic objectives:

- Increase the potato and sweet potato yielding ability, stability and efficiency of production and utilization in developing areas where it is now grown, and,

- Improve the potato and sweet potato adaptability to grow more extensively and efficiently in cold, high regions, as well as in warm, low tropical regions.

An international agricultural research center can take one of two routes to conduct its program: one is for the center to "go it alone," establishing its research program, developing its new varieties and technological packages, and then "transferring" them to developing country programs, or directly to farmers. The second route is for the center to work with national programs from the start. CIP has successfully followed the second route.

CIP's program has as a focal point the exploitation of genetic resources still available in the center of origin of potato and sweet potato and to use them for improvement worldwide.

CIP research develops technologies to solve major problems of potato production in developing countries. Results are further evaluated under a range of developing country conditions in collaboration with national research institutions. This enables both CIP and national program scientists to quickly determine if the technology is applicable to growing conditions in specific regions.

The Research at CIP is organized into Departments. For administrative purposes scientists are assigned to Departments according to their discipline. The Departments of Taxonomy, Breeding and Genetics, Pathology, Entomology and Nematology, Physiology, Social Science and Research Support are headed by a senior scientist responsible to the Director of Research.

Maximum interaction of teams of specialists in various scientific disciplines is gained by grouping research projects into specific areas of research concentration (Thrusts). Each Thrust has a leader responsible for projects in that particular area of research concentration.

CIP scientists may work simultaneously on several projects within different Thrusts as a leader or as a cooperator to provide essential interdisciplinary input.

Before a project begins at CIP, several factors are considered. Advantage is taken of the built-in, two-way communication between National Programs and Lima headquarters through Regional Offices to determine specific problems. Also considered is accumulated documentation on the problem and whether CIP has the expertise and facilities to do the necessary research and the amount of work expected from the scientists who would be involved.

The organization plan permits flexibility for changes in priorities without major shifts in staffing. Additional commodities - sweet potatoes, for example was added without a major increase in funding for staff and facilities.

Regional Research and Training at CIP is guided by priorities developed through headquarters and regional scientists and their national counterparts. The specialists of the Training and Communications Department contribute with guidance and responsibilities toward human resource development and communication flow of information. Priority areas for regional research are currently: regional germplasm evaluation, adaptation of potato and sweet potato to tropical conditions, strengthening national seed systems and planting material, developing technology for potato production from true seed, tissue culture and rapid multiplication methods for seed and planting materials, improving post-harvest technology, agronomic management, and socio-economic studies.

The Regional Research and Training Program works directly with national scientists to conduct production-oriented research and exploit technology available from CIp and elsewhere. Host countries and boundaries for CIP's eight regional programs shift occasionally in response to emerging national capabilities and political developments.

Regional staff members collaborating with national scientists are responsible for identifying key production problems, testing and adaptive research, multiplication and distribution of genetic materials, training, and related activities that strengthen national potato research and extension programs. CIP has few physical facilities at its regional stations and relies on a national institute or another center for office space and logistical support.

Short-term consultants are not a substitute for permanent personnel in regional programs. Effectiveness in region depends on detailed knowledge of the individual countries, insights that can only be built up over time by regional scientists in the field.

CIP's philosophy is to involve institutions and scientists throughout the world in research, training, potato and sweet potato improvement while keeping its own program modest in scope and sharply focused on developing country needs. Several strategies help to accomplish CIP program.

1. Members of the Board of Trustees represent diverse countries, disciplines, and experiences. The 35 individuals who have served on CIP's board are from 17 different nations; 17 from developing and 16 from developed countries. The board has an active role in management, and evaluates the programs and budget annually.

2. CIP's social science program provides management and research scientists with up-to-date information on potato production and use in developing countries. Through their participation in interdisciplinary teams, social scientists also keep the interest of producers and consumers foremost in research and training programs.

3. Progress in all research projects and training is reviewed in a week-long annual meeting of all CIP scientists, representatives of national programs, and board members.

4. Planning Conferences periodically review progress and establish guidelines for future research in each major research area. To date, near 30 conferences have had 300 invited participants from 45 countries attending.

5. Based on planning conferences, assessments of developing country needs and CIP's comparative advantages, a long-term plan till year 2010 was issued in 1987. The plan,

goes to policy makers and potato scientists around the world. It is periodically updated to reflect research progress as well as changing perceptions of developing country needs and capabilities.

6. When country leaders seek external funding for a potato program, CIP attempts to link the country with a donor agency and a locally-based international agency which can administer the funds and implement the project. This strategy called the "third dimension approach" allows CIP to minimize the administrative burden of handling large numbers of special projects. A program such as this has been conducted in Bangladesh, Nepal, Pakistan, and Bhutan.

7. Many developing countries unable to afford a comprehensive potato research program solve their problem through CIP-sponsored collaborative country research networks. These country programs pool their resources to establish their own integrated research programs which investigate problems of mutual interest.

Five collaborative networks are not functioning: two in South America and one each in Central America, Central Africa, and South East Asia.

8. Direct research collaboration between scientists in CIP and national programs is achieved by working jointly in collaborative research projects which are the research unit of CIP's Regional Research Program. More than 100 such projects underway in 50 developing countries.

9. CIP Thrust research is linked to scientific expertise and research facilities throughout the world by means of research contracts. Contracts motivate research to work on priority problems of developing countries, and provide operating funds for conducting needed research. Flexibility is provided for changing research priorities without incurring major changes in headquarters staff and facilities.

10. CIP's training program is based on the philosophy that research and extension efforts conceived and executed collaboratively with national programs are more appropriate, effective and longer lasting than those conceived and executed independently by CIP. All general production training and many specialized courses are conducted in regional and national programs. Since 1978, CIP has trained or facilitated training for about 5000 researchers and extensionists from 102 countries.

11. Experiences in development and dissemination of seed storage technology led CIP's post-harvest team to formulate the "Farmer-back-to-farmer" research model. Based on the belief that problem-solving agricultural research should begin and end with the farmer, this model relies on interdisciplinary teamwork in all phases of a continuous research/diffusion process. The model is now serving as guide to applied potato research in a number of technological areas in several countries. Moreover, agricultural policy makers and development specialists working on other crops and problem areas have expressed great interest in the model, as a guiding framework for applied research and development.

PRESENT STATUS AND FUTURE PROSPECTS OF SWEET POTATOES IN BANGLADESH

Adbus Siddique[1] and Mamunur Rashid[2]

1. THE COUNTRY

Bangladesh, a land of about 144,000 km^2 is situated in the north-eastern part of the South-Asian sub-continent roughly between 20.75° to 25.75° north latitude and from 88.30° to 92.75° east longitude. Except for the hilly regions in the north-east and south-east, the country consists of low flat and fertile land. About 1/3rd of the vast low lying plain is subject to annual floods.

The country is in the humid tropical region. The weather throughout the country tends to remain mild due to the influence of the Bay of Bengal and the monsoon wind. The annual rainfall varies from 1,112 to 5,096 mm with an average of 2076 mm. About 80% of the rainfall is received during June to October, i.e., in the second half of the hot season (Fig. 1). The hot season starts from mid February. The winter, extending from early November to mid February, is almost dry. The mean minimum temperature during the period vary from 8° to 13°C.

The country has a large population of over 95 million people (the approximate population density is 660 inhabitants/km^2) in relation to a limited area of available cultivable land (8.91 million hectare). At the present growth rate, the population of this country will exceed 140 million by the year 2000.

The economy of Bangladesh is traditionally and predominantly agricultural. About 91% of the country's population is rural, and 80% of them are engaged in agriculture. Nearly 1/5th of this number is estimated to be landless. More than 75% of the country's population lives below the poverty line. The agriculture, as a whole, continues to be traditional with its old cultural practices and low yielding crop varieties. Yields of most of the crops are of the world's lowest. As a consequence, the country is far from self-sufficient in food. The country has to import food grains every year to meet the deficit (Fig. 2). It is apprehended that in the year 2000 food deficit of the country will rise to about 3 million tons.

Crop production in Bangladesh is dominated by rice. Other major food crops are wheat, potato and sweet potato. There has been a significant increase in the production of rice, wheat and potato during the period from 1973 to 1985. The position of sweet potato, however did not change much (Fig. 3).

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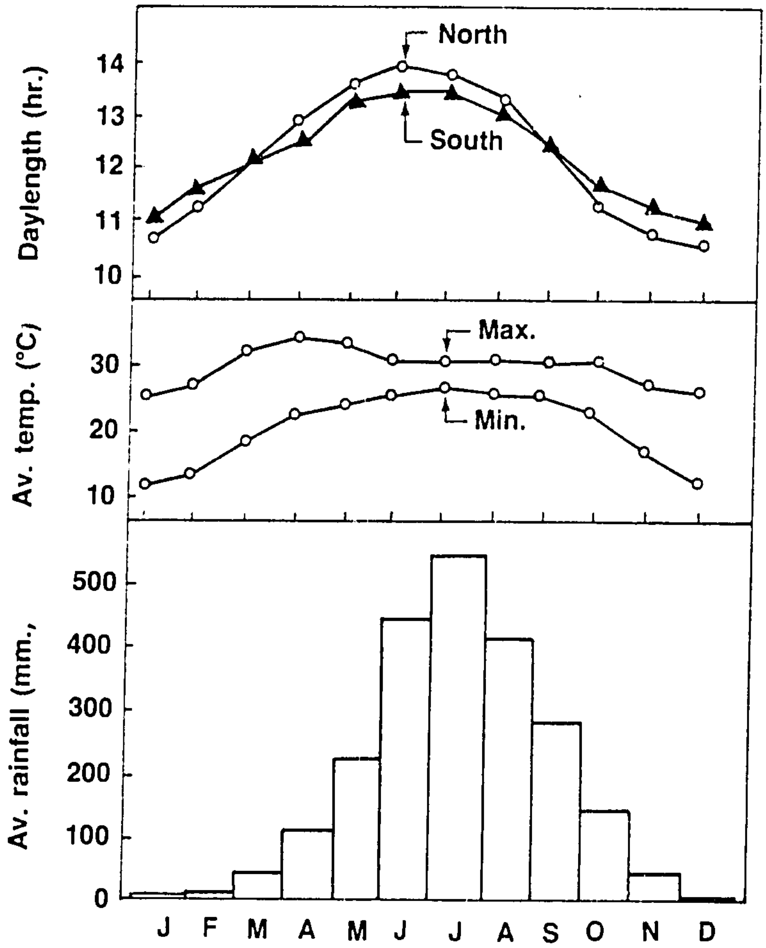

Fig. 1. Moı'thly average rainfall, temperature and daylength of Bangladesh.

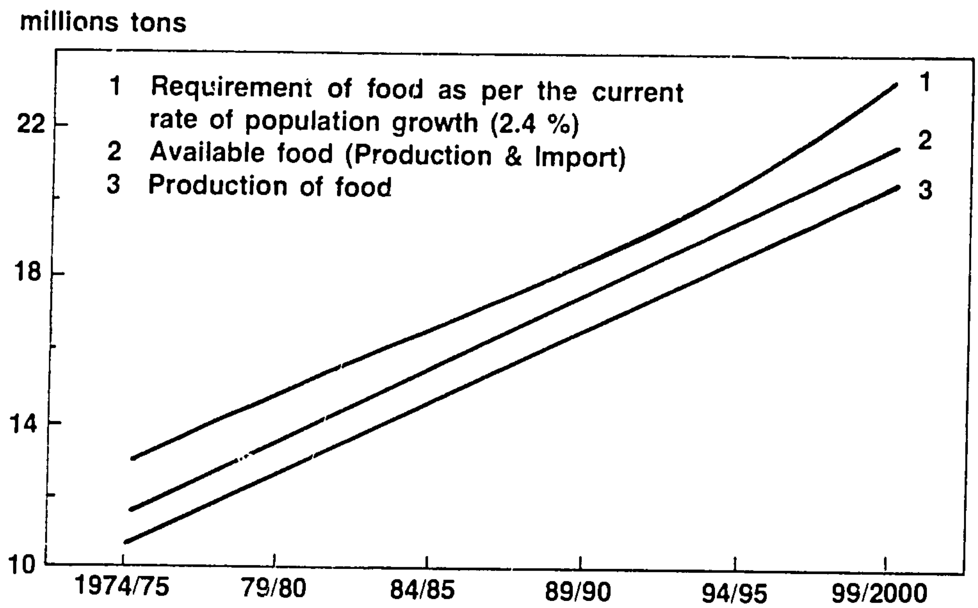

Fig. 2. Position of food supply in Bangladesh at present and in future. (Source: USDA, 1988).

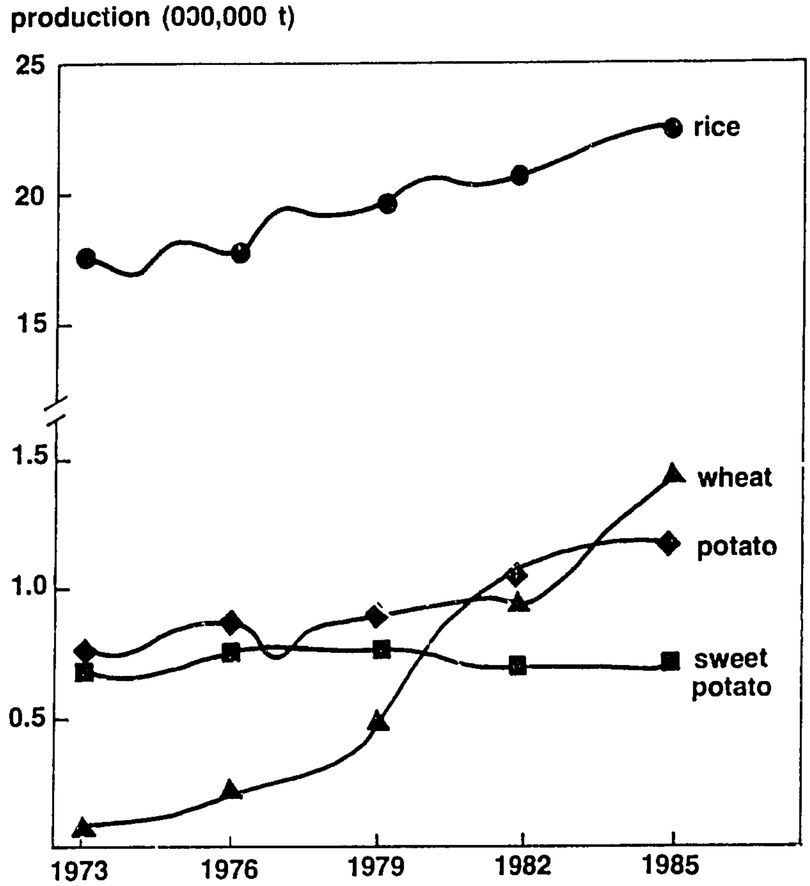

Fig. 3. Production of principal food crops in Bangladesh. (Source: FAO Production Yearbook).

Traditionally and habitually a Bangladeshi's meal consists of a plated of boiled rice and some curry. The average per capita per day intake of cereals in this country is over 500 grams compared to less than 100 grams of roots, tubers and vegetables. The daily calorie supply per capita is about 1,900, which represents less than 85% of the estimated requirements.

2. PRESENT SITUATION OF SWEET POTATO PRODUCTION IN BANGLADESH

Sweet potato is an important supplementary food crop of Bangladesh. Among the food crops it stands fourth in respect of production. The crop is normally grown in the winter season, the optimum time of planting being mid October to early November. The duration of sweet potato in the field is about five months in this country. The country produces about 714 thousand tons of sweet potato per year, with an average yield of 10.9 t/ha (Scott, 1988). With some minor year to year fluctuations, virtually there had been no major change in the production pattern of sweet potato in this country since 1971/72 (Table 1). But in case of other food crops, like rice, potatoes and wheat a remarkable increase in production took place during the stated period (Fig. 3).

Compared to 10373, 573.7 and 110.3 thousand hectares of land under rice, wheat and potatoes in Bangladesh, sweet potatoes are grown in only about 66 thousand hectares of land. The area under sweet potatoes comprise only about 0.74% of the total cultivable land of the country. The relative area, production and yield of the major food crops of Bangladesh are shown in Fig. 4.

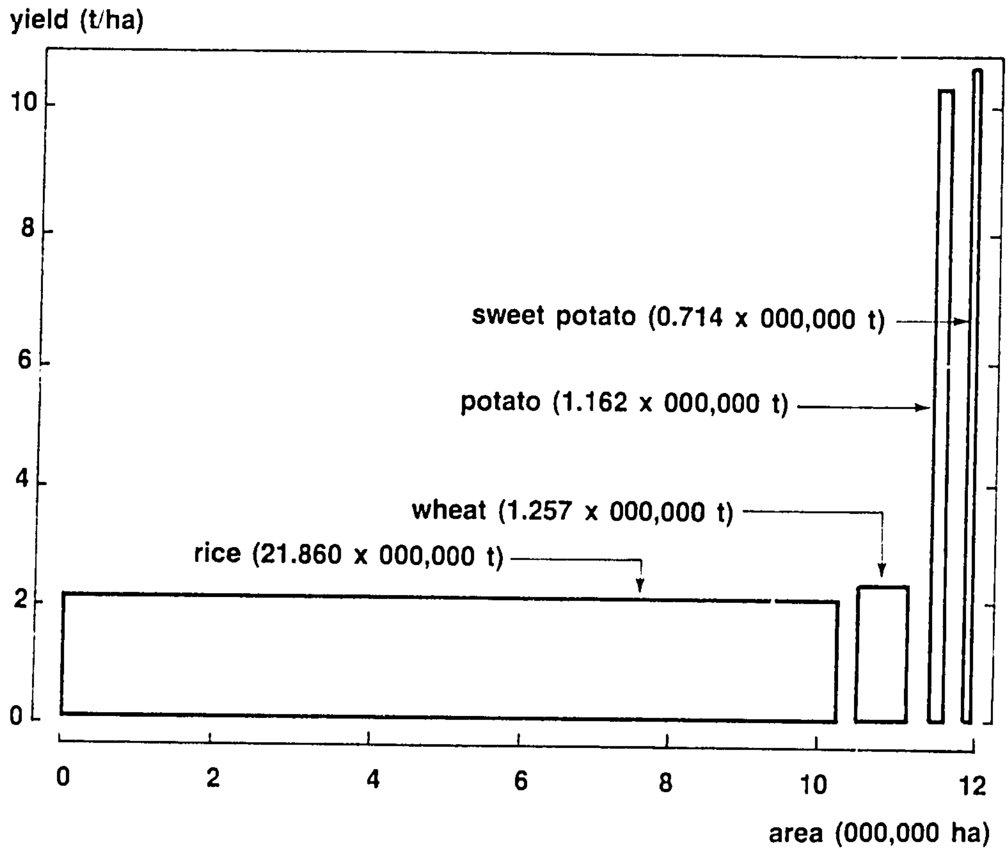

Fig. 4. Area, yield and production of principal food crops in Bangladesh, 1983-85 (Source: FAO Production Yearbook).

The important sweet potato growing areas of Bangladesh comprise the river belts, 'Char' lands, deltas and seasonally inundated flood plains of the country (Fig. 5). The major sweet potato growing districts are Comilla, Dhaka, Noakhali, Faridpur, Barisal, Patuakhali, Jamalpur, Kishoreganj, Mymensingh and Rangpur (Table 2). Mostly the small and marginal farmers are involved in the production of sweet potato in this country. About 44% of the sweet potato growers of Bangladesh grow sweet potatoes in less than 0.1 hectare of land; and only 8% of the growers allot more than 1.0 hectare of land for the production of sweet potatoes (Anonymous, 1984).

A recent thorough survey conducted by the Root Crops Project of Bangladesh, however, has indicated that the production level of sweet potatoes in Bangladesh was underestimated in all other reports including those of Bangladesh Bureau of Statistics (BBS) and FAO. As per the survey, Bangladesh produced 1,240 thousand tons of sweet potato in 82.36 thousand hectares of land in 1983/84, the average yield being 15.05 t/ha (Rashid, 1985).

3. IMPORTANCE AND USE OF SWEET POTATOES IN BANGLADESH

Sweet potato is a neglected crop in Bangladesh, and is considered as a poor man's food in this country. Almost the entire lot of sweet potatoes produced in Bangladesh is used locally as human food. During the harvesting season sweet potatoes are consumed as a staple or supplementary staple food, particularly in the rural areas. It is also consumed as a snack. Sweet potatoes are served mainly in the boiled and baked form. The sweet potato roots and leaves are also widely used as a vegetable both in the rural and urban areas. After harvest, the vines are used as cattle feed.

Sweet potatoes are mostly consumed fresh in this country. Only in limited quantities sweet potato flour mixed with wheat flour is used in making breads and cakes. Industrial use of sweet potato in Bangladesh is negligible. Very limited and occasional use of sweet potatoes in the manufacture of starch has been reported.

Table 1. Production trend of sweet potato in Bangladesh during 1971/72 to 1985/86.

Production year	Area (000 ha)	Production (000 t)	Yield (t/ha)
1971/72	67.26	735.32	10.93
1972/73	63.73	680.45	10.68
1973/74	60.60	626.79	10.34
1974/75	66.59	707.33	10.62
1975/76	71.65	778.11	10.86
1976/77	70.59	743.63	10.53
1977/78	71.87	770.36	10.72
1978/79	72.93	782.40	10.73
1979/80	72.39	778.77	10.76
1980/81	67.93	693.25	10.21
1981/82	66.27	680.61	10.27
1982/83	65.99	702.30	10.64
1983/84	65.30	701.77	10.75
1984/85	61.51	671.78	10.98
1985/86	55.87	602.29	10.78

Source: BBS

In the past, the importance of sweet potatoes was not recognized by the planners and policy makers of Bangladesh. Consequently, until recently, the crop did not receive any attention for its improvement and extension. Sweet potatoes are now considered as an important crop in the post-flood crop rehabilitation programme due to its high yield, low production cost and high nutritive value. It has also been realized that a greater thrust, leading to increased production and consumption of non-traditional staple food like sweet potatoes, should be given in order to minimize the food shortage of the country.

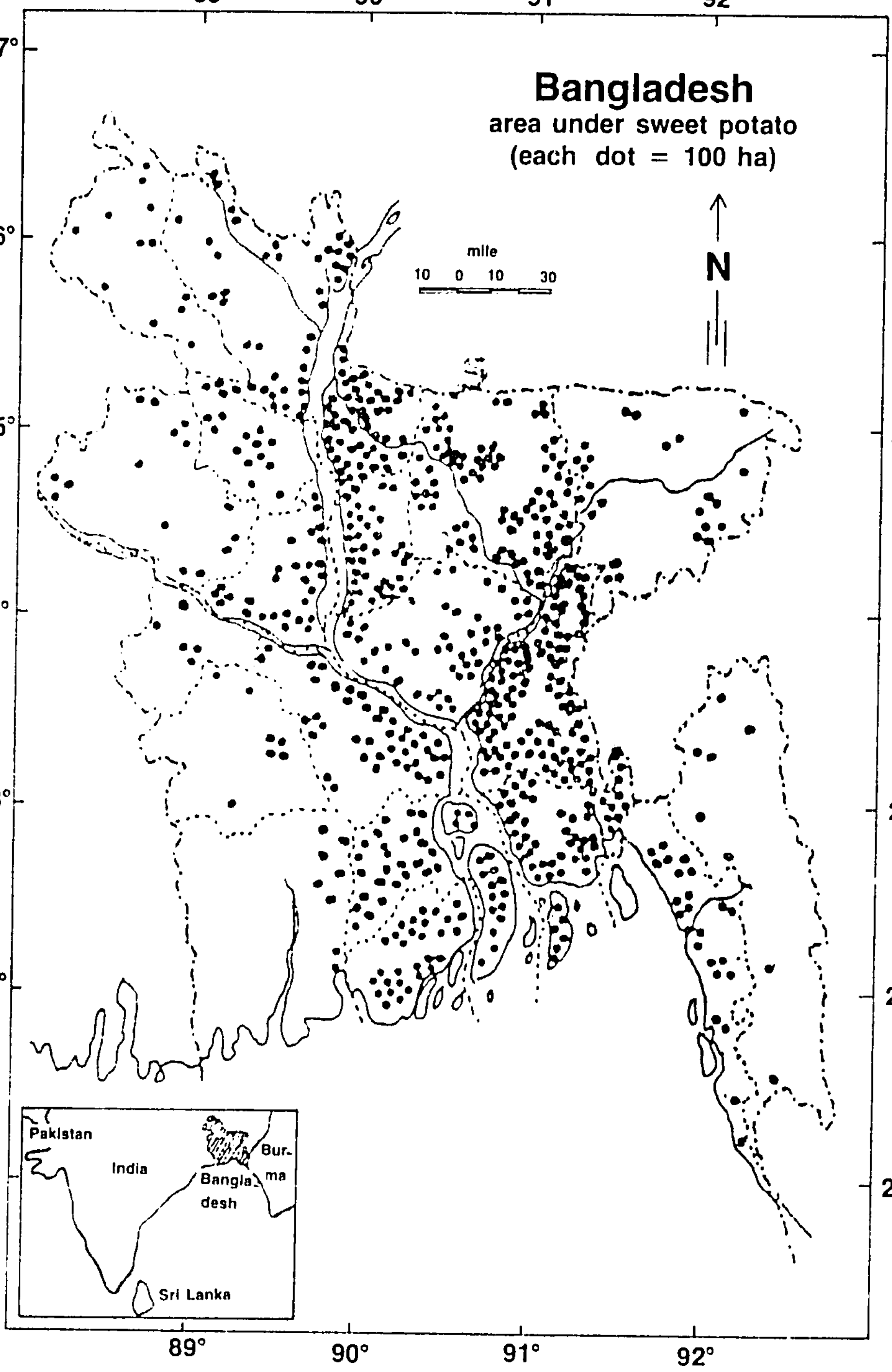

Fig. 5. Regional distribution of sweet potato in Bangladesh

Table 2. Area and production of sweet potato in different districts of Bangladesh during 1985/86.

Name of District	Area (ha)	Production (t)	Yield (t/ha)
Bandarban	151.8	1352	8.91
Chittagong	2678.1	35862	13.39
Comilla	7795.5	84695	10.86
Khagrachari	372.5	3947	10.60
Noakhali	3894.7	37480	9.62
Rangamati	234.8	2251	9.59
Sylhet	1864.4	24444	13.11
Dhaka	3374.5	41620	12.33
Faridpur	3301.6	35388	10.72
Jamalpur	5014.2	72217	14.40
Kishoreganj	2836.0	30910	10.90
Mymensingh	2471.7	34600	14.00
Tangail	1601.2	17892	11.17
Barisal	5161.9	50335	9.75
Jessore	753.0	6651	8.83
Khulna	827.9	12926	15.61
Kushtia	524.3	4128	7.87
Patuakhali	4358.3	30863	7.08
Bogra	1421.1	11348	7.99
Dinajpur	712.6	4895	6.87
Pabna	2325.9	21465	9.23
Rajshahi	1174.1	10198	8.69
Rangpur	3018.2	26818	8.89
Bangladesh	55868.3	602285	10.78

Source: BBS, 1987

4. PROBLEMS RELATED TO PRODUCTION, STORAGE AND MARKETING OF SWEET POTATOES IN BLANGLADESH

4.1. Cropping Patterns and Agronomic Aspects

As sweet potatoes are grown mainly in the flooded river belts and 'Char' areas, the lands used in the production of sweet potatoes are mostly single cropped. As soon as flood water goes down at the end of rainy season, the lands are prepared and sweet potato vines are planted. Planting generally takes place in the months of October and November. The crop is harvested in March-April; and only after a few weeks of harvesting flood water comes in and inundates the land again. The pattern thus is 'Fallow - Fallow - Sweet Potato'. However, in some relatively high lands broadcasted aus paddy is grown immediately after the harvesting of sweet potatoes, the cropping pattern being 'Broadcasted Aus Paddy - Fallow - Sweet Potato'. In few instances 'Broadcasted Aus Paddy - Transplanted Aman Paddy - Sweet Potato' followed by 'Broadcasted Aus Paddy - Fallow - Sweet Potato' pattern is found, particularly where the land is medium high (Elias, 1985).

Most of the sweet potatoes are grown under rain-fed condition in Bangladesh. A survey conducted throughout the country showed that only 8% of the sweet potato growers irrigate their crop (Anonymous, 1984). Although irrigation increases the yield of sweet potato to a great extent (Anonymous, 1985), the crop is raised without irrigation due to the dearth of irrigation facilities in most of the present sweet potato growing areas.

The production of sweet potatoes can be extended in the double and triple-cropped areas, where flood water does not get in and there is facility for irrigation.

In Bangladesh sweet potatoes are propagated entirely by vine cuttings. Both tip and middle cuttings are used. Vines are maintained in a small piece of land. In areas where the crop is grown in flooded soils; seed vines are maintained around homesteads during the rainy season. Farmers either use their own vines or procure the same from neighbouring farmers or from the local market. Up to recent past there was no institutional source for the supply of seed vines. Limited quantities of seed vines of improved sweet potato varieties are now supplied by the Agricultural Research Stations, Agricultural Extension Department and Bangladesh Agricultural Development Corporation.

The sweet potato growers often do not maintain an optimum spacing during the planting of vines. Plant spacings vary widely from place to place and farmer to farmer. Growing of the crop in flat method is more common throughout the country. However, in some areas ridges are made during the growth of plants.

About 60% of the sweet potato growers do not apply any chemical fertilizer in their crop. Those who apply fertilizers, do not do so in a judicious manner. Use of cowdung or farmyard manure is also not very common. This is mainly due to lack of awareness and knowledge. A good benefit can be obtained by applying balanced fertilizers particularly with high yielding varieties and under irrigated conditions (Siddique et al., 1985; Hossain et al., 1987).

Most of the farmers do not take any loan for sweet potato cultivation. There is no institutional source of loan for the production of sweet potato. About 50% of the growers are in the opinion that loan is not required for the cultivation of sweet potato. It is not due to their solvency, but mainly due to the utilization of a small piece of land and poor production practices followed.

4.2. Germplasm and Varieties

A large number of indigenous varieties of sweet potato are grown in Bangladesh. The varieties are mainly of two types - red skinned and white skinned, both having white flesh. There is a great variation among the indigenous varieties in shape, size and yield of tubers (Hossain and Siddique, 1985; Anonymous, 1985). Two high yielding and nutrient rich improved varieties, namely, Tripti and Kamalasundari have been released recently (Siddique, 1986). The farmers are still growing the indigenous varieties extensively due to non availability of vines of the improved varieties.

4.3. Pest Problems

Sweet potatoes are relatively free from serious insect pests and diseases in the field. However, in some areas and seasons weevil attack (*Cylas formicarius*) becomes a problem. The weevil often seriously damages the tubers in storage. Among other insect pests, cut worms, hairy caterpillar and crickets cause some damage in the field. There is no clear evidence of any major disease. Application of insecticides and fungicides is very uncommon. Damages caused by rats often become serious.

4.4. Storage of Tubers and Associated Problems

Sweet potatoes are highly perishable, and are seldom stored for a long period in Bangladesh. Most of the tubers are consumed or sold immediately after harvest. Some of the growers store a part of their harvest for future sale or consumption. The tubers are stored in the dwelling houses or in 'Doles' (bamboo made container). In the dwelling houses the tubers are kept either on a bamboo made platform or on the floor. Sometimes sand or wood ash is used between the layers of stored tubers. Rot, insect damage and sprouting are the common causes of spoilage in storage. The length of storage period under ordinary room conditions varies from 1 to 6 months, but in most cases not more than 3 months. Sweet potatoes are not cool stored in Bangladesh.

4.5. Marketing of Tubers and Associated Problems

Most of the sweet potato growers sell a part of their produce in the local markets. The big growers often sell their crop from the field to the visiting 'Beparis' (traders) who transport the same mostly by boat to the consuming markets. Sweet potatoes are also directly brought to the city markets by the growers. The main channel of sweet potato marketing in Bangladesh is 'Grower - Faria - Aratdar - Retailer'. The important sweet potato assembling markets in the country are Savar, Babuganj, Bera-Nakalia, Nandina, Daudkandi and Takerhat (Ahmed, 1985). Rapid perishability of the tubers, storage problems, increased transport cost and market glutting during the peak harvesting period are the major problems in the marketing of sweet potatoes in Bangladesh.

4.6. Price and Profitability

The price of sweet potatoes in Bangladesh is gradually increasing over the years. The average whole sale prices in the important markets of the country were Tk. 946, 1,416 and 1,629 per ton in 1983, 1984, and 1985 respectively (Ahmed, 1985). In this country more than 80% of the sweet potatoes produced are sold. The farmers consider this crop as a very profitable one. Under the existing production practices, cultivation of sweet potato requires an average cost of about Tk. 6,000 per hectare.

About 63% of this cost is incurred due to labour and 22% due to seed vines. With an average yield of 11 t/ha, the average gross margin stands at about Tk. 5,000 per hectare, compared to Tk. 3,000 in case of wheat (Clements, 1985).

4.7. Import and Export

A number of varieties and breeding lines of sweet potato were imported from time to time from different countries, namely, Taiwan, Japan, Nigeria and USA. The materials were collected in the form of tubers or seeds, and were used in the varietal improvement of sweet potato in Bangladesh. The collected genotypes are being maintained by BARI at Joydebpur. There is no report of any import or export of sweet potatoes for human or animal consumption or for industrial use.

5. RESEARCH ON SWEET POTATOES IN BANGLADESH

5.1. Historical Background

Until 1980, sweet potato did not find a good place in any institutional research programme. Only a few field experiments were conducted mostly in connection with postgraduate studies. In 1980 a contract research project sponsored by the Bangladesh Agricultural Research Council was initiated for overall development of the tuber crops having greater emphasis on sweet potato and aroids. The project was initially for 3 years, but subsequently extended for 5 more years. One of the authors of this paper, Dr. Md. Mamunur Rashid acted as the Coordinator of the project. Since 1 July, 1988 the activities of the project have been merged with the present Tuber Crops Research Center of BARI.

5.2. Objectives and Achievements

The research project had the following objectives:

- To develop improved varieties of sweet potato
- To standardize the method of production and storage
- To explore the possibilities of processing of the crop.

Substantial achievements have been made under the project. Two improved varieties of sweet potato named Kamalasundari and Tripti developed by the project have been released through the National Seed Board. Kamalasundari is very rich in carotene content, and Tripti is a high yielder.

Production technology in respect of time of planting, type of planting material, spacing, manuring and irrigation have been standardized. It was not possible to give adequate attention to the storage aspects. A number of experiments on the utilization of sweet potato flour as an ingredient of bakery products were conducted. Good results were obtained, but the findings have not yet been packaged into usable technology.

5.3. Institutional Facilities and Manpower

The root crop project mentioned earlier was implemented jointly by BARI and the Bangladesh Agricultural University. In doing so, existing physical facilities of both organizations were utilized. With the merger of the tuber crops with potato, the facilities available at the Tuber Crops Research Center of BARI will be utilized for future research activities. BARI has a network of sub-stations for field experiments throughout the country. A laboratory for research on the quality aspect of sweet potato is needed to be developed.

The contract research project on root crops was implemented with the help of both full time and part time scientific staff. For future research activities on sweet potato, there will be a shortage of trained manpower. New positions of scientific staff have been created, and recruitment will be made in near future. Specialized training of the new recruits will be necessary.

6. EXTENSION AND EDUCATION ON SWEET POTATOES IN BANGLADESH

Sweet potato was so long absent from the routine activities of the extension department. With the development of new improved varieties and associated production technology, the department of extension has included the crop in their programme. Several hundred demonstration trials of the new varieties are planned for the 1988/89 crop season. The extension department has a big network of staff up to the village level.

Sweet potato has been given adequate coverage in the curricula of the agricultural colleges and universities. It is included in the horticulture syllabi both at the undergraduate and postgraduate level. There is a programme of introducing short training courses on sweet potato for the officials of the extension department.

7. INTERNATIONAL COLLABORATION

In implementing the contract research project on tuber crops from 1980 to 1988, technical assistance in the form of supply of germplasm and literature was received from different international institutions like AVRDC and IITA. Several scientists from AVRDC and IITA have visited Bangladesh to see the sweet potato programme. There has however been no formal agreement with any international organization for support to this programme. For implementing the contract research project, partial financial support was available from USAID, Netherlands government and the International Foundation for Science.

A new project named Crop Diversification Project (CDP) in which overall development of pulses, oil seeds and tuber crops (potato and sweet potato) is envisaged is going to be started from the current year. The project, initially approved for 5 years has research, seed production and extension components for each group of crops and also has provision for development of infra-structure and manpower.

8. FUTURE PROGRAMME FOR RESEARCH AND DEVELOPMENT OF SWEET POTATO

8.1. Strategies for Development

As the season of growing sweet potatoes in Bangladesh is specific, an increase in its production will create problem for its marketing and storage. Experiences have shown that under ordinary room conditions the roots can be stored for only 2-3 months. Cold storing will make it too costly for the consumers who are mostly of low income group. To avoid the problems it is essential to find alternative uses for the roots. Manufacture of industrial starch and animal feed from sweet potato are two prospective areas for exploration. At the same time efforts may also be made to increase its direct consumption. In the coming years studies on the feasibility of establishing mini factories for the processing of sweet potatoes will constitute a major area of activity. Sweet potato flour may also be promoted as an ingredient of various food items, particularly by mixing it with wheat flour.

8.2. Research programmes and priorities

For the overall development of sweet potato in Bangladesh it is necessary to strengthen research activities in the following areas:

8.2.1. Variety development

The two newly released improved varieties are moist fleshed and relatively less sweet. Due to the moistness of flesh the varieties have encountered some dislikings from the consumers who are used to dry fleshed varieties. In view of this fact it is necessary to develop varieties that combine high yield with dryness and sweetness of flesh and high carotene. Hybridization work towards this direction has already been started and will be strengthened during the coming years.

8.2.2. Storage

The area of storage deserves serious and immediate attention. It may be possible to extend the storage period of sweet potatoes to some extent by applying simple management practices. The economic feasibility of storing sweet potatoes under refrigerated condition will also be examined.

8.2.3. Processing

The per capita direct consumption of sweet potato in Bangladesh cannot be increased substantially mainly due to the briefness of the period of its availability. Hence, processing in some form or other offers the possibility of taking up a programme for the expansion of sweet potato production in this country. Since the potential yield of sweet potato is high and its production cost is relatively low, the crop is expected to be a cheap raw material for processing. The assumption needs to be confirmed through research.

8.2.4. Infra-structure and man power development

Physical facilities for conducting field oriented experiments on sweet potato are available. The existing network of research sub-stations of BARI can be used for this purpose. Laboratory facilities of the tuber Crops Research Center are not adequate for conducting research in different areas. Additional laboratory equipments will be required.

Manpower with specialized training on sweet potatoes, particularly in the area of post-harvest technology and processing is very much lacking. Training of manpower in processing and breeding will be needed in order to implement the proposed research programme.

8.2.5. International collaboration

So long the international collaboration for sweet potato research in Bangladesh was limited to the procurement of germplasm from AVRDC, IITA and some other organizations. In the coming years there is a plan to extend the same to other activities so that expertise available in other countries may be utilized, particularly in the area of processing. In view of the new mandate of CIP to take up sweet potato, the existing cooperation with that organization will be strengthened.

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SWEET POTATO PRODUCTION AND RESEARCH IN CHINA

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1. INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the major crops in China. It was introduced into China 420 years ago. Since then, it has spread to almost every province of China. It can be grown from Hainan Island in the South (18 N) to Heilongjiang province in the North (45 N) and at elevation ranging from sea level to more than 2,000 m. Sweet potato now ranks as the fourth most important crop after rice, wheat and corn.

Growing sweet potato provide famine relief food for the people. It is also being fed for animal husbandry particularly pigs and used as raw material for starch industry. On a worldwide basis, China is the largest sweet potato producer. It produces and utilizes approximately 80 percent of the world's sweet potato. China has a massive amount of experience and expertise in sweet potato production and research. Also, many problems and constraints need to be solved and removed.

2. COUNTRY PRODUCTION DATA

From 1940's-1980's, sweet potato sown area in China varied greatly, about 3,344,000 hectares in 1946 increased to 5,811,000 ha in 1950. The sown area peaked in 1963 with 9,640,000 ha in the wake of the 1959-62 famine period. From then on, area declined steadily. Total sweet potato sown area in China is now at its lower level in recent history. In 1987, 6,174,700 ha of sweet potato were planted.

The average yields, however increased steadily from 8.9 t/ha (1940-1949) to 13.35 t/ha (1970-1979), and to 17 t/ha in 1982-1984. The yield level vary a lot in different regions. In Shandong, average yield has increased to 24.46 t/ha in 1987, but Guangxi province has the lowest yield of 4.94 t/ha only. This differences are attributed to natural conditions, varieties, agronomy practice and mostly, the supplementation of fertilizers. (See Table 1, and Table 2).

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Categorized according to the conditions of geography, climate and cropping systems, the production area in China can be divided into five zones.

2.1. Northern Spring Cropping Zone

It is a,narrow area including a portion of north China and northeast China. About 5% of Chinese sweet potato is planted in this zone, mainly in spring cropping.

2.2. Yellow-Huai River Basin

It locates between Yellow River and Huai River, and it covers 40% of China's total sweet potato growing area. In this region, sweet potatoes are planted in both spring and summer cropping.

2.3. Yangtze River Basin

This belt includes some portions of those provinces along Yangtze river only except Qinhai plateau and mountain area in west Sichuan, about 30% of China's total sweet potato distributed in this zone mainly cropped in summer type.

2.4. Southern Summer and Autumn Cropping Zone

It is a narrow and long belt between Yangtze river basin and the Tropic of Cancer. About 15% of Chinese sweet potato cultivated there mainly in summer and autumn cropping.

2.5. Southern Autumn and Winter Cropping Zone

Only 10% sweet potato are planted in this zone but sweet potato can be grown here all year round. This zone includes the southern coastal area and some islands in South China Sea. (See Table 3).

3. IMPORTANCE OF SWEET POTATO IN CHINA

Sweet potato is one of the most important crops in China. It ranks the fourth in terms of sown area only after rice, wheat and corn. Historically it had played a very important role in providing relief food against famine in the event of calamity. Sweet potato is an integral part of life of every family. In 1950's, about 60 percent of total Chinese sweet potato was for direct human use. Even before 1970's, sweet potato was still served as staple food in the rural area.

In the past ten years, sweet potato for human consumption has declined rapidly due to bountiful harvests of other crops such as rice, wheat and corn. Now, most of sweet potato in China is used as food for livestocks, particularly pigs, and used as raw material for starch processing.

China's food crop production peaked in 1984 (400 million tons). After that, it declined and has hovered for several years. Calamities, particularly drought made it difficult to increase the yield of other fine grain crops without big amount of input. So, in those areas where irrigation is not available, sweet potato is the best choice for its lower input requirement, comparative stable yield and high productivity.

China's food supply is about 370 kg per capita, that is the biggest restriction of the developing of animal husbandry; sweet potato has been playing a very important role in pig feeding which provide most portion of protein for Chinese people. In Sichuan province, the biggest pork producer of China, it is estimated that 60% of sweet potato is used as food for pigs.

The following utilization purposes were investigated by the Chinese Agricultural Ministry in 4 biggest sweet potato producing provinces (1987).

About 14.4 percent of sweet potato in these provinces were used as staple food and food processing. (Processing is usually made in family or village enterprises, products include noodles, dried, candied and preserved sweet potato bits, jam and other handicraft items).

About 43.3 percent used as food for livestocks (mainly for pigs). A small portion was used as food for cows and poultry. Sweet potato vine are also used for this purpose.

33.3 percent are used for industrial purpose, major products are starch, alcohol, citric acid, etc.

Nine percent is used as seed plus storage losses.

4. PRINCIPAL PROBLEMS

4.1. Seed Production

Practically, there is no sweet potato seed production system in China. Seed company has not put sweet potato into their business due to the high cost on storage and transportation. Farmers have to propagate and store seed by themselves, which often results in variety mixing. Even though the seed division of Chinese Agricultural Ministry had a regulation on seed roots tuber grading and quality requirement, it has not been conducted practically.

4.2. Germplasm and Variety

Large number of new varieties have been developed by Chinese Scientists since 1950, which has greatly improved the sweet potato production in China. Also, a lot of work has been done on germplasm collection preservation and utilization. However, the varieties used in production have some shortcomings, such as lack of multiresistance. Xushu 18 is the example, it has good resistance to root rot and has high productivity but is very susceptible to black rot and rot nematode. When this variety was distributed to Sichuan, black rot limited its yield productivity. Poor adaptability is another problem. In 1985, 4 starch type varieties were released by the national breeding program, but they were not accepted by farmers due to their poor adaptability in barren land. Varieties with superior characteristics are inadequate. The demand for high dry matter, good eating quality and high yield has not been met. No population improvement approach taken as a part of variety improvement in China. Further genetic improvement has gradually become more difficult due to lack of superior parental clones in breeding program.

The selection method and efficiency also need to be improved. Such as rapid screening and identification of nutrition quality and disease resistance.

4.3. Diseases

More than 30 different sweet potato diseases have been reported in China. Among them, black rot (Ceratocystis fimbriata), root rot (Fusarium solani), rot nematode (Ditylenchus destructor), and bacterial wilt (Pseudomonas solanacearum) are considered as 4 major diseases. Scab (Sphaceloma batatae) and Fusarium wilt (Fusarium oxysporum var. batatae) are also important diseases in some areas. During storage, soft rot (Rhizopus nigricans) and dry rot (Fusarium spp.) are the greatest pathological limitation.

Black rot is a problem in all sweet potato growing area, but in South China it is less severe than in north. Root rot mostly occur in Yellow River and Huai River basin. Yield reduction caused by this diseases range from 10-100 percent.

Rot nematode, though can be a problem in all China. Severe yield loss was found in north China. It also damaged tubers during storage. Ten to fifty percent yield reduction is estimated.

Bacterial wilt of sweet potato, a disease caused by Pseudomonas solanacearum has been reported only in south China. In this region it does occur; it can be severe, causing yield reductions estimated from 30-40% to 70-80%.

The root-knot nematode is another destructive nematode of sweet potato; it is mainly distributed in Shangdong coast area and Zhejiang province, reducing both yield and root quality.

In recent years, concern for virus diseases was increased due to the increasing virus symptoms in collected germplasms. In Xuzhou Institute SPFMV and SPLV were identified in two thirds of their introductions presenting virus sypmtoms.

In Sichuan province, one very susceptible variety Okinawa 100, often exhibited field losses estimated at 30 percent. Clonal material with healthy appearance derived from meristem tip tissue culture yielded 47% more with 3% higher dry matter than diseased (SPFMV) material.

In all China's sweet potato production, however virus disease has not been a serious problem yet. Also, they are not well characterized and little is known about their yield reduction effect.

4.4. Pests

The weevil (Cylas formicarius) is the most important insect pest in south China, it attacks the sweet potato tubers both in the ground before harvest and during storage. The estimated yield loss ranges from 5 to 20 percent in Guangdong province.

More than 20 different sweet potato insect pests are also found in China. Generally speaking, the yield reduction caused by pests are much less than diseases.

4.5. Storage

Sweet potatoes are stored in two forms: one is stored in form of fresh tubers, another is in dried chips. The latter is only available in north China and is much more safer than the former.

During storage, soft rot is the most important problem followed by black rot, the former is caused by Rhizopus sp. that penetrates wounds. In the 1960's, a good storage system had been developed by Chinese Scientists and well practiced in rural areas. The storage loss was greatly reduced by avoiding injuries to tubers, avoiding cold storage temperatures, using fungicide dip prior to storage and heat treatment for healing. But storage loss have increases since commune was dismantled in the 70's and large heated stores are no longer used. Control of rots is necessary, especially for prolonged storage of seed tubers. In Hebei province, estimated storage losses are 10-20 percent while in Anhui province 40% of sweet potato was rot during storage.

Additional storage problems are rot nematode and green mold (Botrytis cinerea), the latter also causes soft rot.

4.6. Constraints Related to Cultivation

- Environmental stresses such as drought and flooding (mostly drought)

- Poor soil fertility which often associated with drought stress. Usually encountered in hillside, production area.

- Frost injury during the early spring cropping or towards the end of the summer cropping season.

- Low production input available for sweet potato cultivation. Sweet potato usually received little input of fertilizer and water, which leads to poor seedling growth in the nursery, delayed transplanting time and poor root production.

- Planting density is often inadequate when intercropped with corn or other crops.

4.7. Marketing

The major barriers in sweet potato marketing is no stable market requirement for sweet potato. Not like rice, wheat and corn, the government grain bureau has not purchased sweet potatoes in recent years. The starch or alcohol factory only purchase dried chips and most of their requirement is bought during peak season when the price is lower. Payment to farmer is entirely on delivery of product contrasting with the circumstances for some other crop subject to advance purchase agreements (free credit) or subsidized input (e.g. high quality fertilizer) allocation prior to planting, or as reward for sales.

4.8. Utilization and Processing

Starch production is mostly a family or village business and the product is often made into noodles, but this business was not very profitable due to poor product quality and backward processing technology. Besides, lack of facilities and equipment in processing is also concerned. The waste after starch extraction is not used which might be a useful resource for further processing.

5. QUARANTINE REGULATION AND GERMPLASM EXCHANGE

The national custom is in charge of the quarantine for import and export of sweet potato for human or animal consumption.

International germplasm exchange requires the involvement of the Quarantine office of the airport and the Institute of Crop Germplasm Resources (ICGR). Two sweet potato diseases *Pseudomonas batatae* (Cheng et al.) and *Xanthomonas batata* (Hwang et al.) are for strict control. Virus diseases are not mentioned in the quarantine regulation. The incoming germplasm will be first received by National Quarantine office (QO) and then by either QO or ICGR for phytosanitary status. In the case of germplasm export from China, ICGR checks germplasm and coordinates with QO for issuing phitosanitary statement.

6. NATIONAL SWEET POTATO PROGRAM

Sweet potato research program is under the leadership of Chinese Agricultural Ministry and National Science and Technology Committee. More than 100 Chinese scientists are emphasizing on breeding program. Breeding objectives are set up for three types of use. However, all new varieties should have good adaptation for environment and growing conditions of the area and have resistance to at least one of the four major diseases/pests.

6.1. Staple Food or Supplementary Staple Food

Specific attributes for this type of use are high nutritional value (5 mg of B-carotene per 100 g of fresh roots, 10 mg of Vitamin C per 100 g of fresh roots), sweetness (3% of soluble sugar per 100 g of fresh roots) and good shape (spindle type). Yield requirement is not as strict as for industrial use, but acceptable yield is required.

6.2. Animal Feeding

High vine yield as well as high root yield are needed. During a growing period, vines are usually harvested three times or more by farmers. Thus, varieties should have a vigorous vine regrowth after vine cutting. The target is to get varieties with a total dry matter yield (vines and roots) 10% higher than that of Xushu-18, the leading variety.

6.3. Industrial Use

The present leading variety is Xushu-18 with a dry matter content of 27-28%, and starch content of about 20%. The aim is to produce varieties which have starch contents higher than Xushu-18 by 3% and 2% in the spring crop and summer crop, respectively. Yield should be as good as or better than that of Xushu-18 and thus, total starch yield per unit area must be 10% higher than that of Xushu-18. Genotypes of white color starch are highly desirable.

6.4. Breeding Strategies

The methodologies that have been utilized by the sweet potato breeders in China to select and develop improved cultivars are as follows:

Germplasm introduction, testing and selection, intervarietal hybridization and selection, inbreeding, hydridization with wild relatives, induced mutation, and natural clonal variation.

To explore new breeding methods to backstop breeders national program are actively involved in developing and testing some new basic ideas such as mutation breeding, cytochemical screening techniques, use of wild germplasm, in vitro variation selection, protoplasm fussion and genetic transformation.

Most of the breeding projects are carried out in agricultural research institutions and universitites in more than 20 provinces. The main research groups are in Xuzhou, Nanjing, Shangdong, Beijing, Sichuan, Zhejiang, and Guangdong. The germplasm resources were assembled in Xuzhou and Guangdong respectively. Presently, 15 provinces were included as active members in the breeding program at national level. Three agro-ecological regions are designated. Annually, 20 or 30 entries are submitted by member provinces and evaluated in about 20 locations.

6.5. Education and Extension

There are more than 30 Agricultural Universities in China. The crop breeding and agronomy department in almost every university have the courses on sweet potato. Now M.S. training for sweet potato science is also available in Beijing, Zhejiang Henan, Sichuan, etc.

The Agricultural Bureau and Seed Company in each province is in charge of new variety examination, approving an extension.

6.6. Future Plan

Now, China's sweet potato breeding has reached a plateau due to the inadequate parental lines with superior characteristics and slow improvement on the breeding methodology. New idea and new germplasm must be taken into use for the further progress.

First, the conventional breeding method should be still considered as the main approach for sweet potato development in future. Certainly, it is necessary to enhance the breeding efficiency rather than enlarge the breeding scale. The breeding goal has to be altered from the single quantitative selection into qualitative selection such as for high starch content purpose.

Second, the modern biotechnology probably can bring a bright future to sweet potato breeding. For instance, haploid breeding should be a desirable approach to induce more heterosis in sweet potato than general sexual plants. The plant tissue and cell culture in vitro of sweet potato can provide an opportunity for increasing the possibility of inducing genetic variation for somatic clonal variation selection. The in vitro fertilization technique, the protoplasts fussion and genetic transformation will make introduction alien gene into cultivar possible.

7. INTERNATIONAL COLLABORATION FOR SWEET POTATO IMPROVEMENT

China has had some collaboration with international organizations and foreign countries for sweet potato improvement. CIP has already had contract and project with two Chinese institutions (Xuzhou Sweet Potato Institute and Gangdong Agricultural Academy) on germplasm research. IITA also has a coooperation project with Guangdong AAS on this aspect. AVRDC have had its regional trail at Xuzhou, Jiangsu, Sichuan and Guangdong. FAO/IAEA had collaborated with Beijing Agricultural University on radiation mutation breeding for sweet potato.

The Chinese Scientists hope to strengthen and broaden these collaboration in the following aspects:

- Exchange methodology and technology for sweet potato improvement.
- Exchange germplasm and wild relatives to broaden the genetic background.
- Exchange production and research experience and information.
- Cooperation on virus diseases identification, postharvest and processing technology.

Table 1. Sweet potato sown area, yield, total output in China

Ages	Sown area ('000 ha)	Yield (t/ha)	Total output (million tons)
1940's	581.1	8.90	51.50
1950's	721.8	10.65	76.59
1960's	948.7	9.60	90.95
1970's	813.0	13.35	105.63
1980's	675.0	17.00	110.50

Table 2. Production data of top ten sweet potato producing provinces in China (1986).

Provinces	Sown area ('000 ha)	Yield t/ha)	Total output ('000 tons)
Sichuan	1,229.50	15.53	19,100.00
Shangdong	818.00	24.46	20,015.00
Henan	783.30	11.38	8,910.00
Anhui	658.20	21.06	13,860.00
Guangdong	579.50	11.96	6,930.00
Hebei	351.90	15.98	5,625.00
Jiangsu	275.10	24.17	6,650.00
Hunan	265.20	13.39	3,350.00
Guangxi	236.70	4.94	1,170.00
Fujian	216.80	15.25	3,305.00
China total	6,174.70	16.22	100,165.00

Table 3. Climate conditions and cropping systems in five production zones.

Environment and cropping type	Sweet Potato Production Zones				
	I	II	III	IV	V
Rainful (mm/year)	450-750	480-1100	780-1800	960-2690	1510-2060
Annual average temperature (C)	10.5	13.8	16.6	20.0	22.4
Frost-free period (days)	130-140	210	225-310	290-350	325-365
Cropping type	Mono cropping	tripple cropping in 2 years	double-cropping or tripple cropping in 2 years	double-cropping	tripple or multi-cropping
Main rotated crops	Maize, soybean, potato, spring wheat, sorghum, millet	Maize, soybean, peanut, rape, winter wheat	Winter wheat, barley, rape, pea, faba	Spring wheat, soybean, early rice	Soybean, Peanut, early rice, vegetables

SWEET POTATO PRODUCTION, UTILIZATION AND CONSTRAINS IN INDIA

G. G. Nayar and P. G. Rajendran[1]

1. INTRODUCTION

Sweet potato, the highest amount of calorie producer per unit land area of all useful crops, is yet to receive its due importance in India. Apart from its importance as a food crop, it has recently come to be considered promising as an industrial raw material with reference to biomass energy. But ironically the area and production of sweet potato in India has recently come down. In 1980-81 the country had an area of 0.208 million hectares under the crop and the production was 1.5 million tonnes of tubers. In the year 1985-86 the area was reduced to 0.17 million hectares and the production came down to 1.36 million tonnes (Table 1). The productivity of sweet potato in India is almost 50% of the world/Asian average (8.16 t/ha). The crop occupies only about 0.11% of the total cropped area of the country which is lesser than the area under potato (0.46%) and cassava (0.17%).

Eventhough the crop is grown in 19 States/Union territories of the country, the bulk of area and production confined to Orissa, Bihar and Uttar Pradesh (Fig. 1).

2. GENETIC STOCKS AND VARIETIES

The important centre in the country with regard to sweet potato germplasm is CTCRI, Trivandrum. A total number of 835 genetic stocks are being maintained at the centre which are being systematically evaluated based on important descriptors and catalogued. The exotic sources are Japan, Taiwan, Nigeria, Puerto Rico, USA, Sudan, Nairobi, Argentina.

Recently a joint exploration and collection programme was undertaken along with NBPGR regional station, Trichur and few collections have been added to the germplasm from Karnataka.

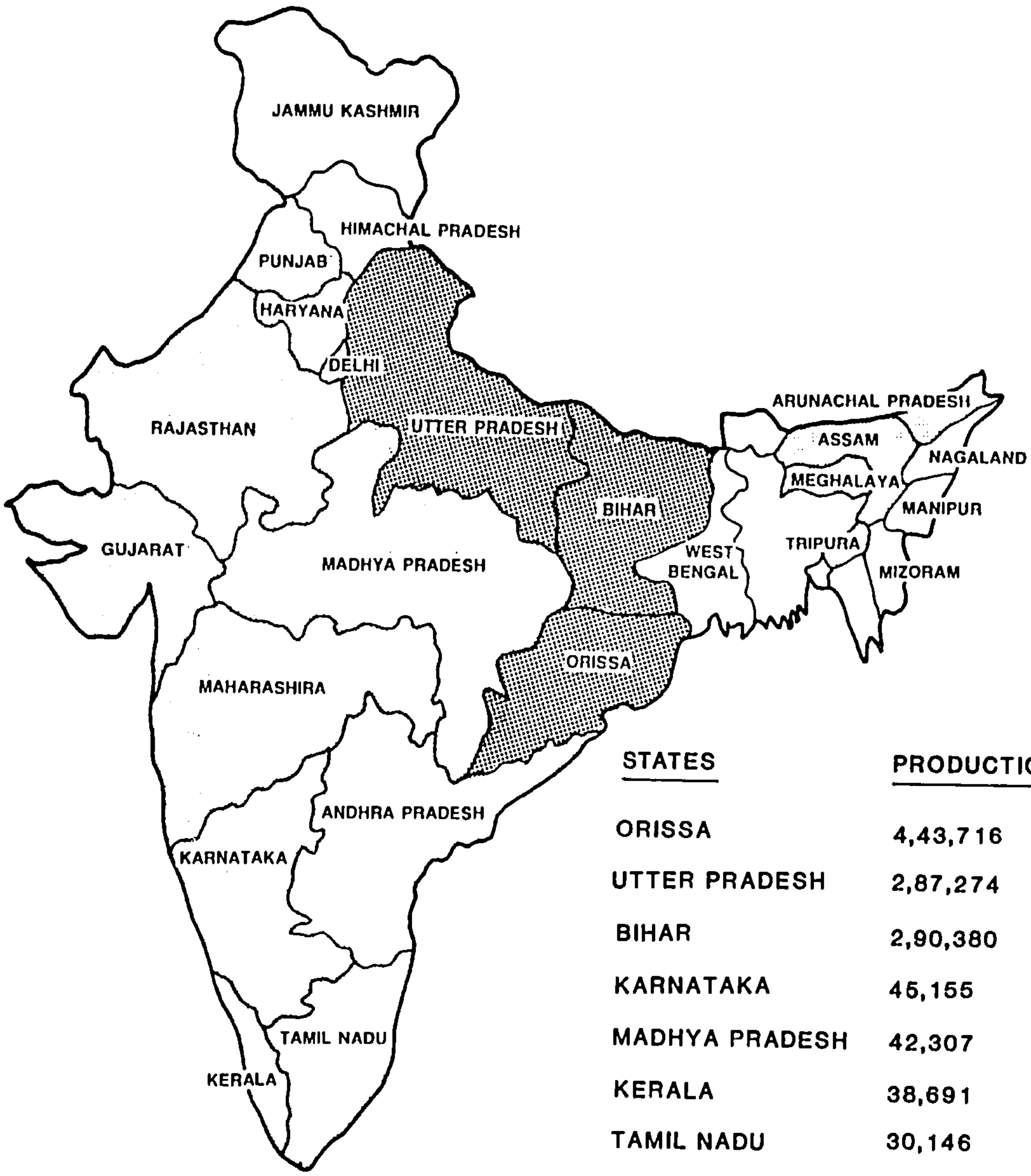
About 275 accessions of sweet potato are being maintained at NBPGR Satellite Centre, Amaravathi.

Germplasm is also maintained in the two All India Coordinating Centres of tuber crops as follows:

R.A.U. Centre, Dholi	498 accessions
CTCRI regional Station Bhubaneswar	407 accessions

[1]Central Tuber Crops Research Institute, Trivandrum 695 017 India

SWEET POTATO PRODUCTION IN INDIA 1985-86



STATES	PRODUCTION (TONNES)
ORISSA	4,43,716
UTTER PRADESH	2,87,274
BIHAR	2,90,380
KARNATAKA	45,155
MADHYA PRADESH	42,307
KERALA	38,691
TAMIL NADU	30,146
ASSAM	27,360

Table 1. Sweet Potato Area and Production 1985-86

	Area (ha)	Production (Tonnes)
Andhra Pradesh	2,700	14,800
Assam	8,248	27,360
Bihar	35,669	2,90,380
Gujarat	856	12,540
Haryana	1,082	19,165
Karnataka	7,053	45,155
Kerala	4,601	38,691
Madlhya Pradesh	7,123	42,307
Maharaahtra	5,200	74,400
Orissa	58,673	4,43,716
Punjab	72	429
Rajasthan	1,893	3,308
Tamil Nadu	1,398	30,146
Tripura	1,397	13,753
Uttar Pradesh	31,834	2,87,274
Arunachal Pradesh	300	1,400
ALL INDIA	1,72,649	13,60,645

Source Agricultural situation in India August 1987.

In the recent past, the following number of exotic collections have been introduced to India through NBPGR.

Source	No. of collection	Form of introduction
Nigeria	87 seedling selection	True seeds
Puerto Rico	12	Tuber
U.S.A	2	Tuber
Japan	2	Tissue culture
China	6	Tissue culture

3. PROBLEMS IN THE EXCHANGE OF GERMPLASM

Germplasm exchange in the form of tuber is likely to transmit many diseases, insect problems from the source to the new centre. So introduction of genetic stocks through *in vitro* culture is adopted to check bacterial, fungal and mycoplasm infection.

4. PRESERVATION OF GENETIC RESOURCES

Sweet potato germplasm is normally propagated in field by means of vine cuttings. This is risky as valuable materials may get lost due to adverse weather insect or disease problems. So *in vitro* preservation technique has been initiated at CTCRI as an alternative method of preserving sweet potato germplasm.

The successful introduction of a sweet potato plant through *in vitro* culture would imply that the plantlet is probably free from bacterial, fungal and mycoplasm infections. The plantlet may still however, be infected with viruses or viroids. The maintenance of the plantlet *in vitro* (rather than in the field) does, however, limit further viral degeneration of the collections that could result from cross contaminations. It is therefore, possible to enhance the phytosanitary status of the collections by *in vitro* introduction. It is also beneficial to virus/viroid eradication programmes which already have the germplasm in *in vitro*.

5. POPULAR VARIETIES GROWN IN MANY SWEET POTATO REGIONS

In Kerala, "Kanhangad" is the most popular local variety. Recently CTCRI has developed and released two sweet potato varieties for early harvest viz. "Sree Nadini" and "Sree Vardhini" which have recorded an average yield of 20 t/ha at 105 days after planting.

In Bihar X-5 (RS-5), X-24, X-25, V-35 and Kalmengh have been identified as promising varieties. They have recorded an average yield of 15-20 t/ha.

In Andhra Pradesh, S-30 (Samrat), C-71, Kalmegh and OP 21 are the promising varieties. In Tamil Nadu, V-35 and Co-2 are the popular varieties. In Jorhat, V-35 and C-43 are reported to be good yielders. For Maharashtra region, H-268 developed by CTCRI is the popular variety.

6. BREEDING ASPECTS

Although sweet potato is an important food crop, the improvement of the crop has been given very little attention. The major problems in breeding are non-blooming, erratic blooming and low fertility of blossoms due to self-and cross-incompatibility and sterility (Fujise, 1964, Martin, 1965, 1967). Seed set is rare even in the most compatible groups. High seed set may indicate good physiological balance or low genetic load and high seed set may lead to long term yield improvement (Jones and Dukes, 1976).

6.1. Major Breeding Objectives

- High yield potential
- Palatability
- Resistance/tolerance to pests and diseases
- Wider adaptability
- Early maturity
- Drought resistance
- Good keeping quality
- Processing and nutritional value

6.2. Breeding Strategies

The conventional breeding methods like introduction, selection and hybridization are extensively used in sweet potato improvement.

7. INTRODUCTION

Genetic stocks are collected from as many diverse sources as possible and they are systematically evaluated for various economically important characteristics.

8. SELECTION

The larger the population size one can handle the higher the selection intensity that can be imposed on the population and retain genetic diversity for the improvement of trait. Mass and recurrent selection techniques have been used for sweet potato improvement in India.

9. HYBRIDIZATION AND EVALUATION OF OPEN POLLINATED PROGENY

These two techniques have been extensively used in the breeding of the crop. Two high yielding single cross hybrids H-41 and H-42 were released by CTCRI in 1971 for cultivation in Kerala State (Magoon *et al.*, 1970). Another high yielding double cross hybrid H-268 was released for Konkan region of Maharashtra. Taking advantage of the incompatibility mechanism prevalent on sweet potato, screening of open pollinated seedlings lead to the identification of two promising selections 76-OP-217 and 76-OP-219 (Nayar *et al.*, 1984). Rajendra Agricultural University, Bihar released a high yielding, early maturing hybrid 80/168 developed by CTCRI (Nair *et al.*, 1986) recorded a yield of 19 t/ha in 3 months and contained high carotene of about 7000 i.u. which is very near to that in carrot.

10. POLYPLOIDY

Interspecific hybridizations have been successfully done between diploid species but crosses between tetraploid species and between diploid and tetraploid species have been less successful. Miyazaki and Kobayashi (1975) succeeded in synthesizing Tetraploid Sweet Potato (2n= 4x= 60) by using the species I. trifida (3x) I. batatas (6x) and I. leucantha (2x). By crossing tetraploid sweet potato with hexaploid species few pentaploid sweet potato (2n= 5x= 75) were synthesized (Vijaya Bai and Hrishi, 1977). A few pentaploid were found superior to the hexaploid in yield and other attributes. Two high yielding promising pentaploid identified were 5x 45 and 5x 34. Successful crosses between hexaploid and pentaploid were done and many obtained. Some of the superior pentaploid lines are under various stages of evaluation.

11. AGRONOMIC PRACTICES

In India sweet potato is grown throughout the country, utilizing the monsoon rains during Kharif (June-July) and under irrigation during rabi (October-November). Investigations carried out at different regions on the optimum time of planting revealed that planting in late September or early October (Shanmugavelu et al 1972) and in the months of October-November (Singh and Mandal, 1976) resulted in the highest tuber yields of sweet potato in hilly tracts of Tripura when planted in June.

Sweet potato is usually propagated through vine cuttings obtained either from freshly harvested plants or from nursery. Ray et al., 1983, observed that the recurrent use of vine as planting material did not show any market variation in the market grade tuber yield, but it significantly increased weevil infestation in tubers. Vines obtained from nursery are healthy and vigorous resulting in maximum tuber production (CTCRI, 1971).

Mount method, ridge and furrow method, bed method and flat methods are practiced in different parts of the country. Among the different methods of land preparation, the highest tuber yield was realized on mounds (Ravindran and Mohan kumar, 1987). A close spacing is generally recommended for maximum yield. A spacing of 30-60 cm between rows and 15-20 cm between plants within rows is ideal. However, when planted on mounds no specific spacing is followed and vines are planted on top of mounds accommodating 3-6 slips per mound. By adopting the above spacing about 83,000 cuttings are required to plant one hectare of land. At the time of field preparation and planting 5 t/ha of FYM or compost is to be incorporated. A fertilizer dose of 75:50:75 kg/ha of NPK has been recommended for the Kerala region. Full dose of P, K and half dose of N has to be given as basal and the remaining half dose of, N as top dressing at 30-35 days after planting along with intercultural operation and earthing up.

12. PROBLEMS RELATED TO DISEASES

Sweet potato is comparatively free from serious diseases in India although the crop has been reported to be attacked by more than 40 diseases in field and storage, from different countries. Among the diseases reported viz. Leaf spots (Cercospora timorensis, C. ipomoeae, Helminthosporium euphorbiae, Alternaria capsiciannui, Colletotricum capsici). Stem rot/wilt (Fusarium oxysporum var. batatas), Collar rot (Sclerotium rolfsii) root rot (Rhizoctonia solani) and tuber rot (Rhizopus sp.) are reported in India. Stem rot/wilt caused by Fusarium oxysporum var. batatas is important and widespread in Orissa, West Bengal, U.P. and Bihar. A few foliar diseases reported on this crop are inocuous in nature and therefore harmless. An unconfirmed report of a mosaic disease transmitted by aphids has been made from west Bengal and Bihar.

13. PESTS OF SWEET POTATO

Though nearly eighty species of insects and non-insect pest infest sweet potato, the most destructive and wide spread one is the root and shoot boring weevil. (Cylas formicarius Fab). Eventhough insects like wireworms, whitegrub and ground beetles feed on the edible roots, none of them comes anywhere near sweet potato weevil in inflecting direct damage, yield loss and at times total destruction of the crop. The weevil attacks sweet potato in the field as well as the tubers in storage. In the field, adults feed on tender buds, leaves, vines and tubers, while grubs feed on vines, roots and tubers. Pre-treatment of vines with 0.05% fenthion or fenitrothion and foliar spray with the chemical at monthly intervals is recommended for controlling sweet potato weevil.

Studies have indicated that sweet potato weevil incidence is a complex phenomenon influenced by several factors such as seasons, type of soil, moisture, age of the crop, varietal susceptibility and cultural practices including crop sanitations, crop rotations, etc. Two cropping sequence viz. (i) paddy-sweet potato-cowpea and (ii) paddy-paddy-sweet potato were ideal in controlling the pest. Recently synthetic sex pheromone has been found successful in reducing substantially the male population of weevil in sweet potato fields. Thus we can integrate mechanical and cultural practices, use of pheromone, resistant/tolerant variety and biological means with minimum use of insecticide, for the effective control of weevil (Pillai et al., 1987).

14. NEMATODE ON SWEET POTATO

Two important nematodes infesting sweet potato in India are root knot nematode (Meloidogyne spp.) and reniform nematode (Rotylenchulus reniformis). Heavy populations of Rotylenchulus reniformis, a semi endoparasitic nematode is encountered from soil and root of sweet potato. The symptoms and damage associated with the nematode require detailed investigation. Besides, sweet potato is also infected by Radopholus similis but the damage caused by this nematode is not studied so far in India.

15. PROCESSING, STORAGE AND UTILIZATION OF SWEET POTATO

Processing and storage of sweet potato is one of the important aspects in the management of sweet potato production technology. Shelf life of sweet potato is affected by various factors like physiological and microbiological changes, resulting from harvesting and handling damages and improper storage conditions (Ann. 1969, Cooley et al., 1954). The primary storage problems are respiration, development of pithiness, internal cork formation and decay.

15.1. Curing

Sweet potato should be cured immediately after harvest preferably at 85°F and a relative humidity of 85-90%. Only a small ventilation need be provided during curing to prevent CO_2 accumulation and oxygen depletion.

15.2. Chilling

Sweet potato cannot be storaged for long at temperatures below 55°F at this leads to chilling injury in the tubers (Lieberman et al., 1958). If stored below 30°F, the tubers freeze and are ruined.

15.3. Storage houses

The primary objective of storage conditions is to reduce the physiological and pathological losses. The cured sweet potatoes have to be stored at temperatures of 55-60°F with RH of 85-90%.

15.4. Dehydration of sweet potato

An alternative method to improve the shelf life of sweet potato is the conversion to chips and flour. Drying emerges as the most cost effective processing method of sweet potato as compared with canning and freezing.

15.5. Utilization

The post harvest processing of sweet potato has not been practiced to any great extent in India, unlike in other countries like USA where canned sweet potato flakes etc. are very common and popular. There is very good scope for these products in India. Flour based products like liquid glucose, high fructose syrup and alcohol also seem to have good promise. In addition the vines can be used for feeding animals either as such or after ensiling. The excess tubers can be used as carbohydrate source in animal feed. In some parts of eastern India, the harvested tubers are treated with a red dye to make the color more attractive. In Maharashtra state, boiled pulp of sweet potato is dried into shreds and used during feasts and festivals (Nanda, 1984). The only processed product of sweet potato available in India is sweet potato flour. The tubers are cleaned, sliced, and dehydrated in the sun in open yards. They are powdered and used as supplement to cereal flours in bakery products, pancakes, pudding etc. The flour has been used in production of "chapathi" (a hand made cake) along with wheat flour. The flour can be used as dough conditioner in bread manufacture as stabilizer in ice creams and also consumed along with peanut cake. In CTCRI, some attempts have been made to produce bread and biscuits using sweet potato flour. It was found that up to 25% substitution of wheat flour with sweet potato flour can be carried out without very much affecting the quality of the products. They are sweeter, but are slightly harder and more dark, colored compared to wheat bread.

CTCRI has done some work on pickling of sweet potato chips. 1%, 2%, 5% brine and 50% sucrose syrups were tried as medium for pickling. However, the chips could be stored at ambient conditions for only 8 weeks in 50% sucrose syrup. Sweet potato starch can be extracted similar to cassava starch, except that the pH is maintained at 8.6 by using lime water which floculates the impurities and also dissolves the pigments. The tubers are ground with lime water and starch is separated by washing over a series a screens. It is bleached with sodium hypochlorite and centrifuged. The yield is around 20%.

Sweet potato starch has a granule size of 15-25 and it has a high viscosity with a reasonably high viscosity breakdown. Other properties are similar to cassava starch. Pregelatinized starch has been used in production of pudding type products. CTCRI has successfully carried out conversion of sweet potato starch to alcohol on a laboratory scale. Liquid glucose and high fructose syrup can also be conveniently manufactured from sweet potato starch and Japan is reported to produce most of its liquid glucose using sweet potato starch. India can also divert excess produce for extraction of liquid flucose and alcohol.

16. NATIONAL SWEET POTATO PROGRAMME

The National Commission on Agriculture in India, has made a targeted production of 10 million tonnes of tubers from an area of 0.5 million hectares by 2000 AD. It is envisaged that the average yield of sweet potato has to reach the mark of 20 t/ha from the present level of productivity of 8.16 t/ha. The reasons for low productivity are:

- Prevalence of late maturing inferior varieties adapted to low fertility conditions.
- Poor management practices including plant protection measures.
- Limited product diversification and absence of organized marketing channel for the produce.

Good progress has been made in identifying and testing cultivars suited to different agro-climatic zones capable of yielding 25-30 t/ha tuber yield. Emphasis has also been given to replace the traditional long gestation varieties with early maturing, high yielding cultivars less susceptible to sweet potato weevil which can be conveniently accommodated in the prevailing cropping patterns in different parts of the country. Proper cultural and management practices have been standardized to realized the full production potential from sweet potato. Attempts are also being made for the proper utilization, processing and marketing of the tubers to make sweet potato cultivation more profitable and attractive.

The improved production technologies identified for different agro-climatic zones are being extended through various development departments and all India Coordinated projects on tuber crops improvement programme of the Indian Council of Agricultural Research. Keeping in view of the importance of sweet potato in food, feed and industry research activities are undertaken in the following centres in India: Bihar, Maharashtra, Tamil Nadu, Andhra Pradesh, Kerale, West Bengal, Karnataka and Assam. In these centres work is mainly centred around collection and evaluation of sweet potato germplasm, agronomic stability and adaptability of genotypes, standardization of suitable agrotechniques and distribution of elite seed materials to farmers.

17. INTERNATIONAL COLLABORATION FOR SWEET POTATO IMPROVEMENT

In 1987, ICAR has entered into a memorandum of understanding with CIP, for collaborative research programmes on sweet potato. Consequently there has been a spate of joint endeavours in the research and development activities of sweet potato in India. In August, 1988, the two institutes have jointly organized an international training course on sweet potato production in Trivandrum. A series of advanced training programme for the benefit of scientists of both the centres are also being formulated. The regional workshop on sweet potato which is being organized here today is also outcome of the joint effort between ICAR and CIP.

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SWEET POTATO PRODUCTION, UTILIZATION, AND RESEARCH IN INDONESIA

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1. INTRODUCTION

In the Fifth Five-Year Development Plan (REPELITA V) starting in 1989, the Government of Indonesia will give an emphasis on food diversification after reaching rice self-sufficiency in the current Five-Year Development Program (PELITA IV). Sweet potato may play an important role in the diversification program since it has been the second most important root crop after cassava.

Food crops have given a significant contribution to the Gross Domestic Product (GDP) of Indonesia. In 1985 from the total GDP of Rp 94,491.5 billion about Rp 22,412 billion or 23.72% was contributed by agricultural commodities. Food crop contribution to the country's GDP was the largest among those given by agricultural commodities. Food crops in 1985 gave 61.4% of the total contribution given by agriculture or about 14.56% of the national GDP. At the same year the contribution of sweet potato was Rp 102.24 billion or about 0.77% of the food crop contribution or 0.46% of the agricultural contribution (CBS, 1988). This was smaller than its proportion in the previous years. In 1981 when the contribution of food crops was 60% of the total agricultural GDP, sweet potato contributed 0.7% of the agricultural contribution (AARD, 1984).

Current figures on sweet potato production reflect the diminishing importance of the crop in the increasing agricultural development. Harvested area of sweet potato in the last four PELITA periods declined considerably from 403,866 ha in 1968 to 253,067 ha in 1986. During the same period, its yield increased only slightly from 6.05 t/ha to 8.46 t/ha. Consequently, during the same period production decreased slightly from 2,364,297 tons to 2,090,568 tons (Central Bureau for Statistics, 1969-1988).

Java is still the most important production area, although the harvested area on this highly-populated island considerably decreased from 247,018 ha in 1968 to only 99,219 ha in 1986. Hectarage wise, the second most important production area is Irian Jaya where the harvested area increased slightly from 27,947 ha in 1968 to 42,838 ha in 1986. The regions with the highest production of sweet potato is still Java with the production of 940,065 tons, followed by Sumatera with 314,791 tons, Nusatenggara with 308,643 tons, and Irian Jaya with 239,893 tons. However, if the population in each region is taken into consideration, the degree of importance of sweet potato was highest in Irian Jaya with 169.2 kg/capita/year, followed by Nusatenggara with 32.3

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kg/capita/year, and Sulawesi with 17.6 kg/capita/year. In Java the ratio was only 9.2 kg/capita/year (CBS, 1988). Soenarto (1987) estimated the average consumption of sweet potato in Jayawijaya, Irian Jaya was 3 kg/capita/day which indicates higher consumption rate thah the figure above.

Nationally, sweet potato's role as human food is still the most important one. In 1984 and 1985 food balance sheet data, 88% of the sweet potato production was used for human consumption (CBS, 1985-1986). The figures of production per-capita ratio in different regions indicate to some extent the degree of importance of sweet potato as human food in the corresponding area. In Irian Jaya sweet potato is the most important staple food although taro (Colocasia esculenta) is also used by several ethnic groups in the lowlands. It is also an important staple in Nusatenggara in addition to rice, maize, and other root crops. In other islands such as Java, Sumatera, Sulawesi and Kalimantan sweet potato is an additional food used as snacks, desserts, or salads.

The role of sweet potato as livestock feed is still unimportant. In 1984 and 1985 only 2% of the production was used for feed. However, the figure indicate only the marketable product used for feed. Other parts of the plant such as leaves, vines, pencil roots, and damaged roots are also used for feed. In Irian Jaya, regular storage roots from certain cultivars are exclusively given to pigs (La Achmadi, 1988).

The amount of sweet potato used for industrial processing has not been recorded nationally. Our observations, however, indicate that sweet potato is indeed used for making catch-up, chips, and other products in home, small-scale, and medium-scale industries. One of the catch-up factories near Jakarta operating 300 days a year, uses about 30 tons of sweet potato daily.

The importance of sweet potato in the Indonesia's economy is felt more by the farmers growing the crop. The commercial farmers in Java considered sweet potato as technically and economically advantageous for it is easy to maintain, it does not require a lot of inputs, it is less risky than most vegetables, its marketing is easy since the channels and mechanisms exist, and the farmers feel that they have sufficient skills and konwledge to manage the business (Dimyati et al., 1988). Commercial farmers are less dependent on sweet potato than subsistent farmers using sweet potato for their staple. The commercial farmers may change their crop to more profitable ones. In Irian Jaya where sweet potato is the life of the people they are more dependent on the crop. The crop is even used in their rituals and ceremonies (Mampioper, 1988; La Achmadi, 1988).

2. PROBLEMS IN PRODUCTION AND UTILIZATION

2.1. Planting Material

The farmers meet their planting material need by themselves either from previous crop or from stored roots. Apical parts of the vines are usually taken for planting material in the overlapping cropping pattern found in several producing areas in Java and in most parts of Irian Jaya. This practice may cause the spread of diseases such as scab and viruses. Many farmers, however, do know the danger and avoid using infected cuttings or renew their planting material using root sprouts every 3-4 crops. In the intermittent cropping pattern the use of storage root to produce planting material is a common practice.

2.2. Germplasm and Varieties

The cultivars used by the farmers are different from one region to another. They are mostly local cultivars adapted to each production region. In Java the farmers grow one or two most popular cultivars in a large area with, to a lesser extent, several additional less popular ones. This practice apparently may cause genetic erosion and endanger the future breeding efforts. In contrast, in Irian Jaya the farmers usually grow a large number of cultivars in a particular field. For instance, in a subdistrict of the district of Jayawijaya, the Daniese grow 65 clones in the valley area and 16 clones on the hillslopes. However, the possibility of genetic erosion still exists since they tend to grow earlier-maturing varieties recently. Severall late-maturing cultivars were rarely found (La Achmadi, 1988).

Sweet potato breeding has been done at several research institutes under the coordination of Central Research Institute for Food Crops (CRIFC) and in several Root Crop Research Centers of several Universities. Collection of landraces and introduction of exotic material from overseas are maintained by Bogor Research Institute for Food Crops (BORIF), Root Crop Research Centers of Brawijaya University at Malang, East Java and Cendrawasih University at Manokwari, Irian Jaya. Two introduced cultivars, Southern Queen 27 and Portorico, were released by BORIF and widely grown by farmers in and around Bogor area. The most recent releases from BORIF Daya (1978), Prambanan and Borobudur (1981) were not equally adopted, probably because of the less-preferred taste. The three cultivars have high yield and high carotene and moisture content, whereas the farmers and consumers prefer cultivars with "dry" texture (Dimyati et al., 1988).

2.3. Agronomic Practices

Cultural practices of sweet potato vary widely from one place to another. Soil and water management seems to be the most important aspect emphasized by the farmers. Fertility is maintained by traditional practices which are sufficient to sustain the current level of productivity.

In Java, most farmers grow sweet potato on single-row ridges with different dimensions depending primarily on the depth of solum. The soil is plowed, drained, and dried before the ridges are made. The ridges are rewatered up to three fourth of their heights just before planting. These ridges are dug up along their sides 3-4 weeks after planting to improve soil structure, to provide the place for fertilizer application, and to remove the weeds. The kinds and rates of fertilizer applied are also different from one place to another. Many farmers do not apply fertilizers at all. For those who use fertilizers, single and double applications are equally common. The types of fertilizers commonly used are urea, ammonium sulphate, triplesuperphosphate, and potassium chloride. The rates applied, however, are usually lower than the recommendations for each area. Fertility seems to be maintained by crop rotation with rice and other crops or by intercropping with other food crops such as bean and peas.

In Irian Jaya, farmers' practices are even more diverse than those in Java. The cultural practices of sweet potato in the highland areas are highly developed. Cropping systems practiced in the Baliem Valley and Paniai lake areas are the best examples of the various sophisticated cultural practices. Soenarto (1987) described the growth and development of sweet potato and analyze nutrient cycling under the cultivation system in the Baliem Valley known as Wen Hipere. La Achmadi (1988) described briefly Wen Hipere as well as the two systems for the hillslopes of the valley known as Yabu and Wen Wanggangwi. The prominent features of Wen Hipere are the sophisticated drainage channels which also function as nutrient traps therefrom and mud is smeared to the mounds of sweet potato. The mud is enriched by placing weed material and crop residues into the ditches. These mounds about 30-40 cm high are parts of beds of 3-5 m wide by 5-10 m long. The ditches and beds are permanent structures used repeatedly without changes during both sweet potato growing period and fallowing period. The duration of fallowing period depends on the growth rate of certain indicator species such as Dedonia viscosa whose importance is reflected in its use in the ritual ceremonies of the Daniese.

In the drier area, the hillslopes of the valley, the drainage channels are shallow. Sweet potato is grown on beds with mounds (Yabu) or without them (Wen Wanggangwi). Since the sedimented material in the ditches is little, the application of ditch sludge is consequently restricted. Maintenance of fertility in the two systems is done by building soil beds on the burried weed and crop residues in the ditches of previous crop. The beds are made parallel with the slopes making the soil prone to erosion. To prevent this, wooden or rock barriers are built at certain intervals to slow-down the runoff.

Similar level of sophistication is observed in the cropping systems on lake-shore gardens and hill slopes at Enarotali and Wagete or on highland narrow valleys and hill slopes at Tiom, Polimo, and Angguruk (Anonymous, 1988).

2.4. Pest and Diseases

The most important insect pest for sweet potato in Indonesia is root weevil (Cylas formicarius) whose importance has been recorded from production centers in Java (Dimyati et al. 1988) and Irian Jaya (La Achmadi 1988). In Java the intensity of weevil infestation is usually less than 5%, but the intensity higher than 50% may be observed during extremely dry periods. Sufficient irrigation of the crop every 2-4 weeks can suppress the pest effectively according to many farmers experiences. This may explain why sweet potato cultivation in the drier areas is restricted. Other pests occasionally observed by farmers in Java are Aphis sp., Agrius convolvuli, Omphissa sp., Brachmia convolvuli, Tabidia aculealis, Cassia obturtata, and rats.

The most important disease observed in Java and Irian Jaya is scab (Sphacelosoma batatas). The disease was also reported from Lampung. The occurence of the disease has been kept at low intensity in Java probably because of the proper use of planting material and crop rotation. In Irian Jaya the intensity is also kept at low level perhaps due to multiclonal culture. Moisture and temperature in most highlands in Irian Jaya are favorable for the disease outbreak (Amir, 1988).

Viruses were reported from dry areas in Lampung, South Sumatera which is not an important sweet potato production area. Nematodes have never been recognized nor given any attention.

2.5. Storage

For commercial farmers in Java, and perhaps other islands as well, storage of sweet potato is not important. All farmers sell the root before or just after harvest. Only small portion, 50-200 kg per harvest, of the root is brought home for family use or given to neighbours or visitors. There are several ways of storing root: spread over cemented or uncemented floor, spread over wooden or bamboo bench, piled under the bench, or put into bamboo container. Almost always the most popular clones have also longer storability than most other clones. Storage is not an important issue for traders either. Sweet potato is usually sold out within 1-3 days in the major markets.

So far storage is not a problem in Irian Jaya. The farmers harvest sweet potato at certain intervals to obtain large roots and to allow the remaining small roots to grow to the desirable sizes. Therefore they do not store large quantity of roots for long period of time. However, the efforts for increasing food availability through diversification which may also involve increasing cropping intensity, introducing intermittent harvests and reducing crop's growth duration, may impose the need for longer term storage of roots to fill the gap between harvests (Anonymous, 1988).

2.6. Distribution, Marketing, and Utilization

In many cases the demand for sweet potato in the consumers' centers is fulfilled from the sorrounding production centers as well as from production centers in remote areas which needs well-established transportation and marketing infrastructure. No marketing studies on sweet potato have been done in Indonesia. A preliminary survey is being underway in a collaborative work between CIP and Central Research Institute for Food Crops. Our informal survey (Dimyati et al., 1988) revealed that the existing distribution and marketing systems in Java are sufficiently efficient to provide the outlets for sweet potato production and to create pricing reasonably affordable by the consumers and attractive to the farmers. Distribution and marketing are not important in Irian Jaya, where most sweet potato is consumed for farmers' own need.

In Java, transportation infrastructure is well-established and sufficiently maintained to support distribution of sweet potato from production sites to the consumers' points. Most farmers sell their sweet potato to village traders, who are usually among the farmers, prior to harvest. These village traders sell the product to collectors from within or outside the village who bring the root to large-scale traders who own lots in the major markets in the big towns who then sell the product to small retailers, processors, or consumers. The collectors play the most important role among various traders in channelling sweet potato from the producers to the consumers. They are the most mobile in seeking the sellers and the potential purchasers, the most active in sorting-out the product, and in many cases they have to provide big capital since the product is usually consigned to the big traders in towns. The farmers usually receive 50-60% of the consumers' price depending on the distance between production and the consumer centers.

We believe that the current status of sweet potato utilization is only sufficient to sustain current levels of production and productivity. It will need more alternative uses to create more demand for sweet potato which in turn will encourage better marketing and pricing. This is expected to trigger more production and higher productivity through the use of more land and production inputs.

3. NATIONAL SWEET-POTATO PROGRAM

3.1. Production Systems

There are two distinct types of farmers involved in sweet potato production: subsistent farmers who grow sweet potato for their own need and to feed their own livestocks and commercial farmers who usually sell most of their product although may still store a small portion of it for their consumption. The first type of farmers are common in Nusatenggara and Irian Jaya where sweet potato is an important staple food. The second type of farmers are common in Java and other major islands.

In Java and several other major islands, sweet potato is mainly grown in the paddy field (sawah) in the post-rainy or dry season after rice crop. The land planted to sweet potato may be irrigated or rainfed. Additional growing areas are found on rainfed drylands (tegalan). The altitudes range from almost sea level to the frost line but with decreasing tendency towards altitudes higher than 700 m.a.s.l. due to competition from vegetable crops.

In Irian Jaya growing areas of sweet potato spread over lowland and highland areas from about sea level to the frost line with increasing importance towards higher altitude. At lower altitudes *Colocasia* play an important role substituting for sweet potato. However, the problem of leaf blight (*Phytophthora colocasiae*) may reduce its significance in the future. At higher altitudes white potato is spreading recently but its potential has yet to be realized (Anonymous, 1988).

The prominent feature of sweet potato production in Irian Jaya is the continuous planting and harvesting to meet the food supply of the people. Monocropping is predominant with varietal mixture in each growing space as a common practice.

3.2. Research program

The Central Research Institute for Food Crops (CRIFC) is the main organization responsible for coordinating research activities on food crops which include cereals, legumes, and root crops. CRIFC is one of several commodity-oriented Coordinating Centers under the Agency for Agricultural Research and Development (AARD) of the Ministry of Agriculture. The mission of CRIFC is implemented by six Research Institutes for Food Crops located at Bogor (BORIF) and Sukmandi (SURIF) in West Java, Malang (MARIF) in East Java, Sukarami (SARIF) in West Sumatera, Banjarbaru (BARIF) in South Kalimantan, and Maros (MORIF) in South Sulawesi.

In addition to the CRIFC system, there are other institutions doing research on root crops such as universities, non-ministerial research institutions, and private sectors. Among universities are Bogor Agricultural University, Brawijaya University at Malang, Pattimura University at Ambon, Maluku, and Cendrawashih University at Manokwari, Irian Jaya each having Root Crop Research Center.

Collaborative work has been undertaken by MARIF, MORIF, Brawijaya University, and Cendrawasih on root-crop research including sweet potato with a project supported by IDRC and the Government of Indonesia.

3.3. Extension and Education

Although it is almost impossible to quantify, the allocation of resources for sweet potato within extension and education programs is proportionally small. Sweet potato is usually included in the books or brochures for extension material. Sweet potato is also included in the campaign for food crop intensification known as BIMAS, and acronym for Mass Guidance in Indonesian. However, the level of intensification program is much lower than those for rice, corn, and soybean (Secretariate of BIMAS Guiding Body, 1988). Therefore, it is easy to understand that the diffusion of technology is slow, slower than that of rice, corn or soybean.

Fortunately, sweet potato still takes part in the education program. Most major universities do teach production techniques of sweet potato as part of annual crop or food crop production in their curricula. Sweet potato may also enter students' notes or reading assignments when they are learning general agronomy or agricultural economics. Student theses concerning sweet potato, however, are rarely found on the bookshelves of the libraries. In the agricultural technical school sweet potato cultural practice is also taught as part of annual crop production course. The course consists of lecture and field practice which gives the students elementary skill to grow sweet potato.

3.4. Research Personnel

The number of personnel involved in sweet potato research at research institutes under CRIFC is summarized in Table 1.

Table 1. The number of professional, holding BS degree and up, on root crop program at CRIFC.

Disciplines	BORIF	SURIF	SARIF	BARiF	MARIF	MORIF	TOTAL
Agronomy	3	3	2	1	3	1	13
Physiology	2	-	1	-	1	-	4
Breeding	2	-	1	1	-	1	5
Entomology	1	4	-	-	1	-	6
Pathology	3	1	-	-	-	-	4
Economics	1	-	-	1	2	-	4
Postharvest	1	3	2	-	1	1	8
Total	13	11	6	3	8	3	44

Out of the 44 people working on root crops 3 hold a PhD degree, 17 MS, and 24 BS/Ir. Working experiences of the personnel range from three to 23 years. It is clear that more recruitment is needed. However, recruitment is difficult at this time due to limited budget for new positions. To alleviate the problem two ways can be considered: temporary contract and reallocation of staff, i.e. acquiring personnel from other program to work for sweet potato. Disciplinary fields that need additional personnel the most are breeding, physiology, pathology, and economics. Furthermore, our program has no social scientists. Recruitment should be considered.

3.5. Future Plans for Improvement

Sweet potato improvement program should comprise both research and development activities. There are tremendous problems associated with the efforts to improve sweet potato production and utilization. However, limited resources allocated for sweet potato research limits the extent of the research work. Several of the criteria for setting research priorities are: the relative importance of the problems to be solved, the possible extent of application of research results, economic significance of the problems, social and political considerations, probability of research project to be succesful, and the applicability of the research results in the real farmers conditions (Manwan and Dimyati, 1988).

The future plans for sweet potato improvement in Indonesia are divided into two categories: those for subsistent, those for commercial system, and those common for both systems.

For subsistent farming systems the likely activities are:

- improvement of multiline cultivars,

- introduction of better fertility maintenance such as using leguminous crops during fallow period,

- better soil conservation techniques,

- development of storage techniques,

- introduction of intermittent cropping system combined with diversification with cash-earning crops or other alternative food crops such as potato.

Priorities for commercial farming system are:

- development processing and utilization technologies to find new alternative uses,

- marketing studies including identification of potential markets for newly developed products,

- improvement of cultivars suitable for food, feed and processing industry,

- survey on farmers' and consumers' preferences,

- studies on adoption of technologies by farmers.

Activities that are common for both subsistent and commercial farming systems or independent of the systems are:

- further characterization of the systems,

- collection and evaluation of local germplasm,

- improvement of base population of breeding material in the forms of continuously improved gene pools, and

- development of integrated pest management procedures.

It is also clear that considering the existing resources, no single research institution can handle all aspects of improvement program. The endeavors should be done collaboratively by these different institutions. Collaborative work will make more effective and efficient use of the resources. Even the collaborative work should not be exclusive to national institutions. International collaboration has always been and will always be useful in the research and development program. Indonesia's sweet potato program has taken the benefit from international collaboration so far. Many introduced varieties from IITA, AVRDC and other institutions abroad have been used in our breeding program. Another area of international collaboration is the training of manpower. International collaboration also plays a significant role in providing or seeking additional funds for research and development. International donor agencies like World Bank, UNDP, USAID, IDRC, ADB, ACIAR, etc. have helped agricultural research program in Indonesia. Their significant contributions are expected to continue in the future.

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COUNTRY REPORT OF LAO P. D. R. PARTICIPANTS

B. Souvirnmonh and S. Inthisane

1. INTRODUCTION

Mr. Chairman, Distinguished Delegates, Ladies and Gentlemen.

Let me on behalf of the Lao People Democratic Republic participants extend our heartiest congratulations and felicitations to all, at this sweet potato workshop.

I would now like to introduce my country in this meeting and speak on the sweet potato production at the present and in the future in my country.

Laos is situated in South-East Asia between 100-108 longitude and 13-23 latitude which covers an area of 236,800 km^2 comprising 680,000 hectares arable land. Laos is mountainous country ranging between 100-2,800 m above sea level. There are plains in the Middle and the South and along the rivers. The low- land and plateau area is estimated 3'440,000 hectares. Major crop production are the Boulovens and Nahay plateau in the South and Middle of the country respectively, they are 600-1,300 m above sea level. Laos is influenced by a moonsoon system which brings two seasons per year from June-October the rainy season, November-May the dry season.

The present population of the country is estimated at more than 3'900,000 involving 68 tribes with diversified traditions and cultural practices. They are mainly concentrated in the low-land and along the rivers where the soil is more fertile and the infrastructures are available. Laos is land-lock country. In recent years Laos lives with the calamities of nature, flood and drought which play a profound influence on the lives of the people and the economy of the country.

There are two systems of farming in my country:

- Permanent cultivation mainly in the low-land where the flood irrigated production of paddy rice is practiced.

- Shifting cultivation is carried out in uplands where every year thousands of hectares of forest are destroyed.

Laos has the ability to greatly improve its agricultural production. But because of the low level of agricultural technology available in the country this improved production has been unable to be realized at present. There are many examples of fertile areas in Laos such as the Boulevens plateau, which are used well below their full potential.

2. IMPORTANCE OF SWEET POTATO IN LAO PEOPLE DEMOCRATIC REPUBLIC

The total area under sweet potato and other root crops production is 16,600 hectares with an average yield of 7.12 tonnes per hectare. The main crop is rice grown on a total area of 663,500 hectares with an average yield of 1.5 tonnes per hectare. Other production figures are listed in table No. 1.

In Laos sweet potato is used to supplement the main staple rice and is eaten seasonally. In the lowland it is sown in the period October to January and consumed from January to May and in the highland sown May-June and consumed November-October. As well as tuber, the young shoot of the vine is consumed as a vegetable. A small amount is used for livestock feed and the industrial processing is negligible. The technology of processing is not available in my country.

Sweet potato is presently of low economic, but has some social importances. The price of sweet potato as displayed in the market is approximately the same as paddy rice and sometimes may be higher. Sweet potato plays a minor role in the Lao diet and is consumed seasonally which also includes festivals and ceremonies.

In Laos the only planting material used are runners of local varieties. There are no imported varieties or breeding programs at present. There are pests and diseases in Laos that affect the tubers and above ground vegetation. The expected consequences are leafless vines, the holes and galleries in the tubers roots in the tuber etc.

3. PRODUCTION ZONES, AGRONOMIC PRACTICES, MARKETING BARRIERS, FUTURE PROGRAMS OF SWEET POTATO PRODUCTION.

There are three production zones of sweet potato:

- In the highland it is grown, mixed with rice in the slash and burn system and is planted in holes. Maintenance is done the same as rice. Tubers are harvested as they are required.

- In the lowland like the Vientiane plain sweet potato is sown after the rice harvest, where there is alluvial soil and irrigation available. Land preparation begins with ploughing and harrowing by animal power. The sweet potato is sown in seedbeds with the space of 10-15 cm, the seedbed width is 80-100 cm and height is 30-40 cm. Fertilizer and pesticide application is minimal. They are harvested 4-5 months after planting, giving the yield of 7-9 tonnes per hectare.

- The third production zone is that of the vegetable farmers along the river banks where there are many plots of alluvial soil left after the rivers have subsided. The sweet potato is planted on the ridges with spacing of 10-15 cm. The ridge is prepared by hand with hoe and rake, the ridge height is 20-30 cm and its width is 60-80 cm. Chemical are not used, the farmers harvest their potato in March-April yielding 7-8 tonnes per hectare.

In my country the sweet potato is eaten seasonally bacause storage technology is non-existant. The tubers can generally only be stored for a few days.

However the crop is grown in all provinces of Lao People Democratic Republic. Table No. 2 gives area and yield per province. The main barriers to marketing are transportation, storage, processing and food preparations. It is consumed as boiled, roasted, fried, steamed potato plus it is made into a cake.

Concerning quarantine regulations and germplasm exchange Laos has no germplasm exchange programs and no quarantine regulations unless the goverment becomes aware of diseases that are likely to be introduced. There are no facilities at present for the quarantine of imported germplasm. Increasing food production is a priority of the country as in the 5 year plan 1986-1990. Therefore the goverment is interested in importing improved genetic material.

I would like to mention that there are no national public or private institutions doing any work with sweet potato in the country. We are keen to start a national improvement program with sweet potato production. To do this we need:

- A center for sweet potato applied research to fit into Lao farming systems.

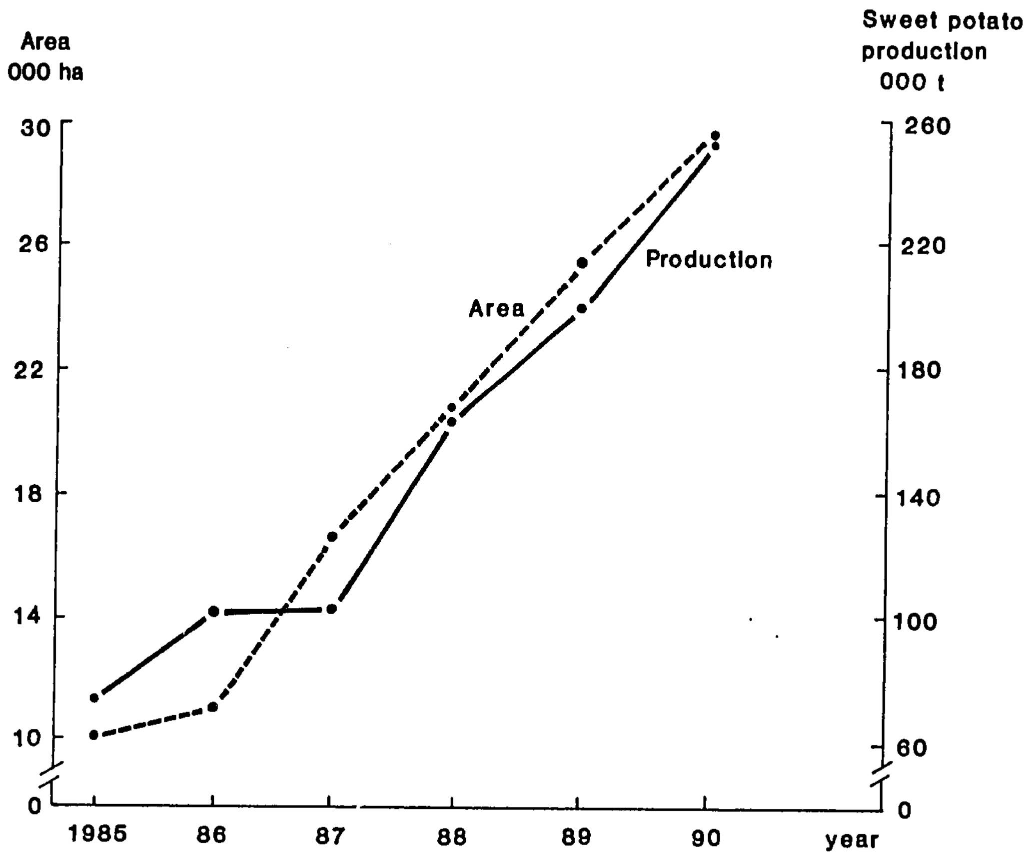
- An improved germplasm through international collaboration with other countries research centers.

- Lao People Democratic Republic has an acute shortage of trained agriculturists especially extension workers. So any training collaboration programs and exchange of sweet potato production information would help improve Lao agriculture.

Mr Chairman, Distinguished Delegates,

I would like to take this opportunity to express our sincere appreciation for having a chance to participate in this workshop. Thus enabling us to learn more about the success of other countries in sweet potato production as well as to share in their experiences all of which proves valuable to us.

Thank you.



Area
000 ha
Sweet potato
production
000 t
30
26
22
18
14
10
0
260
220
180
140
100
60
0
Area
Production
1985
86
87
88
89
90
year

Table 1. National Agricultural Production, 1985.

	AREA 000 ha	YIELD t/ha	PRODUCTION 000 t
RICE	663.5	1.06	1,308.28
IRRIGATED RICE	383.1	2.67	1,022.87
UPLAND RICE	270.4	1.28	345.31
SWEET POTATO AND OTHER TUBER CROPS	10.2	8.38	85.40
CORN	26.9	1.24	33.34
MUNGBEAN	4.3	0.62	2.60
SOYBEAN	3.05	0.72	2.51
PEANUT	14.0	0.78	11.30

Table 2. Yield and area of Sweet Potato and other tuber crops in the country by provinces.

	1985		1986		1987	
	AREA	YIELD	AREA	YIELD	AREA	YIELD
1. VIENTIANE MUNICIPALITY	361	17.9	218	14.23	165	6.0
2. PHONGSALY	257	8.5	545	8.55	685	8.66
3. LUANGNAMTHA	52	8.0	180	8.11	225	8.26
4. OUDOMXAY	1,300	8.0	1,329	5.0	1,500	8.0
5. BOKEO	150	8.25	129	8.33	150	8.46
6. LUANGPRABANG	286	8.0			275	8.08
7. HOUAPHANH	2,530	7.8	3,065	7.8	3,855	7.9
8. SAYABOULY	680	5.0			289	6.0
9. XIENGKHOUANG	1,187	8.0	289	5.5	3,941	5.04
10. VIENTIANE	486	8.9	258	7.7	422	8.02
11. BOLIKHAMXAY	360	6.66	365	6.8	260	6.7
12. KHAMMOUANE	300	7.93	365	8.0	330	8.1
13. SAVANNAKHET	1,150	9.0	983	9.0	1,300	9.0
14. SARAVANE	190	18.95	970	7.57	1,220	17.6
15. SEKONG	545	7.3			1,774	7.3
16. CHAMPASACK	225	6.95			61	8.0
17. ATTOPEU	206	8.0			200	7.5
TOTAL	10,200		8,687		16,652	

SWEET POTATO CULTIVATION IN MALAYSIA: A COUNTRY REPORT

N. M. Shukor[1] and M. H. Khelikuzzaman[2]

1. ABSTRACT

Among the root crops, sweet potato ranks second to cassava. A total of 3,563 hectares were planted with sweet potato in 1985.

The crop is not as profitable as other short term crops like vegetables. Its production in Malaysia is entirely a smallholders' activity with average farm size of less than 0.1 ha.

Farmers grow their own selected varieties which yield ranges from 10 t/ha to 22 t/ha. Some of the problems faced by farmers are inferior production techniques, soil and moisture problems, nonavailability of good planting materials and varieties, pest infestation, shortage of labor, poor storage and uncertainty in marketing.

The Malaysian Agriculture Research and Development Institute (MARDI) and University of Agriculture, Malaysia (UPM) undertake the bulk of the research on sweet potato in collaboration with Asian Vegetable Research and Development Center.

2. INTRODUCTION

Malaysia is a tropical country with a population of about 13.34 million. It is situated between 1° to 7° north of equator. It has an average temperature of 25-27°C, uniform all year round. The humidity is high (80-85%). Annual minimum and maximum rainfall are 1,651 mm and 4,216 mm, respectively. There are two periods of heavy rains which occur in April and May and from October to December.

The area under root or tuber crops is small compared to rubber, cocoa, fruits and oil palm, the major plantation crops of the country. The area is also smaller compared to vegetables. In 1984, only 7,289 hectares were grown to root crops (Table 1) (Ministry of Agriculture Malaysia, 1981-1985). Tapioca is the main root crop grown. Other root crops are sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), yams (*Dioscorea* spp.), tannia (*Xanthosoma* spp.), giant taro (*Alocasia* spp.), Hausa potato (*Coleos tuberosus*), Queensland arrowroot (*Canna edulis*), and arrowroot (*Maranta arundinacea*) (Khelikuzzaman, 1987a).

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[2]MARDI, Serdang, Selangor, Malaysia.

The present report attempts to give an overall view of sweet potato production in Malaysia with respect to status, problems and constraints, and research projects conducted on the crop.

3. CURRENT CROP SITUATION

3.1. Production and Consumption Status

Sweet potato was an important food substitute in Malaysia during and shortly after the Second World War when rice, the staple food, was in short supply (Chan, 1977). At present, the crop is no longer widely cultivated as a food crop in the country.

Among the root crops, sweet potato ranks second to cassava (Table 1). A total of 3,563 hectares were planted with sweet potatoes in 1985 (Table 2). The area is steadily declining. State of Sabah and Sarawak in the East Malaysia are the major producers. In the Peninsula, sweet potato areas are mainly situated in the states of Kelantan and Malacca, 31% and 28% of the total area, respectively (Azmi, 1985).

The crop is not as profitable as other short-term crops like vegetables. The cost of production is estimated at US $690.00 per hectare and net returns total US $631.00 (yield of 11 t/ha and price of US $0.12 per kilogram) (MARDI, 1985). Thus, sweet potato is mainly favored under conditions not suitable for other crops such as in single-crop paddy fields and on "idle" farm land (Khelikuzzaman, 1987b).

At the minimum reported yield of 10 t/ha (Khelikuzzaman, 1987b), the estimated production of sweet potato for 1985 was more than 35,630 t with an approximate value of more than US $4.3 million (MARDI in 1985 reported a moderate price of US $0.12 per Kg.).

The per capita consumption of sweet potato is estimated at 2.74 kg. The tubers are boiled, fried in butter, moulded and made into cakes or cooked with vegetables for immediate consumption. They are also taken as snacks in different forms of preparation: roasted, candied or in cookies. Sometimes, the tubers are used by bakeries, confectionaries, and tomato sauce manufacturers.

3.2. Production system

Sweet potato production in Malaysia is entirely a smallholder activity. It is backyard crop with an average farm size of less than 0.1 ha. (Saad and Yap, 1985). It is cultivated as part of market-gardening or for home consumption. It is often planted in rotation with paddy, groundnut, maize and tobacco, or intercroped with young perennial crops like rubber, oil palm and fruits (Khelikuzzaman, 1987b).

Farmers grow their own selected varieties. Farmers select certain varieties based on consumer preference. Varieties with soft texture which are sweet, yellow or orange in color are preferred for boiling and cooking. Varieties for frying are those with white or purplish flesh and harder texture (Khelikuzzaman, 1987b). Yields of 10 t/ha on sandy loam and 22 t/ha on peat have reported by farmers (Khelikuzzaman, 1987b). The majority of the farmers save their own planting materials from one planting to another. Some obtain planting materials from other farmers.

Farmers plant sweet potato on raised beds. Cuttings of 20-25 cm long are planted on the beds at a spacing of 20-30 cm between plants.

There is no standard fertilizer practice. Most farmers do not fertilize their crop. Those who do fertilize use poultry manures supplement with NPK compound fertilizers (12N: $12P_2O_5$: 17 K_2O: 2 Mg and 15N: 15 P_2O_5: $15K_2O$), as the main source of nutrients. Farmers rarely spray their crops with insecticides or fungicides.

Harvesting is normally done manually 4 to 5 months after planting. The vines are sometimes used as feed for livestock and freshwater fish.

Most of the sweet potato produced is marketed fresh. The marketing system follows the pattern of farmers-collectors-truckers-wholesalers-retailers-consumers. By far the most prevalent is the consigning method of selling whereby the produce is consigned by the farmers through local collectors or transport agents (or truckers) for sale in the terminal market with prices known only after scale at such market.

4. PROBLEMS AND CONSTRAINTS

4.1. Production techniques

Farmers' yields are low and inconsistent. Most farmers use traditional cultural management techniques. In general, the crop is not properly managed.

4.2. Soil and moisture

The more fertile soils of the country have been utilized for plantation crops and vegetables. Land for sweet potato is usually marginal or problem soils, and greater inputs and management skills are essential to grow the crop economically. Irrigation and drainage facilities in these areas are absent, and moisture stress and waterlogging are regular problems. Lack or excess of moisture reduces the yield considerably (Khelikuzzaman, 1987b).

4.3. Planting materials and varieties

There are no established sweet potato cultivars in Malaysia (Khelikuzzaman, 1987b). Most of the varieties which are currently available are low in yields and some are of poor quality (Khelikuzzaman, 1986b). Farmers in rainfed paddy areas find it difficult to get high quality planting materials for use in the following season (Khelikuzzaman, 1978b).

4.4. Pests

Two pests are of economic importance, i.e. the sweet potato weevil (*Cylas formicarius*) and the stem or vine borer (*Omphisa anastomolasia*) (HO, 1970). The more serious is the sweet potato weevil. Yield loss of up to 80% has been reported due to the weevil. Losses due to borers are slightly more than 40%.

4.5. Other problems

Cultivation of sweet potato requires high labour inputs, especially for harvesting which is normally done manually. Thus, the present shortage of labour inhibits the expansion of the crop.

Sweet potato tubers are considered highly perishable and have poor storage life. Post-harvest rot is often a problem for some farmers (Khelikuzzaman, 1987b).

The price of sweet potato is unstable and is usually tied up with the problem of seasonality in both supply and demand. Market outlets are not always secured and market demand is uncertain.

5. RESEARCH AND DEVELOPMENT

The objectives of the sweet potato research programme in Malaysia can be summarized as follows (Khelikuzzaman, 1987b).

- To increase the productivity of sweet potato through breeding and selection for superior varieties adapted to various agro-ecological regions, for use as food as well as for industrial purposes.

- To develop new technologies in the cultivation of sweet potato in order that productivity may be raised, and costs of production reduced, ultimately improving farm income.

- To develop and improve products from sweet potato.

5.1. Varietal development.

Varietal development and improvement work date back to 1948 when a variety testing programme was initiated. Research conducted in 1948, 1965 and 1966 resulted in the identification of four high yielding varieties, namely Large White, Serdang-1 Hoey Tong and Empat Bulan (Chan, 1966; Khelikuzzaman, 1987b).

Germplasm collection in Malaysia was and is still being carried out by the Malaysian Agricultural Research and Development Institute (MARDI) and University of Agriculture, Malaysia (UPM). Several intensive and systematic collection trips have been carried out for local and introduced germplasm. At present there is a total of

624 accessions (Table 3) (Khelikuzzaman, 1987b). Accessions from these collections are being evaluated and characterized, and promising ones are being evaluated further.

Wide variations exist in respect to tuber skin and flesh color, yields, leaf shape and color, vine pigmentation and plant type (Saad and Yap, 1985: Khelikuzzaman, 1987a). Bukit Nega was identified as the best yielding variety (Table 4) (Khelikuzzaman, 1987b).

Variations were also detected in tuber number, dry matter content, susceptibility to the sweet potato weevil, and starch content and quality (MARDI, 1987). One of the accessions, namely Accession 30, has a dry matter content of up to 37.9% (MARDI, 1987). Four accessions, namely Accession A34, 198, 174, 94, and A150 have been identified as being less susceptible to weevil. Accessions 93 showed a starch yield of up to 7.5 t/ha. Results of evaluations conducted on some of the accessions are presented in Tables 4 and 5.

MARDI has opted to collaborate with AVRDC to expedite its sweet potato improvement programme. A total of 27 superior varieties from AVRDC have been tested in two yield trials. Yield data of some of the best yielding varieties are presented in Table 6 and 7. Varieties CN941-32, 1444, CN1219-1 and 1423 have great potential and will be tested further.

5.2. Crop management

Studies done on planting density showed that a spacing of 90 cm x 20 cm gave the best yield (Chan, 1969).

On mineral soils, the ratio of N and K fertilizer given to the crop is critical (Chan, 1977). Application of fertilizer with low N and high K (i.e. 1N: $2K_2O$ by weight) increases tuber yield. Optimum yield was observed at a fertilizer rate of 35 kg N, 35 kg P_2O_5 and 67-70 kg K_2O per hectare (Chan, 1966: Chan, 1977).

The yield of sweet potato responds to liming up to a pH of 5.8 on pest soil (Chew, 1970). Higher rates of N and K are needed when sweet potato is planted on peat (Chew, 1970).

Currently, studies to formulate fertilizer, cultural and management practices for cultivation of sweet potato on tin-tailing and bris soils (both sandy) are being conducted (Khelikuzzaman, 1987b).

Work on the modification and utilization of a potato harvester to harvest sweet potato is being undertaken at MARDI (Khelikuzzaman, 1987b).

5.3 Pest control

Chemicals for the control of sweet potato weevil have been evaluated by MARDI. Presently, Gamexane 20 E.C., and Heptachlor at the concentration of 4 ml/l are effective in reducing the weevil population (Khelikuzzaman, 1987b).

5.4 Post-harvest technology

MARDI has conducted several research projects to supply the local sweet potato processing industry with an insight of the sweet potato processing aspects and its potentials. The emphasis is on the improvement and development of suitable sweet potato-based products, its processing techniques, and appropriate packaging materials for the products. Three products, namely sweet potato chips, sweet potato crackers and high fructose glucose syrup (HFGS), are currently under study. The studies include aspects of packaging, sensory evaluation and shelflife.

6. FUTURE NEEDS

There is a need for concerted efforts to develop, improve, and promote the crop in Malaysia.

Breeding and selection should be given top priority to improve yield, quality and resistance to weevil.

Suitable and optimum cultural and management practices of the crop as well as the management of its environment need to be develop. The research must include the study of proper water management of the crop to alleviate the problem of adverse conditions, development of an efficient and storage technology. One of the major factors involved in the successful cultivation of sweet potato is the supply of adequate nutrients for the plant growth (Khelikuzzaman, 1987b). Therefore, economical and suitable fertilizer recommendations are needed.

Research on the control of weevil is essential.

7. CONCLUSION

Sweet potato has great potential in the various agroecosystems in Malaysia. Since it can grow on a variety of soils, it has potential in off-season paddy fields, abandoned or "idle" low-lying areas and other marginal soils.

It can also be used as an intercrop in the major plantation crops because it can double as a cover crop and cash crop. It can also be grown in rotation with other short-term crops or on integration with livestock and freshwater fish.

However, attempts to develop the crop further in Malaysia must take full account of the problems related to utilization, marketing, post-harvest handling and storage, supply of planting materials and appropriate production technology.

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Table 1. Hectarage under sweet potato as compared to other root crops and vegetables.

Year	Vegetables	*Colocasia esculenta*	Tapioca	Sweet potato	*Coleus tuberosus*
1980	11,303	1,529	13,331	2,604	239
1981	9,562	1,530	11,759	2,083	184
1982	12,540	1,199	8,393	1,543	174
1983	12,513	846	7,418	1,644	92
1984	13,474	780	4,975	1,447	87

Source: Ministry of Agriculture Malaysia

Table 2. Hectarage under sweet potato cultivation in Malaysia (1976-1985)

Year	Peninsular[a] Malaysia	Sabah[b]	Sarawak[b]
1976	2,096	-	-
1977	2,493	-	-
1978	2,782	-	-
1979	2,263	-	-
1980	2,604	-	-
1981	2,083	1,613	-
1982	1,543	1,523	-
1983	1,644	1,846	-
1984	1,447	1,602	-
1985	1,240	1,258	1,065

[1]Source: Ministry of Agriculture Malaysia

[2]Source: Saad, M. S., 1986 (pers. comm.)

Table 3. Number of sweet potato accessions currently in the germplasm collection.

Source	Number of accessions	
	Collected	Surviving
Peninsular Malaysia	606	524
Sabah	25	18
Sarawak	102	82

Table 4. Average performance of the top 10 varieties over five locations in peninsular Malaysia.

Variety	Fresh tuber/yield (t/ha)	Dry tuber yield (t/ha)	Dry matter content of (%)
Bukit Naga	14.7 a	4.0 a	23.8 d
Empat Bulan	12.0 b	3.3 b	25.1 cd
Large White	11.0 bc	2.7 bcd	20.7 e
White Baby	10.9 bc	3.1 bc	24.1 d
CH-1	10.6 bc	3.0 bcd	23.2 d
Nakamurasaki	10.1 bc	3.0 bcd	23.8 bcd
Serdang-1	9.9 c	3.2 b	29.6 b
Reza	7.5 d	2.5 cd	26.9 c
Wong Fatt Chai	7.5 d	2.3 d	24.7 d
Keledek	7.1 d	2.7 bcd	31.2 a

Means on the same column bearing the same letter/s are not significantly different from one another at the 5% level of probability (DMRT).

Table 5. Harvest data of nineteen top-yielding potato accessions from 50 tested at University Kebangsaan Malaysia, Bangi, Selangor.

Accession	Fresh tuber yield (t/ha)	Tuber number per plant	Dry matter content of tuber (%)	Harvest index	Weevil suscepti-bility (%)	Starch content of tuber (%)	Starch yield o tuber (t/ha)
Bukit Naga-Check-Variety	48.9a	6.1a	20.5ef	0.521ab	41.9abc	6.7	3.3
270	43.6ab	2.8cdef	17.1f	0.458abcd	19.7abcde	7.0	3.1
285	40.7abc	4.1bcd	20.5ef	0.413abcdef	27.2abcde	6.6	2.7
101	36.1abc	4.8ab	23.8cdef	0.57a	46.2a	8.4	3.0
299	34.5abc	4.5abc	20.6ef	0.388bcdef	17.5abcdew	6.1	2.1
242	32.3abc	2.6cdef	32.4abc	0.356bcdef	2.9e	8.4	2.7
276	30.7abc	4.1bcde	25.2bcdef	0.473abc	31.0abcde	7.6	2.3
282	28.3bc	4.0bcdef	27.8bcde	0.437abcdef	29.8abcde	2.9	0.8
5	28.1bc	3.3bcdef	26.2bcdef	0.499abc	20.8abcde	10.3	2.9
A 246	27.5bc	2.8cdef	22.6cdef	0.300def	14.8bcde	5.7	1.6
274	25.9bc	2.1f	20.5ef	0.303def	21.6abcde	18.7	4.8
185	25.1bc	2.3def	22.7cdef	0.344bcdef	13.0bcde	4.8	1.2
221	23.5c	3.1bcdef	27.7bcde	0.269f	1.1e	4.6	1.1
172	23.4c	3.8bcdef	28.4abcde	0.275ef	24.6abcde	3.6	0.8
278	23.4c	2.6cdef	26.0bcdef	0.287ef	21.9abcde	4.8	1.2
93	22.6c	2.7cdef	28.0bcde	0.279ef	23.1abcde	33.3	7.5
192	22.3c	3.2bcdef	24.7bcdef	0.347bcdef	26.2abcde	8.6	1.9
6	22.2c	2.5def	26.6bcdef	0.288ef	20.3abcde	7.2	1.6
130	22.1c	2.9cdef	31.7abcd	0.305def	3.4e	10.4	2.3
1	21.3c	2.3def	31.8abcd	0.270f	25.9abcde	13.3	2.8

Note: Figures in the same letter are not significantly different at the 0.05% probability level.

$$\text{Harvest Index} = \frac{\text{Weight of tubers}}{(\text{Weight of tubers} + \text{Weight of foliage})}$$

Table 6. Harvest data of sixteen promising varieties from AVRDC and MARDI at Serdang, Selangor.

Variety	Fresh tuber Yield (t/ha)	Dry tuber yield (t/ha)	Tuber no. per plant	Dry matter content of tuber (%)	Plant establishment (%)
CN 941-32	15.94a	3.77abc	5.57a	23.47ab	79.30a
I 444	15.33ab	5.40a	5.30a	35.55a	78.13a
CN 1219-1	13.50abc	4.22ab	4.44b	32.85a	74.67a
Bukit Naga	12.89bcd	3.66abcd	2.95de	27.67ab	63.77a
CN 1028-15	12.89bcd	2.62bcd	2.93de	20.25ab	71.23a
I 423	12.50bcde	3.50abcd	4.29b	28.00ab	70.01a
CH-1	12.00cde	3.30abcd	2.63ef	28.06ab	72.37a
Large White	11.67cdef	1.69cd	2.69ef	16.11b	70.07a
CN 1229-16	11.08cdef	3.78abc	4.33bc	33.95a	74.67a
Local Variety	10.33defg	3.25bcd	2.31ef	30.93ab	71.23a
AIS 0122-2	9.56efgh	1.92cd	3.53cd	20.41ab	73.57a
CN 1100-13	8.92fgh	2.45bcd	3.73bc	27.49ab	70.13a
Empat Bulan	8.72fghi	2.12bcd	2.35ef	24.29ab	70.07a
AIS 35-2	7.58ghi	1.65cd	2.03f	21.86ab	67.80a
Serdang-1	7.17hi	2.11bcd	2.56bcd	29.92ab	68.90a
Nakamurasaki	5.89i	1.52d	2.17ef	25.58ab	74.67a

Note: Figures in the same column bearing the same letter/s are not significantly different from one another at the 0.05 probability level (DMRT).

Dry tuber yield (%)= Dry matter content of tuber (%) x Fresh tuber yield.

Table 7. Harvest data of sixteen promising sweet potato varieties from a MARDI/AVRDC yield trail at Serdang, Selangor.

Variety	Fresh tuber yield (t/ha)	Dry matter yield of tubers (t/ha)[a]	Tuber number per plant	Dry matter content of tuber	Plant establishment (%)
CN 1219-1	20.9a	5.1a	4.8a	24.1bcdef	91.7ab
I 423	18.4ab	4.0abcd	3.0bc	22.1cdef	90.0ab
Bukit Naga	17.6abc	4.8abc	2.3bcd	26.9bcde	96.7a
CN 1280-3	15.9abcd	4.0abcd	2.4bcd	24.7bcdef	98.3a
PC1-177	15.8abcd	5.0ab	3.0b	31.1abc	97.5a
CN 1028-15a	14.8abcde	2.0defghi	1.6de	14.5f	85.0ab
CN 1181-312	14.7abcde	2.7cdefgh	2.5bcd	18.4ef	87.5ab
Local Variety	14.7abcde	3.8abcdef	2.4bcd	23.9bcdef	95.8ab
CN 1232-9	14.4abcde	3.5abcdefg	1.8bcde	24.5bcdef	94.2ab
AVRDC Selection 1	14.2abcde	2.7cdefgh	1.5de	18.9def	77.5ab
I 444	13.1abdef	2.8bcdefg	2.1bcde	21.0cdef	93.3ab
CN 1028-15b	12.9abdefg	2.5bcdefghi	2.0bcde	19.4def	78.3ab
AVRDC Selection 5	12.3abcdefg	3.9abcde	2.4bcd	32.5ab	89.2ab
Empat Bulan	11.6abcdefg	3.1abcdefgh	2.1bcde	38.1a	82.5ab
CN 1229-16	10.1abcdefgh	2.8bcdefgh	2.4bcd	26.9bcde	91.7ab
CN 941-32	9.7abcdefgh	1.7defghi	1.9bcde	16.8ef	80.8ab

Note: Figures in the same column bearing the same letter are not significantly different at the 0.05% probability level.

[a]Dry matter yield of tubers (%)=Dry matter content of tuber (%) x Fresh tuber yield.

COUNTRY PAPER - PAPUA NEW GUINEA

V. Hadfield[1]

Although sweet potato is by far the most important subsistence crop in P.N.G. there is remarkably little reliable information on production and in the past ten years estimates have ranged from 600,000 tonnes per annum, through 1.8 million tonnes to 2.4 million tonnes. Later on I will postulate on possible reasons for these vast differences but it is important to note that P.N.G. is a major producer of sweet potato and it forms the basis of subsistence farming systems in the highlands and is, in some areas of the lowlands, replacing taro as the major staple. I would suggest that a figure of 2 million ± 200,000 tonnes will suffice for the purposes of this paper and I will continue and discuss the importance of the crop in P.N.G.

The highlands of P.N.G. are the most densely populated areas of the country and for many hundreds of years have been geographically isolated from the coastal areas. Over the course of time man, pigs and sweet potato have formed an association so interwoven into the anthropology of the people that it is difficult to speak of one of them in isolation. It is mainly because of this there is far more literature on sweet potato in the Anthropology section of the National Library than in the Agricultural section and that attempts to extrapolate the results of detailed studies in a single village to the vast areas of the highland provinces have produced such conflicting figures on national production.

In general, sweet potato is used as a basic staple for the bulk of the population of the highlands and the surplus is fed to pigs.

It is estimated that about 40% of the total production is fed to pigs but again this figure must be treated with caution. Pigs have no natural enemies in P.N.G. and have a very special place in tribal ritual, bride price and social status. When the pig population becomes such that they actually compete for food with people there tends to be 'pig kills' which reduce numbers very considerably and the cycle starts again.

The build up of the pig population can be regarded as a form of storage into which surplus sweet potato production is placed until required and pigs are virtually the only animals which are involved in the highlands farming system.

A few attempts have been made in the industrial processing of sweet potato but none have reached the commercially viable stage as yet. The main reason is the high costs of the raw material and transportation to industrial centers and there is little likelihood of these costs being reduced in the foreseeable future.

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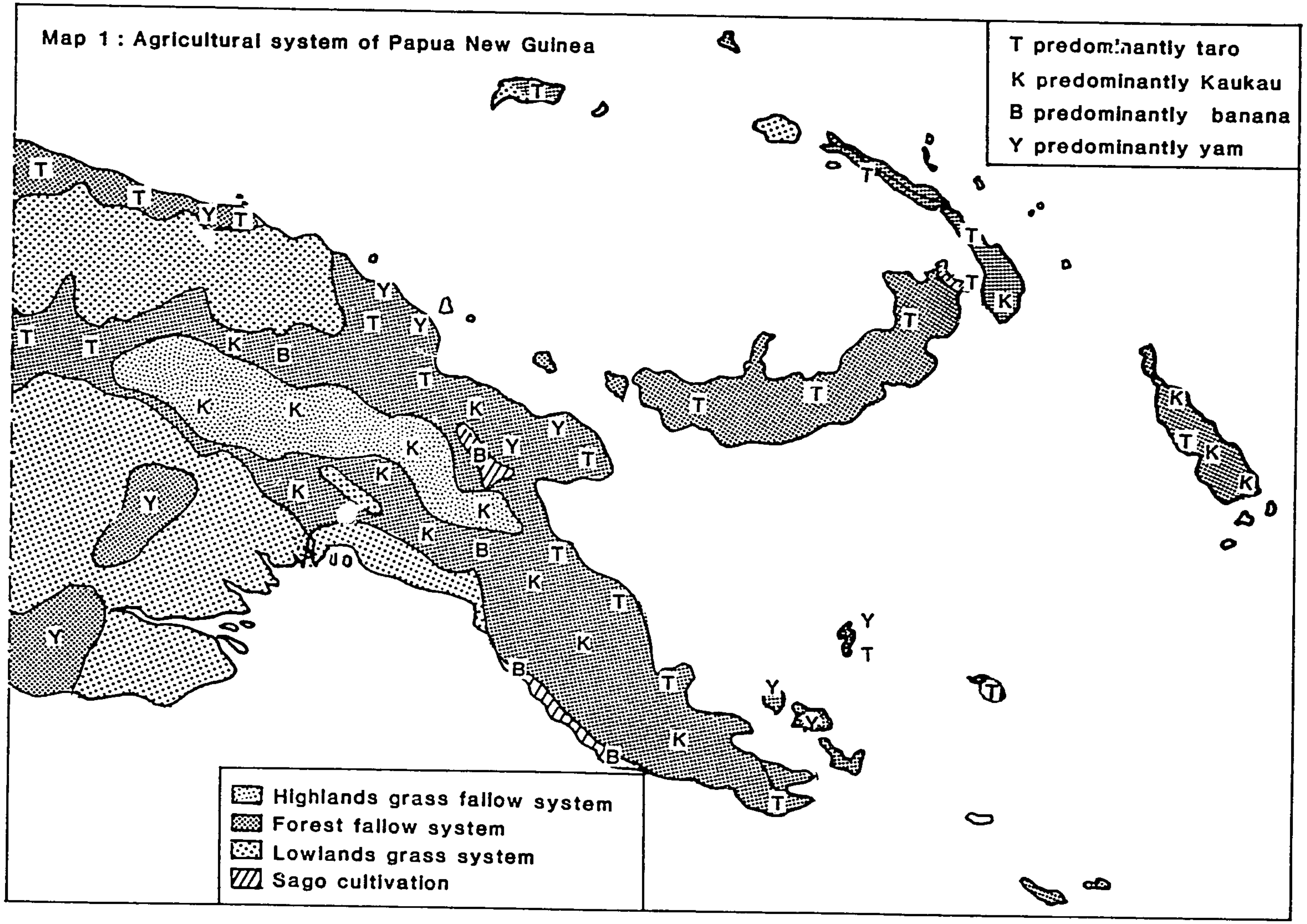

Map 1 : Agricultural system of Papua New Guinea

Finhros (1986) estimates post harvest losses at 30% and a recent paper by Joaghin (1987) gives details of comparative prices of locally produced staples compared with imported rice and discuss the consequences in terms of likely future trends.

As stated previously sweet potato is the major staple food in the highlands and various estimates on the proportion of total calory intake have been made over many years. Some 600 plant species are known to be eaten at one time or another in P.N.G. and the seasonality and availability of many of these species will affect the estimates but some 80% of total calorific intake would be a reasonable figure.

Problems in the cultivation of sweet potato are quite sharply divided into "research worker perceived" and "farmer perceived" and I will not attempt to slavishly follow the outline given in the country paper format until I have had the chance to enlarge on this statement.

For some hundreds of years farmers have selected varieties of sweet potato which they recognize as possessing some desirable characteristics and we have almost 1300 varieties available on our research stations. These collections remain a largely untapped resource as we have neither the manpower nor infrastructure to deal with more than a minute proportion of the collection. Until this mass of material has been fully exploited it does not appear to be a particularly valuable exercise to embark on a breeding programme to increase the number of untested varieties.

There may be up to 40 varieties being used in a single village and all these varieties will have been chosen for one or another characteristic found desirable by the farmer. Differences in taste, texture, colour, duration of harvest period, ease of propagation, cold tolerance, etc., may all be involved, as well as the total yield and size of tuber. In general the varieties may be site specific and not at all suitable for other locations which may be apparently very similar.

The validity of attempting to carry out protein analysis of 1300 varieties in multilocation trials is extremely doubtful before reliable yield trials have been completed and although I do not expect too many people to agree with me I consider that most of the research carried out on sweet potatoes in P.N.G. over the past 40 years has not produced sufficient clear cut or reliable data to convince farmers to change either their methods or their varieties. Subsistence farmers do not normally have access to chemicals, whether they are fertilizers, herbicides, fungicides or insecticides and even if research had been able to produce a tested recommendation they do not have the means to carry it out in the vast majority of cases. In other words research has been oriented towards the researcher rather than the farmer and the result is a huge collection of random pieces of information which lack general applicability to the major problems of the crop. Two examples of this may serve to illustrate my point. The visit of a consultant nematologist to P.N.G. resulted in a two year project on which a number of nematodes were identified, nematicides applied and populations monitored. By the time the project was completed no evidence had been presented which demonstrated a loss of yield from nematodes, or, equally important, whether nematode populations were affected by the normal practice of not using the same piece of land for more than a single crop.

We have been involved in a virus project for almost four years, with at least two more years to go; and both ACIAR and SPC are collaborating in this work. A tissue culture laboratory has been set up, personnel trained in the relevant techniques and a significant proportion of our limited resources utilized in these trials. I would welcome unequivocal evidence of the effect of the infection on yields of sweet potato under P.N.G. conditions rather than assume that viral symptoms must signify a reduction is yield.

We do have pests and diseases and these will be discussed in detail during the appropriate sessions in the course of this most valuable workshop but at this point I am merely indicating areas where I feel we need to concentrate on the relevance of research to problems.

Little needs to be said regarding quarantine regulations and germplasm exchange. Import and export for human or animal consumption is not carried out in P.N.G. and the exchange of genetic material is a continuous process which is subject to the normal quarantine requirements of P.N.G. and no major problems exist in this area.

In terms of Research P.N.G. does not have a national sweet potato programme as such and for many years has carried out either ad-hoc research or participated in a variety of regional projects with varying degrees of success. A long series of transfers, resignations, reorganizations, funding problems, etc. has been responsible for the fragmented research effort and less than 25% of the trials carried out in the past 20 years have actually been published in any form.

This is by no means a situation unique to P.N.G. but it does not provide a satisfactory base from which to embark on a new programme. You are all at least more aware of these problems than I am and I will take this opportunity to inform you of our new research programme with particular reference to sweet potato.

The Crop Research Division of the Department of Agriculture and Livestock is now entirely committed to subsistence farming research, mainly through a Farming Systems approach.

The resources available to the Division are not sufficient, either in manpower or funding to continue the component research into individual crops which was possible ten years ago. The formation of autonomous research institutes for coffee, cocoa, coconuts and oil palm, the creation of a Food Management Division dealing with food grains, citrus, minor crops, etc., plus the separation of Plant Protection, Animal Health, Chemistry and other functions had left the severely reduced Research Division with no specific role and a radical reorganization was necessary if it was to maintain viability. This structure and programme which will clearly indicate our priorities and where P.N.G. can fit into the regional projects for the most important subsistence crops is outlined below.

The whole research programme is based on the simple premise that, due to a rapidly increasing population and consequent reduction in available land per unit of population the traditionally stable low input subsistence farming systems of P.N.G. are under stress. The stress on the system will continue as long as population increases more rapidly than the availability of suitable land.

For many tropical countries the situation in P.N.G. would be regarded as almost utopian and there is certainly no evidence of a crisis in either food supply or population pressure. Unfortunately there is equally little evidence that the lessons now being painfully learned in other countries are even being taught in P.N.G.

The fact that P.N.G.'s time bomb has a longer fuse than most will not affect the final result unless action is taken to defuse it in the near future and the programme is designed to make this action possible.

Traditional subsistence farming systems are noted for the complexity of their detail and have provided happy hunting grounds for anthropologists, human geographers and other social scientists. Basically however they are virtually identical with minimal or no input systems throughout the tropics in that land is cleared, a crop or crops are planted and harvested until yields become unacceptable when the area is abandoned and a new area cleared. It may have taken more than 20 years fallow before a piece of land was reused and this may well have permitted the soil to regain its original fertility although information on fertility is poor. This system still exists in a few isolated areas of P.N.G. with very low population densities but in the Highlands fallow periods have generally been reduced to between 5-8 years in several provinces and in parts of the coastal areas and specially in East New Britain fallows of 6-12 months are being practiced.

In the past decade there has been a very significant increase in the area of good land turned over to cash crops, mainly coffee in the highlands and cocoa in the coastal regions. The entry into the cash economy by such a significant part of the population has had many effects but only those relevant to the research programme need be considered here. The first is that land planted to coffee or cocoa is obviously unavailable for subsistence farming and secondly that the requirements of the cash crop in terms of labour inputs reduce mobility and tends to concentrate populations in the areas most suitable for the cash crop. The reduced subsistence base is compensated for by the access to cash and ability to purchase food in the market place and again PNG does not differ from many other countries in this respect. There are however some risks attached to the dependence of world commodity prices and these risks are now becoming clearer to P.N.G. smallholders who have seen incomes fall dramatically in the last two years and it is likely that this fall will continue.

There is considerable potential for a smallholder to increase yields of his cash crops but this would require cash inputs which cannot be afforded if prices are low. He is rarely in a position to revert to subsistence farming unless he uproots his cash crop as land is no longer freely available in the area and there is always a hope that prices will improve.

There exists therefore two major classes of small farmer, the purely subsistence farmer using a minimum input system and under increasing pressure for the land on which the inherent stability of this system depends, and the cash crop smallholder whose survival is the cash economy depends on world commodity prices over which he has no control.

There are five research stations in the Division of which three (Bubia, Keravat and Laloki) are in the lowlands and two (Kuk and Aiyura) are in the highlands. Bubia is the center for Lowlands Farming Systems Research and has a multidisciplinary team of scientists including agronomists, plant protection scientists, agricultural economists and supporting staff. Rapid Rural Appraisals have led to the formulation of a research programme which will investigate methods to overcome those biological constraints to sustainability which have been identified by the team.

Kuk has a similar team working on highland systems and the programme is at a more advanced stage due to the completion of RRA's earlier than Bubia, and has already built the necessary extension linkages between scientists and farmers. On farm trials are in progress and further trials will be laid out as the programme progresses.

Keravat, which is shared with the Cocoa/Coconut Research Institute has developed a cocoa/coconut farming system research programme which aims to combine cash crop and subsistence farming in the cocoa areas of East New Britain when population density is the highest in P.N.G. and fallow periods are becoming too short to sustain even basic productivity for much longer. This team has only recently been formed and completed its first rapid rural appraisal from which its programme will be formulated. Cooperation with the CCRI and the local extension services is built into the programme which is already generating considerable interest.

A smaller but similar programme is planned for Aiyura which shares the station with the Coffee Research Institute and the size of this programme is limited by the facilities available but the collaboration of the CRI will add to the resources as well as help them to fulfill their obligations to the smallholder coffee sector. Aiyura will also be the centre for the DAL Agroforestry project which has been formulated as a result of a months consultancy visit by Professor J. Ewel of Florida University.

This project will be shared with DAL's Land Use Section and the Chemistry Section who will carry out fundamental studies on soil fertility and erosion with the Aiyura team.

The remaining station (Laloki) is not representative of any major climatic zone in P.N.G. and will act as the center for germplasm agronomy for the Division. It will also be the major station for the biological control programme which is being developed in collaboration with the South Pacific Commission, ACIAR, CSIRO and other Regional and International bodies. In view of the very limited capacity of smallholders and subsistence farmers to apply chemical control measures against the potential increase of pests and diseases as cultivation methods become more intense and concentrated I regarded a biological control programme as a priority area and special attention has been given to this.

Laloki has excellent but virtually unused post harvest facilities and an officer has been sent overseas to gain experience in post harvest work as these seems little point in advising farmers to grow food and watch it rot because storage advice is not available.

The above gives the base outline of what is in fact a detailed and comprehensively integrated farming systems research programme designed specifically for P.N.G. conditions. It has not been easy to produce such a programme out of the structure left behind in the reorganization process but it is viable and if allowed to develop without further changes offers an opportunity for research to serve the most neglected sector of the countries population.

Finally, I turn to the main reason why I am here this week which is to try and workout relevant international and regional cooperative research programs which do not weaken PNG's already very fragile research structure. We already have ongoing projects with ACIAR, SPC, AEPBR and have signed an agreement with EEC in which P.N.G. will provide our collection for screening, selection and testing for improved varieties at multilocation trial plots. This is a large regional project and our resources are now spread very thinly. We have already heard from the previous country papers how diverse are the major problems and very few individual countries are in a position to handle all of them. Our research effort is now geared to overcoming the constraints to the long term sustainability of subsistence farming systems, which are based in low input traditional methods, under the inevitability of increasing population leading to an eventual shortage and therefore potential degradation of available land. We are not very concerned with making industrial alcohol or sweet potato chips but are concerned with the survival of a system which involved almost 80% of the rapidly increasing population of Papua New Guinea. I trust that as a result of the deliberations taking place here this week it may be possible to identify some solutions to our problems and if so, the efforts of the organizers will not be wasted.

SWEET POTATO RESEARCH AND DEVELOPMENT IN THE PHILIPPINES

M. K. Palomar, E. F. Bulayog[1] and Truong Van Den[2]

1. INTRODUCTION

Root crops, especially sweet potato, play a major role in the diet of Filipinos. The staple food for people in the hilly and marginal areas is sweet potato, with either rice or corn as supplement. Occasional consumers also use sweet potato in various snack preparations. The average per capita consumption from 1968 to 1984 as reported by the Department of Agriculture (DA) was 18.68 kg. Likewise, about 5% of the total sweet potato production is used as animal feed (DA, 1984).

The industrial use of sweet potato (SP) has been recognized with the advent of industrial processes utilizing SP as an additive, as one of the energy sources in commercial feed manufacturing or as the major raw material in SP fluor/starch processing. In various baked products, SP flour can substitute for 20-60% of wheat flour. New fruit-like food products from SP with similar appearance, taste and nutrient content to that of processed fruit items have also been developed. These include: delicious SP, SP catsup, SP jam/spread and SP beverage/concentrate.

Aside from the above mentioned uses, the Philippine Root Crop Research and Training Center (PRCRTC) has developed a technology on soy sauce production from sweet potato. A natural fermentation technique is followed using SP flour instead of wheat flour (100% substitution). A project has just been initiated to transfer the technology to farmer-cooperatives using a "grassroot-based" development approach.

The present tight economic situation in the Philippines calls for the use of cheap and indigenous agricultural materials for food or commercial uses. Increased sweet potato processing and utilization can help sustain SP demand for industrial uses.

2. PRODUCTION AND PRODUCTION ZONES

In 1986, the sweet potato harvest in the Philippines was 800,614 t of fresh roots. The Bicol region had the highest contribution at 237,543 t or about 30% of the national production (Table 1). Its high SP production is attributable to its being in a typhoon-belt area where high standing crops do not thrive well; hence, SP seems to be the most appropriate crop.

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Only Western Mindanao among the Mindanao regions had the lowest productivity at 2.17 t per hectare. It is because Western Mindanao is situated along the coastal area with generally rocky soil. Other Mindanao regions, particularly Central Mindanao, had better productivity because they are located in valleys and wide plains with relatively cool temperature suitable for root crop production. Of all the regions, however, Ilocos had the highest yield per hectare at 7.99 t.

Table 1. Sweet potato production in the Philippines by region.

Region	Area (ha)	Production (t)	Yield (t/ha)
Ilocos	8,210	65,566	7.99
Cagayan Valley	5,390	19,035	3.54
Central Luzon	6,180	28,645	4.64
Southern Tagalog	8,470	40,231	4.75
Bicol	34,840	237,543	6.82
Western Visayas	7,890	32,256	4.09
Central Visayas	23,060	69,643	3.02
Eastern Visayas	39,320	152,915	3.89
Western Mindanao	6,750	14,662	2.17
Northern Mindanao	11,870	65,728	5.18
Southern Mindanao	8,970	46,499	5.18
Central Mindanao	3,830	27,891	7.28
PHILIPPINES	164,770	800,614	4.86

Source: Bureau of Agricultural Statistics (1986), Manila.

3. PRINCIPAL PROBLEMS OF THE SWEET POTATO INDUSTRY

3.1. Seed Production

Varietal improvement in the Philippines is now being undertaken by the University of the Philippines at Los Baños (UPLB), Visayas State College of Agriculture (ViSCA) and PRCRTC. Conventional breeding techniques are being used due to lack of training and facilities on non-conventional breeding techniques such as recombinant DNA. Breeding is a relatively long and tedious process. Distribution of seed cuttings for propagation and production is constrained by the low adaptability of the resulting hybrid to certain localities. Aside from financial constraints, there is also a growing problem on the maintenance, characterization, documentation, improvement and evaluation of accessions due to lack of facilities for biochemical analysis and the absence of efficient and reliable *in vitro* storage techniques for sweet potato.

3.2. Agronomic Practices

Production technologies of SP in relation to edaphoclimatic conditions have been improved. One major problem identified, however, is the attitude of the farmers towards improved production technologies. Technology adoption is slow since farmers tend to be very selective and extremely cautious as to what to adopt and (the extent of adoption). Other problems in relation to the technologies also exist hence, these technologies must be tested on farmer fields in different locations.

3.3. Pests and Diseases (Production and Storage)

Pest infestation is compounded by almost non-existent pest management practices among SP farmers. Sweet potato insect pests are classified into two groups: the stem and tuber feeders, and the leaf and shoot feeders. The former group causes greater damage than the latter, although some of the defoliating species may at times endanger the crop during pest outbreak. On the other hand, fungi, viruses, bacteria and nematodes have been found to infect SP and cause yield losses as high as 50% and in severe infection may even cause total yield loss. Some of the diseases affect the crop in the field, while others affect the crop after harvest. Poor root quality due to deformed root, undesirable color, texture and flavor reduces SP marketability.

Control measures that have been recommended range from chemical and biological to integrated pest management. Results, however, are still subject to verification in relation to economics and applicability. Current researchers are directed at the improvement of these control measures in terms of effectivity.

3.4. Distribution and Marketing

The high perishability of sweet potato calls for a ready market and efficient transport services. The value of the product declines when it reaches the market deformed and dessicated. Both rural and urban markets prefer SP in fresh form. The lack of and poor transport facilities result to inefficient product distribution and marketing. In cases where there are commercial or industrial processors as ready markets, imbalance between price and product form exists. When SP's are sold as dried chips, the farmer-producer has to incur additional costs in chipping and drying. Both time and labor, and even monetary costs, have to be added into the price. However, the buying price of SP dried chips seems only a few cents higher than the price in fresh form; if the above costs are to be considered the farmer-producer is at a disadvantage.

Moreover, farmers lack the entrepreneurial capabilities in dealing with product market. In general, they do not have the knowledge in presenting their product into the market in relation to form, time and place utilities.

3.5. Processing and Utilization

The farmers' preference to sell their product in fresh form may create a market glut particularly in SP growing areas of the country and therefore reduce the price of the product. However, the government's effort in promoting the use of locally available materials in industrial processing has somehow created an additional market for SP, particularly in livestock feed processing. The ban on yellow corn importation exerted pressure among feed millers to substitute corn with SP meal in commercial feed rations. But after a few years of using SP meal, feed millers now are confronted with the following constraints:

3.5.1. Physical characteristic of the milled product

Taking into account that the poultry industry is the major market of feedmillers, powdery feeds are not preferable since they tend to reduce appetite. Chickens are prone to eat grain, and poultry raisers are conditioned to buy feeds with yellow corn.

3.5.2. Need for additives

Poultry meat and eggs require pigments. Pigmentation provided by yellow corn cannot be supplied by SP and therefore would require the feed manufacturers additional cost load for pigments.

In bakery products, an average of only about 40% of the wheat flour can be substituted with SP flour because of the resulting difference in odor and color.

4. INTERNATIONAL TRADE AND GERMPLASM EXCHANGE

4.1. Export for Human or Animal Consumption

The demand for sweet potato in the international market is inevitable. The Department of Agriculture (1986) reported that the European Economic Community needs SP meal for animal feeds at two million tons per year. There is also the big demand of Japan and Hongkong for yellow-fleshed SP in sweetened form as human food. The Philippines was able to supply the international market only about 73 t of dried SP chips (CB, 1986).

4.2. Germplasm Exchange

The existing varieties of SP commonly grown in the Philippines are a mixture of natives and hybrids. In the effort to improve the characteristics and quality of SP, cooperating countries, particularly in the tropics where SP is abundant, exchange of materials or accessions of SP for breeding purposes is essential.

The creation of PRCRTC gave more impetus to sweet potato research. Realizing the importance of genetic resources, one of the earliest projects conducted by PRCRTC was a collection expedition throughout the Philippines and in some parts of Southeast Asia. Presently, there are 1,079 accessions of SP maintained in the PRCRTC field genebank. Many of these accessions have duplicates at the National Plant Genetic and Resources

Laboratory (NPGRL) at UPLB. Unless new collections can be made from the area where an accession was originally taken, a lost accession is lost forever. It is also costly to maintain many duplicates, but one cannot be absolutely sure that two accessions having similar morphological characteristics are totally the same. Biochemical differentiation is necessary, but as mentioned earlier, the country does not have enough facilities for this purpose.

5. NATIONAL SWEET POTATO PROGRAMS

5.1. Production

The Philippine Seed Board has approved and recommended 11 SP varieties, namely: VSP's 1-6, UPLSP-1, UPSLP-5 (G113-2B), BPI SP1-LO 323 (Kinabakab), UPLSP-2 (Tinipay), BPI SP2 (CI 693-9). These varieties were recommended primarily due to their high yielding characteristics. The extent of their utilization, however, is dependent on several factors such as:

- Purpose

  A variety can be selected based on its intended use. If for table use or when simply boiled, varieties with high dry matter content are preferred. Other HYV's are suitable for animal feeds and other processed SP products.

- Method of harvest

  Some farmers opt to use varieties that are not highly susceptible to weevil because they do not harvest the crop at once.

- Vine characteristic

  Other varieties do not have creeping vines and some farmers prefer these creeping varieties for vegetable production.

Different varieties may have different characteristics as different users have different preferences. Moreover, there are varieties that are now found susceptible to minor pests and diseases. Varietal improvement projects therefore are presently initiated by PRCRTC to minimize if not get rid of the effects of the above mentioned constraints. Production tools and equipment are also under evaluation and modification to enhance SP production. Target beneficiaries of these efforts are both the marginal and medium- to large-scale SP farmers. However, there is specific bias towards the small farmers throughout the SP growing regions.

5.2. Research

PRCRTC is mandated to spearhead all SP researches in the country. Research priorities are directed at processing and utilization (food and feed), varietal improvement, pest management, postharvest storage, and production and processing tools/equipment. Recently, the potential of SP as an indigenous crop with high yield and nutritional value, particularly Vitamin A., Vitamin C and minerals has been recognized. Efforts are now geared towards improving the economic value and upgrading the status of the commodity from being a subsistence to a market-oriented crop. Socioeconomic studies are presently conducted to update information on SP growers, technological adoption (evaluation and constraints studies) and marketing of SP roots and products. PRCRTC is aided by the Bureau of Plant Industry and its experiment stations. Some international funding agencies provide financial and technical assistance.

5.3. Extension

Mature technologies are disseminated through various trainings and demonstrations. Development of the required equipment/tools needed in the above-mentioned processing and utilization technologies, as well as economic feasibility studies are being conducted to facilitate the transfer of technology. Arrangements have been made with private companies for commercialization of the products. For SP-based livestock feed, a Pilot Feed Mill located at ViSCA has been in operation to supply feed requirements of the livestock raisers in the neighboring towns.

Information diffusion through radio and print, primarily through the Philippine Rootcrops Information Service (PRIS), is also being made to arrive at a wider clientele coverage. The effort is made possible with the cooperation of the following agencies: Department of Trade and Industry, Department of Agriculture, Department of Science and Technology, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Visayas State College of Agriculture and other state colleges and universities in the Philippines.

5.4. Education

Agricultural colleges and universities provide agricultural education. The knowledge about SP industry from production to marketing and various SP researches is basically offered by ViSCA where PRCRTC is located. Some of the academic institutions involved as cooperating stations of PRRTC in its SP research are Camarines Sur State Agricultural College, Benguet State University, Tarlac College of Agriculture and the University of the Philippines at Los Baños.

6. SWEET POTATO R AND D WORKERS

As of 1987, the country has a total of 174 SP research and development personnel. Of these, 87 (50%) are B.S. graduates, 57 (33%) are M.S. and about 30 (17%) are Ph. D.'s. Fields of specialization include: plant breeding, agronomy, plant pathology, entomology, postharvest/horticulture, biochemistry, food science, agricultural economics and sociology.

7. INTERNATIONAL COLLABORATION

International collaboration includes financial assistance, germplasm exchange, international symposia and conferences, trainings, scholarships and exchange of scientific publications.

In 1986, an International Sweet Potato Symposium was held ViSCA to identify priority areas for SP research. One important output of the scientific gathering was the putting up of a newsletter to serve as a medium for SP information dissemination.

The SP program of PRCRTC is implemented in cooperation with the International Development Research Center (IDRC), International Potato Center (CIP), Food and Agriculture Organization (FAO), International Foundation for Science (IFS), Tropical Product Institute (TPI) or the new ODNRI, Japan Society for the Promotion of Science, and other international agencies providing valuable assistance.

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THE OUTLINE FOR SWEET POTATO IN KOREA

Moon Sup Chin[1]

1. COUNTRY PRODUCTION DATA AND PRODUCTION ZONES WITHIN THE COUNTRY

1.1 Production Data

Sweet potato is not indigenous crop in Korea, it was introduced in 1763 from Japan. After then, sweet potato has been an important crop in Korea until 1965 because it withstands environmental extremes, such as droughts and typhoons, which few crops can tolerate, and it was tolerance crop to unfavorable conditions of soil. Until 1965, it had been cultivated throughout the country as the famine relief crop because yield potentiality of sweet potato was higher than other staple crops and food production was not sufficient to supply the local demand as the food consumption.

Sweet potato had rolled as the third most important summer upland crop on a quantitative basis, after rice and barley, and sweet potato usually has been cultivated after the harvest of a winter crop like barley. For many generations the sweet potato has been an important crop in Korea. It ranked the third in importance of human food among staple food crops. Maximum area and production was in 1965, when 2,997 thousand metric tons were produced on 152,426 hectares. Since 1965, area planted, total production, per capita consumption and relative importance of sweet potato among food crops has decreased. These changes have occurred in spite of rapid increases in population and substantial increase in yield of sweet potato produced per unit area (Table 1, Fig.1).

Table 1. Area planted, production yield, and index

Year	Area planted	Yield	Production	Percent		
	(1,000 ha)	(t/ha)	(1,000 t)	Area	Yield	Production
1965	152	19.7	2,997	100	100	100
1975	95	20.7	1,953	62	105	65
1985	34	23.5	787	22	120	26
1986	28	24.6	684	18	125	23

[1]Crop Experiment Station Rural Development Administration Suwon, Korea.

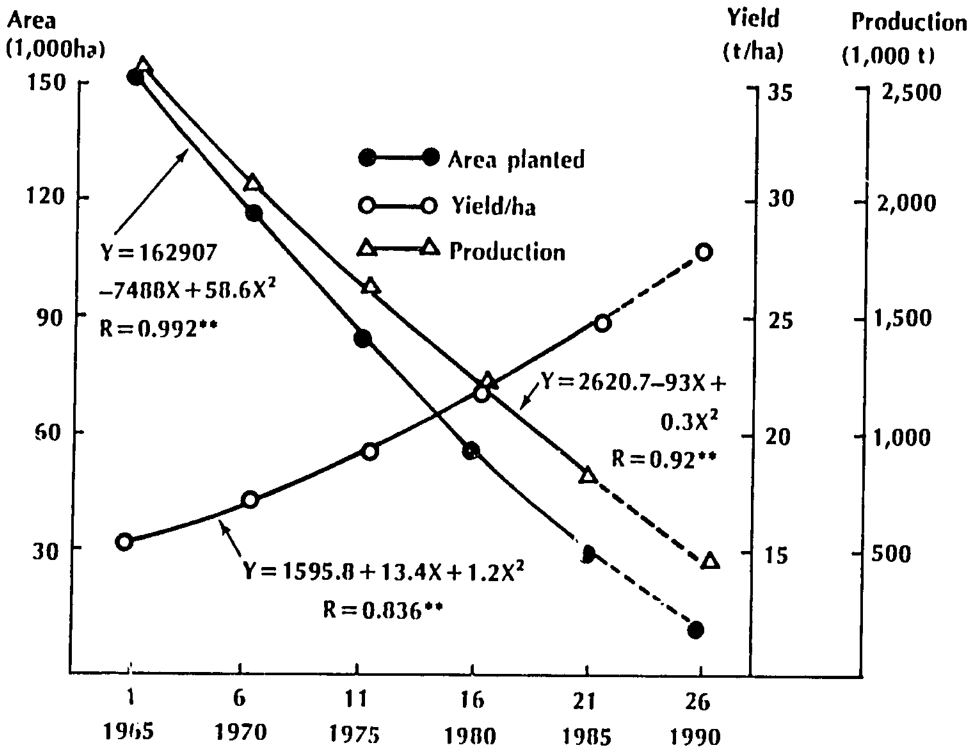


Fig. 1. Changes of sweet potato area planted, production and yield per hectare.

A number of factors have contributed to changes in status of crop.

The reasons are as following:

- Increased urbanization of our population.
- Movement of farm labor to the factory due to the rapid economic development, specially young farmers have been leaving their farmland.
- Government low price measures and importation of the cheaf materials of starch and alcoholic processing.
- Dietary changes of Korean.
- Cash crop growing on sweet potato area like vegetable, ginseng or fruit.
- Decreased farm population and farm labor shortage.
- Difficulties of transport and storage during winter.
- Affluent living of farmer and no mechanical power on sweet potato cultivation.
- Dislike the sweet potato cultivation.
- Low income with sweet potatoes to farmers compared with other competing summer upland crops such as vegetable crops.

As shown on the Table 1, during twenty years, Area planted of 1985 has been reduced to 22 percent and production of 1985 was 26 percent compared to that of 1965 but yield of unit area has been increased to 20% percent.

Fig.1 shows you more clear information on the changes of sweet potato area, production and yield increasement.

1.2. Production Zones

After sweet potato was introduced to Korea it has been grown everywhere throughout country for human consumption as the staple food or subsidiary food nearly until 1970, because it was well adapted to Korea. Sweet potato area planted has been decreasing sharply every year which caused to remove the sweet potato cultivation to the poor soil like newly reclaimed land or to the sea coast and islands, where other crops can not be grown because of the wind damage. There are two types of farmers who cultivate the sweet potatoes. One is the commercial farmer and the other one is the non commercial farmer. The commercial farmer plant the sweet potatoes on the reclaimed land of the inland to sell the whole sweet potatoes as a supplement food, but people living on the islands or sea coast cultivate the sweet potatoes for their own consumption as part of staple food during winter or to sell sweet potatoes for the alcohol or starch processing. On the other hand, sweet potatoes are grown in a small scale everywhere in Korea and people who raise the livestock, have tendency to grown the sweet potato for their animal feed.

2. IMPORTANCE OF SWEET POTATO IN THE COUNTRY

Sweet potato is a very important crop in the view of economic points. It has the potentiality to produce high yield for short period in a unit area and is suitable for human consumption. The numbers supporting peoples with production of sweet potato in a unit area is nearly double compared to rice in the energy basis and cost producing calorie is one fifth compared to the cost of rice. Therefore, sweet potato has potential to support the many people with the cheap expenses for production (Table 2).

Table 2. Comparison of sweet potato with other food crops in the economic view.

Items Crops	Calorie (100 gr)	k Cal/ha	No. of supporting people	Cost (Won/k Cal)
Rice	359	13,320	13.5	652
Barley	337	6,670	6.8	288
Soybean	410	4,550	4.6	537
Sweet potato	134	24,200	24.6	149
White potato	72	7,840	8.0	931
Corn	255	5,860	5.9	262

Sweet potatoes are used primarily for human food, but they may also be used for animal feed, alcohol, starch, and various other industrial purposes. Approximately 70 to 80 percent were used as human food, of sweet potatoes produced each year in Korea before 1965, but uses for human food has been reduced after 1965. On the other hand industrial purposes for alcohol processing have been increasing every year (Fig. 2).

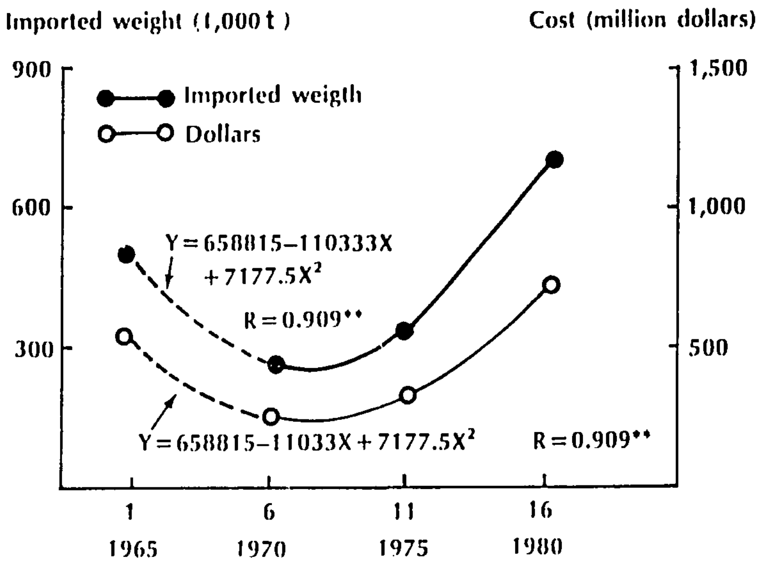


Fig. 2. Changes of weight of imported raw material for beberage alcoholic processing and cost.

Requirements for industrial purposes are not sufficiently covered with the local product, therefore most of materials for alcohol processing have been imported from abroad, so we feel an urgent need to increase the area and production of sweet potato to supply the raw material for alcohol processing. In this point sweet potato is also a very important crop as the industrial crop to help cut down the expenses for purchasing the material for alcohol processing from outside. Sweet potatoes are considered to be an important crop because they grow well in any place; either in the sea coast area which is abundant with wind damage or in the newly reclaimed land in which other crops can not grow well. They give more stabilization yield than other crops do and they have the strong tolerance power to project the soil from the soil erosion. For the above reason, sweet potato has been cultivated for a long time in Korea. A large part of sweet potato is prepared directly for human food and is not prepared canned, frozen, or dehydrated, but recently, some factories are developing sweet potato flakes.

During the winter we do not have enough source for vitamins with the fresh vegetables on the farm, we now recommend one variety with high carotene, dark orange-flesh color to farmers after developing it in 1987. This variety is very suitable for raw flesh and is edible without having to be steamed Petioles of sweet potato also used as vegetables. Limited quantities of sweet potatoes are used as high-carbohydrate feeds for hogs, poultry and other domestic animals, most of sweet potatoes are fed raw on farms where sweet potatoes are grown. Considerable portions of the cull roots are used for animal feed because of their unmarketable root size. Vines and foliage, as well as storage roots are used for animal feed after preparing silage. We have one developed variety for both animal feed and alcoholic processing which has high yield potentiality. Sweet potatoes are very good crops as a source of animal feed if they are properly handled and stored, but sweet potatoes for feeding raw are restricted by handling and storage problems resulting from the high water content and perishability of sweet potato. In industrial processing in Korea, a lot of sweet potatoes had been used for starch production until 1970 with the white- or very light-flesh varieties but now the uses for starch production are not much (Fig. 3).

Starch production industry on a commercial basis has failed because of cheap material imported but sweet potatoes are increasing for the purposes of beverage alcohol processing because demand of beverage alcohol has been increasing in Korea.

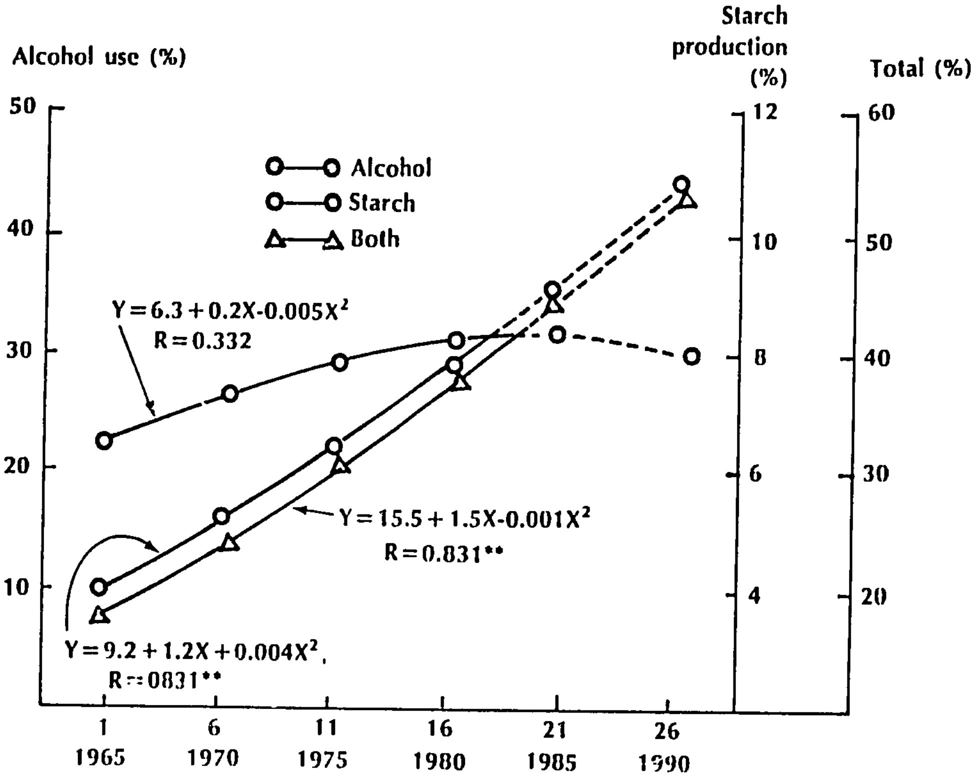


Fig. 3. Changes of alcohol and starch production percent with local sweet potato production.

3. PRINCIPAL PROBLEMS

3.1. Seed Production

In order to produce seed we have to induce the sweet potato to flower. The method is as follows:

In the early spring, we plant morning glory seed to use as the root stock and sweet potato is also bedded to get the cutting to use as the scions. The work of grafting is done by hand and the sweet potato cuttings which were grafted, are kept carefully under the shadow. After cuttings are revived, shortday treatment is given to sweet potato for a long time to induce flowering. In this point, shortday treatment and grafting procedure require a lot of tedious man power.

3.2. Germplasm and Varieties

We have about 300 germplasms and varieties, those varieties are planted every year to maintain and to use as the breeding program but most of the germplasms and varieties are not used as the breeding program. Only they have to be maintained every year. They could be also harbour to the all kinds of pathogens and viruses, as the result of long year maintaining of varieties of germplasms with the methods of field cultivation. We need to maintain those germplasm in vitro culture method to escape from viruses but we do not do that because of shortage of manpower facilities and technique. Our breeding program can be classified into several types according to their principal uses.

- Food types
- Feed or industrial types
- Vegetable types

From the 3rd seedling, selections are carried out in the view of productiveness, appearance, skin and flesh color, acceptable edible qualities and resistance to diseases. Adaptation tests are conducted at the different places in country from 5th seedlings. Many varieties are used for both processing and fresh market in practice. Foodtype varieties, specially those for fresh market use, are often designated as dry-flesh or moist-flesh according to the feel sensation in the mouth during mastication of the steamed sweet potatoes. It is difficult to test the taste and evaluate the quality like dry-flesh or moist-flesh because it needs experienced person, the results are different among people and qualities are different according to produced soil fertility and soil textures.

3.3. Diseases, Pest and Nematodes

Fungus, virus, bacteria and nematode cause the damage to the sweet potatoes. Among the many diseases, nematode and bacteria are not serious losses in yield and quality. Some of the diseases affect sweet potato in the field primarily, others mainly during storage, handling and marketing. Some are serious both in the field and during storage. We have quite a long year for sweet potato breeding, but we only have emphasized on yield and have neglected to the disease control. Recently we have tested the resitance to storage diseases especially on softrot and blackrot and selected one resistance variety to softrot. Losses are heavy during storage as a result of softrot and other diseases, which may make damaged roots unsalable or shorten the storage life of roots and the period of time over which they may be marketed. We don't have any difficulties on fungi disease test but we don't have any idea on viruses. According to the symptoms, several virus diseases have increasingly serious effect on sweet potato production.

Their symptoms are as follows:

Chlorotic leafspot, yellow dwarf, stunting, lowering of the vitality of the plants, less formation of roots, many cellulose roots and yield reduction. Therefore one of our leading varieties was removed from the recommendation to growers but we don't know still the name of virus diseases, transvector their virus character and method of control.

3.4. Storage

Sweet potatoes are stored for six or seven months during winter from October to late in April at low temperature between 10° to 17° C, but the optimum temperature is ranged between 12°-15°C with the 85-90% relative humidity. Storehouse, storing boxes, and incidental equipment are always sterilized before uses. In order to keep the sweet potato well in the store house, optimum temperature and optimum relative humidity are very important but it is costly to store the sweet potatoes because temperature of outside is sometimes very low.

That is why market price of sweet potatoes are very expensive during storage or after storage. We have several storage methods for sweet potatoes during winter. They are, indoor all-underground storage, ? storage, indoor semi-underground storage and tunnel storage. Among above methods, there is no completely safe method.

3.5. Distribution

Once new variety is improved and small amount of breeder's roots are propagated at the breeding station, Provincial Office of Rural Development requested amount of sweet potatoes according to their option and they propagated the sweet potatoes to distribute to farmers. Therefore we do not have much problems in sweet potato distribution but breeder's roots are multiplied every year to distribute to Provincial Office of Rural Development. While the breeder's roots are growing in the field every year, they are easily attacked by viruses, fungi and bacteria diseases. That is why improved variety would give the low yield due to the viruses, fungi or other pathogens after a long year.

3.6. Marketing, Utilization and Processing

Marketing of sweet potatoes in Korea goes on from August, the time of early harvesting, to June of the following year. Market price is very flexible from time to time. The price from early harvesting is the maximum price. From that time to early November, the price has been decreasing until the lowest price start again to rise up after November because sweet potatoes coming to market are the stored ones. They are all food types but industrial types are sold by the fresh or dehydrated forms to the Agriculture Cooperative Association and Agriculture Cooperative Association supplies those fresh or dehydrated sweet potatoes to the factories for starch or alcoholic processing. Those are sold by the low prices with which government set up, compared to those of market prices. Therefore farmers have tendency not to produce the industrial types. On the other hand, demand of industrial types for alcoholic processing has been increasing but with the local production, demands weight for industrial types can not be satisfied. So that importing for industrial purposes has been increasing every year.

4. QUARANTINE REGULATIONS AND GERMPLASM EXCHANGE

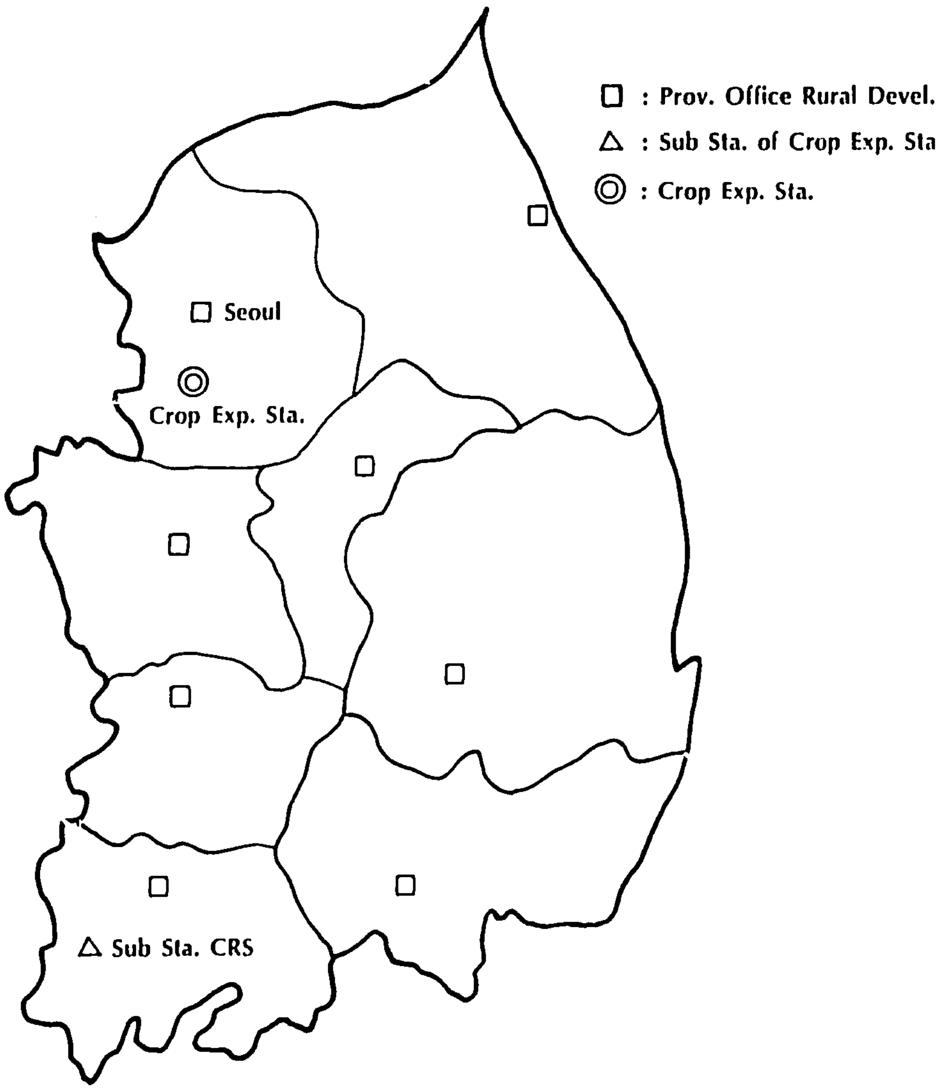
So far we have not exported sweet potatoes for human or animal consumption because production of sweet potatoes have not been enough. But import for human or animal consumption would be possible in future especially import for animal consumption is more urgent because we import corn, barley, soybean, sorghum and other cereals for animal feed. We do not have any difficulties in quarantine regulations to import the dehydrated sweet potatoes for animal feed . Also we can easily exchange germplasm of sweet potatoes for the purpose of breeding. Exchanging germplasm can be possible only during the storage period of sweet potatoes from October to early of April, but it is difficult to export sweet potatoes during the growth on the field, because we have not maintained all germplasm in vitro. But we will keep all germplasms in in vitro method from next year. Then we can export our germplasms or developed varieties anytime to exchange genetic material.

5. NATIONAL SWEET POTATO PROGRAMS IN PUBLIC AND PRIVATE INSTITUTIONS

We do not have private institution for sweet potato programs. Crops Experiment Station belong to government has researched on sweet potatoes for a long time. Sweet potatoes programs can be divided into two groups according to principal uses - food type breeding and feed or industrial types breeding.

In food types varieties, the difference in the character of the solids in the cooked roots causes the dissimilarity in the feel sensation in the mouth. According to the feel sensation in the mouth food types are classified into dry-fresh, moist-flesh and intermediate. In order to select the food types, attractiveness of skin, flesh colors uniformity of root shapes and productivity had been emphasized but recently pleasing flavor of flesh including resistance to diseases has been more important factor in food type sweet potatoes, because demand of food type with the good quality has been increasing as the subsidiary food in the cities. In order to breed the feed or industrial uses, high yielding potentiality, high starch content, and resistance to diseases are important factors. One variety, the deep-yellow-flesh variety, is now available for production of high-quality feeds or for alcohol processing use. Therefore, two type of sweet potatoes are produced mainly in southern part along southern sea cost and are on many islands.

On the islands or sea coast area, farmers cultivate usually sweet potatoes for their food. In land of southern part, specially they cultivate food type sweet potatoes to sell. But food type sweet potatoes are cultivated everywhere of Korea in a small scale for the self-consumption. Crop Experiment Station is the center of sweet potatoes improvement, regional yield tests are conducted at 9 different Provincial Rural Development Administration. And new varieties are released to the farmers with the help of the Provincial Rural Development Administration and Country Rural Guidance Office. At the universities or technical schools they teach the sweet potato but they do not have any breeding program on sweet potatoes except the physiological researches. (see map of Korea)



6. PERSONNEL AND THEIR EXPERIENCE

Only two researchers take in charge of sweet potato improvement in Korea. One person works at the Crop Experiment Station located in Suwon, center city of Korea's agriculture researchers and the other works at the sub-station of Crop Experiment Station located in southern part. Many researchers have been exchanged on sweet potato programs in Korea due to their promotion or transfer. Therefore experiences of researchers on sweet potato program are not long enough; their experience is of nearly 10 years on sweet potatoes. With the two researchers who have not mature experience, it is unreasonable to expect the good result of sweet potato improvement. But I am sure researchers on sweet potato improvement have done their best. Table 3 shows you their achievements on sweet potato improvement.

Table 3. Varietal improvement effect of sweet potato in yield.

Variety	origin	Year	Yield	Index	Remarks
Won-ki	Introduce	1923	1,876	100	Food types
Chungseung100	"	1943	2,202	118	"
Suwon 147	Improvement	1944	2,669	143	"
Chon-mi	"	1948	2,696	144	"
Shin-mi	"	1967	2,642	142	"
Hwang-mi	"	1971	3,096	166	Industrial or food type
Hong-mi	"	1976	3,498	187	"
Eun-mi	"	1982	3,914	210	Industrial type
Chin-mi	"	1984	4,457	239	Feed and industrial type
Seon-mi	"	1985	3,636	195	Food and industrial type
Won-mi	"	1986	4,173	224	Feed type
Suwon 119	"	1987	3,732	199	Raw flesh edible type

7. FUTURE PLANS FOR SWEET POTATO IMPROVEMENT

- Pleasing flavor taste, high vitamin and nutritional value improvement for food type sweet potato.
- Improvement of virus disease resistant variety.
- Technic development for maintenance of germplasm in vitro culture method.
- Meristem culture to keep or to get the virus free stock of sweet potatoes.
- Continuous pollen culture to get the homogenous stock for breeding programs.

8. INTERNATIONAL COLLABORATION FOR SWEET POTATO IMPROVEMENT

- Exchange of information and genetic material.
- Technical support from CIP.
- Establishment of international nurseries for selecting the high yielding resistant varieties to diseases.
- Physiological research.

9. OTHER INFORMATION

- Cooperative research.
- Training on virus disease research and other disease control.
- Training on physiological research.
- Training on the quality improvement of sweet potatoes.

SWEET POTATO IN THAILAND

Manoch Thongjiem and Sansern Piriyathamrong[1]

1. INTRODUCTION

Sweet potato is a rootcrop which has long been grown in the country for domestic consumption. It is produced mainly by small farmers in every region due to its grow well under most of environmental conditions of the country. Sweet potato in Thailand is considered the second important rootcrop next to cassava in terms of planting area and production. Farmers normally planted the old local cultivars and applied improper cultural practices that resulted unfavourable yield. Research on sweet potato is undertaken by the Department of Agriculture and also in universities. Areas of research are concentrated on varieties/cultivars, collection and evaluation, cultural practices, major insect-pests and utilization.

Present research and development emphasized on encouragement of in country consumption, industrial processing and animal feeding.

2. PLANTING AREA AND PRODUCTION BY REGION

Area planted to sweet potato reported by Department of Agricultural Extension in 1984-86 range between 11,000-14,000 hectares with an average yield of 9.87 t/ha. The total annual production was approximately between 100,000-140,000 tons. The area planting to sweet potato is divided into four regions. The central part of the country has the biggest area of sweet potato growing. The southern and northeastern have nearly the same sweet potato hectarage while the northern part has the smallest growing area.

3. IMPORTANCE OF SWEET POTATO IN THE COUNTRY

In the olden time, sweet potato was produced in the farmer's homeyards mainly for their own consumption or shared among relatives. Nowadays, sweet potato is grown commercially in all regions of the country. Consumption of sweet potato in Thailand is typically boiled or steamed and served with or without sugar. But there are many kinds of main dishes and snacks also prepared from sweet potato e.g. curry, soup, sweet potato in syrup, sweet potato with coconut milk, curry puff, chips, baked, etc.

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Industrial processing of sweet potato in the country is done in only a small scale. Tapioca factories sometimes produce sweet potato starch, also. The amount of the sweet potato starch annually demanded in the country has never been identified. Some snacks having sweet potato as ingredients are also produced in the food processing factories. However, sweet potato has a potential to be developed for processing if quality and production of sweet potato is improved. Sweet potato vine and nonmarketable roots are used for feeding animals for example hogs, cattle, chicken, and fishes.

4. PRINCIPAL PROBLEMS TO SWEET POTATO PRODUCTION

4.1. Seed Production

Seed production program of sweet potato has not started in the country to supply the farmers good quality planting material. Generally, the farmers used the stem tips produced in their fields for planting or farmers purchased planting material from the big farmers.

4.2. Germplasm and Varieties

Research on sweet potato varieties is done by the Horticultural Research Institute, Department of Agriculture and also the Universities at Pichit Horticultural Research Center. Over 300 cultivars have been collected from every region in the country and some of them introduced from abroad e.g. U.S.A., AVRDC, IITA, JAPAN, and other countries in southeast Asia. They have been evaluated and characterized using the IBPGR System. The promising cultivars resulted from evaluation trials have been further evaluated in all regions. Some of the cultivars were selected for breeding program.

4.3. Diseases

As reported by the pathologists, there are some diseases found in sweet potato areas, the major are *Cercospora* leaf spot, bacterial soft rot, root knot nematode. Virus diseases also found in Thailand but so far details on crop losses caused by the diseases have not yet been identified.

4.4. Pests

Sweet potato weevil is the most destructive insect of sweet potato in Thailand. Experiments for establishing control measures have been conducted, and some efficient insecticides in controlling the weevil have been found. Other insects are minor e.g. leaf eating beetle, leaf mining caterpillar, red mite and stem borer.

4.5. Agronomic Practices

Research has been carried out on cultural practices for improvement of the production; results have been transferred to farmers. At present, some farmers have adopted the technology derived from research for improving their sweet potato production especially those who grow sweet potato at commercial scale.

5. MARKETING

There are 2 different ways of sweet potato marketing in the country as follows:

- Farmers with average growing area of less than 1 hectare would take the production to the market and sale direct to the consumers. Some farmers bring the production for sale in their small shops beside the road nearby their houses. This type of marketing is a very simple way in some areas.

- The commercial farmers with growing area over 1 ha take the production to the shippers and to local wholesalers and to Bangkok wholesalers then to the retailers.

6. QUARANTINE REGULATIONS AND GERMPLASM EXCHANGE

Statistic records on import and export of sweet potato is not available in the government institution involved in this business e.g. Ministry of Commerce or Department of Customs. So far, no information on quarantine regulations for sweet potato import and export. But import and export of genetic material needs to follow the quarantine regulations like other crops for example phytosanitary certificate is required.

7. NATIONAL SWEET POTATO PROGRAM

Though sweet potato is considered an important vegetable rootcrop in Thailand but it is a neglected crop in terms of research and development. Probably, it is due to the general concept of people that sweet potato is an easy crop to grow and having less problems compared to other vegetable.

Not much have been done in improving the production and quality at farm level. Presently, sweet potato is a crop under the Sixth National Social and Economic Development Plan. It is one of the agricultural commodity to be developed as industrial crop e.g. producing starch, animal feeding products and processed to human food mainly snacks.

The Department of Agriculture and Department of Agricultural Extension are the principal government institutions in research and development plan of sweet potato. Areas of research and development are as follows:

- Varieties/cultivars improvement for high yielding and qualities suitable to specific locations. It is emphasized on processing to starch, animal feeding and other human food products.

- Improve agronomic practices such as soil and water management and plant protection management.

- Improve postharvest technology and utilization at village and industrial level.

- Technologies transfer of above mentioned research area to the farmers.

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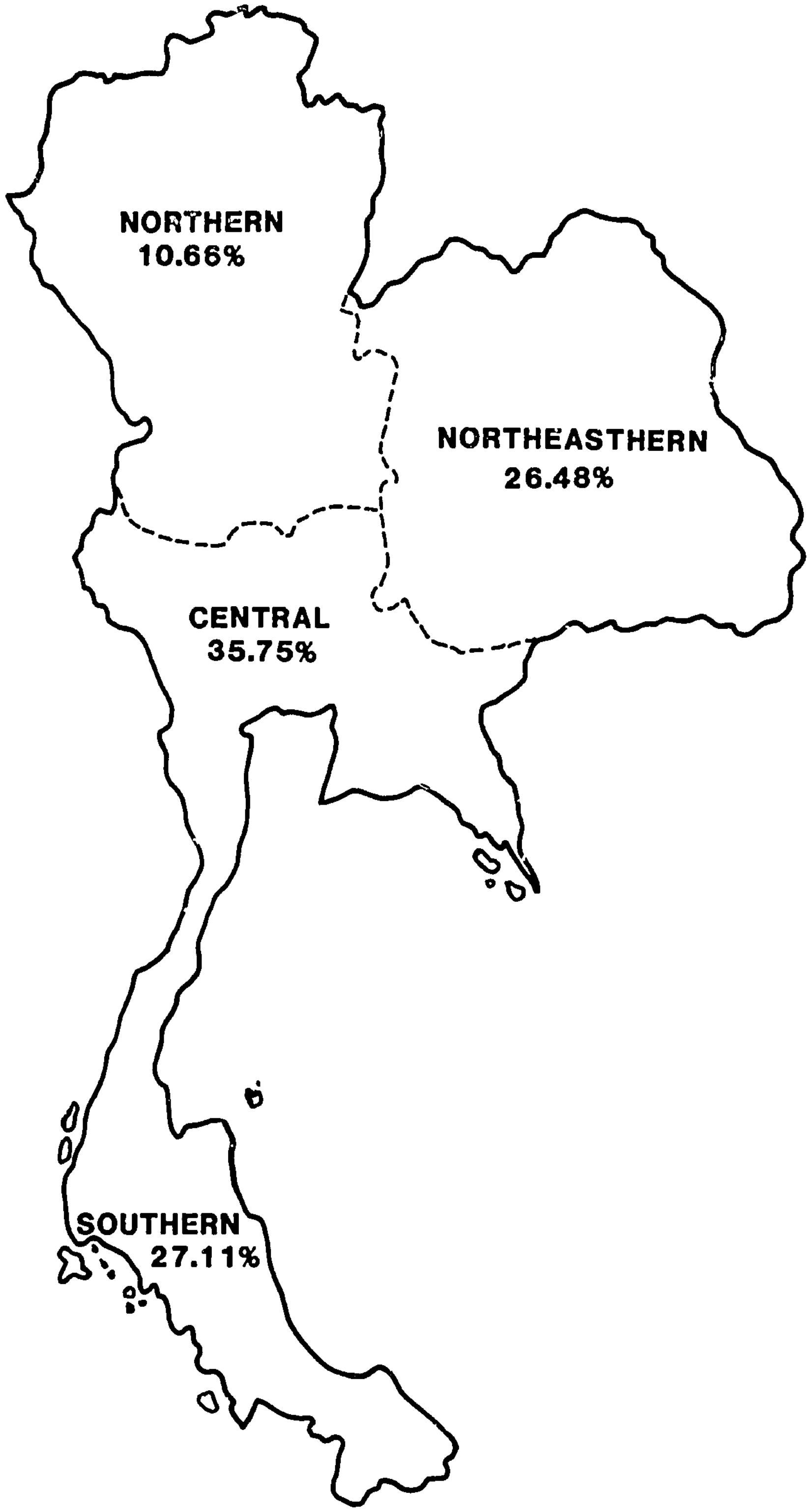
Table 1. Sweet potato planting area, production and average yield by region in Thailand; 1984-1986.

Region	Plant area (ha)			Production (t)			Yield (t/ha)		
	1984	1985	1986	1984	1985	1986	1984	1985	1986
Northern	2,367	1,910	1,232.8	21,899	19,098	11,252	9.25	10.0	9.13
North Eastern	2,848	3,423	3,061.92	25,979	32,382	26,444	9.07	9.46	8.64
Central Plain	4,909	3,578	4,133.76	55,027	45,311	43,172	11.09	10.56	10.06
Southern	3,864	3,545	3.134.72	39,117	38,533	31,857	10.14	10.87	10.16
Total	13,988	12,456	11,563.2	144,747	135,324	112,727	9.89	10.23	9.50

Source: Department of Agricultural Extension, Thailand, 1986.



SWEET POTATO GROWING AREAS BY REGION (1986)

THE SWEET POTATO IN VIETNAM

Vu Tuyen Hoang, Mai Thach Hoanh, Tran Nguyen Tien[1]
and Truong Van Ho[2]

1. ABSTRACT

The sweet potato is the third most important food crop in Vietnam after rice and maize. It is a traditionally cultivated crop for thousand years. The major cultivars grown are of local origin, Hoang long coming from China, new bred such as nos: 59, 6, 8, 251, Hung loc no.4 and some selected lines of local cultivars, Chiem dau and Dong dieu.

The sweet potato is grown in all 8 agricultural geographic regions, but mostly in coastal and in mid-elevation regions, being put into cropping systems with rice and maize. Farmers add only some manure if available, and in some cases add fertilizers in a few amount. Inputs of fertilizers and chemicals have not been made, therefore tuber yield is only 5-6 t/ha or up to 10 t/ha with the exception in some intensified areas.

In the coastal and mid-elevation areas, sweet potato is considered as the main food in some months annually. In the delta where rice is planted to large area, it is considered as the supplemental food for people. Sweet potato vine and tuber are commonly used for the pigs. Sweet potato processing is mostly made by manual labor. In processing industry, it is used to make vermicelli and some other products. Program of sweet potato improvement need to do with the proper policy.

2. INTRODUCTION

Cultivation history in Vietnam indicates that sweet potato is the second most ancient crop. It is the life saver of Vietnam in months of preharvesting rice or in case of rice loss in the delta, maize loss in the highland. It is a versatile crop grown in all 8 agricultural geographic regions of the country (Table 1, Fig. 1). It is the third most important crop after rice and maize with growing area occupying 4.7% of the total food crop area in Vietnam (1987).

The central region, which has less fertile soil and 20% of the total population, grows over 50% of the total sweet potato area for the country. The Red River Delta (RRD) is the second most important region to produce sweet potato followed by the

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Mekong River Delta (MRD). In the past several years there has been a decline in sweet potato production area. This decrease is mainly due to saving a land portion for rice and winter maize crop. Setting up the sweet potato intensification area increases its productivity in spite of the decrease in area (1987). The fluctuation in area, yield and productivity of the sweet potato during 1976-1977 is shown in Fig. 2. This indicates that apply of progresses in varietal improvement and cultivation techniques to sweet potato farming is of great importance to increase its production.

On a worldwide basis, China is the first sweet potato producer with the biggest area followed by Vietnam with not large area. The importance of sweet potato in Vietnam has been affirmed long ago.

Sweet potato is eaten in a wide array of dishes in Vietnam. Fresh tubers are boiled, cooked with rice or prepared into different dishes as soup with meat or fried . . . Dried slicing of tubers is powdered to make cakes or vermicelli . . . The young leaves are used as vegetable.

Vines, and fresh tubers or dried slicings of tubers, and vine cutting are commonly sold in every market. The marketing price of sweet potato fluctuates depending on rice price. In the years of good rice crop, human consumption of sweet potato is less, therefore it is mostly used in animal husbandry. By contrast, in the years of bad rice crop, or in the regions where it is of the major food, human consumption and marketing price are more stable.

3. VARIETAL IMPROVEMENT AND AGRONOMY

3.1. Germplasm

Before 1970's when new intensified rice varieties with short growth duration had not been largely introduced, long duration sweet potato cultivars were grown throughout the country. In the North, farmers grew the locals maturing in 5-6 months in upland for subsidiary crops or in areas where only one rice crop was grown. The "Green Revolution" of rice varieties accompanying the shorter growth duration and higher yield rices resulted in great changes in food crops systems. The long duration sweet potatoes are gradually discarded and replaced by new ones with early maturing in 3-4 months. In northern provinces and in the Central where the sweet potato is considered as an important food crop, it is put into different cropping system patterns as shown in Fig. 3.

The sweet potato germplasm is collected and maintained at the Food Crops Research Institute (FCRI), National Institute of Agricultural Sciences (INSA) and at Hung loc Station.

There is a great change in varietal patterns of the sweet potato. Some good local varieties are parallely grown with new ones. The most commonly grown varieties are: Chiem dau, Lim, Dong dieu, Hoang long in the North; Chiem dau, Tra dos, Quang tri, Nam dan in the Central; and Duong ngoc, Bi, Ekmak in the South. The new varieties nos. 59, 6, 8, 251 and some selected local varieties are being put into varietal patterns in the

North and in North Central. Variety Hung loc no. 4 is being put in multilocation trials in the South. These new varieties have shorter growth duration and higher yield than the local ones.

3.2. Selection of Local Varieties

The FCRI has been doing the selection of some local varieties in cooperation with some provinces in the North. These selected varieties are mostly grown in the North (Table 2).

Varietal improvement and apply of intensification technique (add 10 t of manure, 40 kg N., 20 kg P_2O_5, and 60 kg K_2O/ha) increase tuber yield of the tested varieties at different sites. Althought there is difference in yield depending on different soil characteristics and water management, results from the tests and testing production showed the effects of the selection and suitable agronomical measures resulting in higher yield than the average yield of 5-6 t/ha in production.

3.3. Sweet Potato Breeding

This has been done at the FCRI since 1970's and at Hung loc by the Southern Institute of Agricultural Sciences since 1980's. The main objectives of the sweet potato program were to select new varieties with early maturing in 90-110 days, good tolerance to adverse conditions and high yield.

The FCRI has in the average made 200 crosses annually, among them only 30% with good germinability. Tuber selection then has been done to receive clones. After many years' selection the elite clones with desired traits were isolated. Presently, the FCRI has released new varieties nos. 59, 6, 8, 251 into production. These have higher tolerance to coldness and higher yield than the local ones in winter crop, and satisfy the requirement of expansion of winter crop. The local varieties have lower cold tolerance than the new ones, because there was no demand to plant sweet potato in winter crop as in present. Results of investigation in some provinces the new varieties gave higher tuber yield than the control Chiem dau (Table 3).

The new varieties under cold condition of below 14^{o}C still keep on growing and swelling tubers in winter. This is the outstanding trait over the locals, Chiem dau and Hoang long (Table 4).

The new variety Hung loc is being planted in the Eastern South. Its average yield is 14-15 t/ha under hot condition in the South, that is higher than that of the locals.

Starch content of the new cultivars is 73-76% which is equivalent to that of the locals.

The future objectives of the National Sweet Potato Program are carrying on to breed new varieties with early maturity, good tolerance to adverse conditions, insects and diseases, high yield, high starch content and good taste. Another objective to improve protein content in tubers needs to be also considered.

3.4. Insect Pests and Diseases

In fact, farmers pay less attention to control insect pests and diseases.

The most dangerous insect on sweet potato is Cylas formicarius, which damages tubers. There are also some other insects which damage leaves and vines on the field.

The very common diseases on sweet potato are:

- Actinomyces ipomoea Person et Mart., W. J., damaging tubers. Plants with heavy affection cannot be developed.
- Ceratostomella fimbriata Ell et Hals causing black rots on tubers.
- Rhizopus nigricans Ehr. occurring when the tubers are cut or injured.
- Elsinoe batatas Wr., causing rot of tubers, roots and consequently wilting vines.

Besides, there are some other minor diseases affecting vines and tubers under high temperature and high relative humidity condition in the tropics.

3.5. Agronomy

Agronomical practices for sweet potato production is much more simple than that for potato.

Sweet potato planted to some areas in the highlands or to fertile areas in the delta is usually added with cattle manure or green manure, and in some cases with inorganic N fertilizer. Such application is done in sweet production both on the field and in the garden.

In some areas in the coastal, mid-elevation and in the delta where the sweet potato is considered as of the important food crops, it is added with more fertilizers and manures. In these areas the common dose of manure and fertilizers is 10-15 t of manure, 40 kg N (sometimes up to 60 kg N), 20 kg P_2O_5, and 60 kg K_2O, where 100% of the manure and phosphorus, and one third of N and K doses are used as basal application; one third of N and K is applied as the first top dressing at 20-25 DAP; and the rest as the second top dressing at 40-45 DAP. Digging and ridging up, weeding and irrigation are also done twice or thrice at the time of top dressings.

After land preparation, beds with 1-1.4 m wide and 0.4-0.5 m high are raised. Cuttings with length of 0.25-0.30 m are used as planting materials and planted in rows. The number of cuttings per ha varies with planting time. In winter crop because of low temperature, planting density is 40,000-45,000 cuttings/ha and in spring crop due to higher temperature the density is about 35,000-40,000 cuttings/ha.

3.6. Varietal Maintenance

The traditional technique for varietal maintenance is to plant cuttings for next crop. To improve varietal quality and vigor, the selected tubers are grown in the garden or on the field near the village to produce cuttings for large areas.

3.7. Storage and Processing of Sweet Potato

After harvest, sweet potato tubers are usually placed on the ground in the house where it is dry and with good ventilation. In some locations, the tubers are placed on the ground covered with a paddy ash layer and can be covered with another paddy ash layer. Under such condition tubers can be kept fresh for 2-3 months for human consumption or animal feeding.

Sweet potato processing. The most common way is that the harvested tubers are manually cut into slices and then the slices are sundried and kept in big jars with tight covers. The tubers are also processed into powder. Of the industry in Vietnam there is a part to process sweet potato in powder form.

3.8. National Sweet Potato Program

This is of the National Food Crops Program which consists of research programs of rice, maize, sweet potato, beans. By prognostification, the area planted with sweet potato will be 450,000-500,000 hectares by the year of 2000. This possibility will become true with the proper policy to expand the areas for subsidiary and rice crops. The main objectives of the sweet potato program are to:

a. Breed sweet potato varieties suitable to ecological regions: collect and set up the varietal collection; select the cultivars suitable to mid-elevation and highland regions with good tolerance to coldness and drought; select the cultivars suitable to the fertile delta, among them the good cold tolerance for winter crop and the good drought tolerance for coastal sandy soil classify the cultivars according to maturity duration as early with 90-100 days, medium 100-120 days and late 120 days up; and according to their response to intensive cultivation levels as high intensive response cultivar with mean yield of 20-25 t/ha and intensive response cultivar with mean yield of 14-16 t/ha.

b. Study and test the cropping system and cropping increases between sweet potato with rice and/or with other subsidiary crops; study and apply the technical procedures of sweet potato production to increase its mean yield in ecological regions (involving varietal patterns, fertilization regims, water irrigation and drainage . . .).

c. Study and apply the improved technique of sweet potato production; study and apply the sweet potato storage and processing involving fresh tuber storage, dried slicing storage and processing into different products to improve daily dishes of the Vietnamese who are eating too much rice.

d. Improve the training program on sweet potato in colleges, professional institutes and universities. Issue and distribute documentations, publications, papers . . . on sweet potato.

e. Cooperate and colaborate with other countries and CIP in exchange of breeding materials, documentations, publications and training.

f. Apply the results of technical progresses into production.

Table 1. Sweet potato production in Vietnam (1986).

Region	Area (1000 ha)	Yield (t/ha)
Red River Delta	58.40	8.78
Northern mid-elevation	26.50	6.90
Northern highland	24.40	4.69
North Central	117.60	5.67
South Central	56.40	4.53
Southern highland (Western highland)	16.70	6.28
Southern mid-elevation (Eastern South)	9.70	5.34
Mekong River Delta	18.80	9.74
Total	328.50	5.95

Table 2. Yield of the selected local sweet potato varieties (t/ha) in winter crop (1984).

Variety Local	Hoang long	Chiem dau	Dong dieu	Mam	Bi Dong nai
Thai Binh	26.6	30.8	15.6	23.3	25.0
Ha Nam Ninh	12.1	14.0	12.7	8.3	7.8
Hai Phong	17.5	18.0	16.0	14.0	18.3

Table 3. Yield of new sweet potato varieties (investigated in winter crop, 1986).

Local	Variety	Area (ha)	Yield (t/ha) Average	Max.	Maturing (days)
Nghe Tinh	Chiem dau	-	3 - 4		
	No. 59	10	7 - 8	13 - 15	105
Thanh Hoa	Chiem dau	1,000	6 - 7		
	No. 59; No. 251	3,000	13 - 14	19 - 20	105 - 110
Hai Hung	Chiem dau	-	7 - 8		
	No. 59	3,000	12 - 13	15 - 16	90 - 110
Thai Binh	Chiem dau	-	7 - 8		
	No. 59; No. 8; No. 251				
Thai Thuy	Chiem dau	-	13 - 14		
	No. 59; No. 8; No. 251	650	18 - 22	24 - 30	90 - 110

Table 4. Development of leaves and vines under low temperature condition (treated in phytotron for 4 days, winter crop 1986)

Variety	No. 59	No. 8	No. 251	Control: Chiem dau	Control: Hoang long
Leaf:					
Before treatment, no.	11.00	7.33	8.00	7.67	8.33
Before treatment, no.	12.00	8.33	9.33	7.67	8.33
% (x)	109.00	113.64	116.63	100.00	100.00
colour	Green	Green	Green-yellow	Yellow-green	Dark yellow
vine:					
Before treatment, length, cm	23.40	19.50	13.33	21.83	24.00
After treatment, length, cm	25.00	20.83	15.17	22.50	24.67
% (x)	106.84	106.02	106.31	103.07	102.80
colour	Green	Green	Green-yellow	Dark yellow	Dark yellow

(x) % as compared with that before treatment.

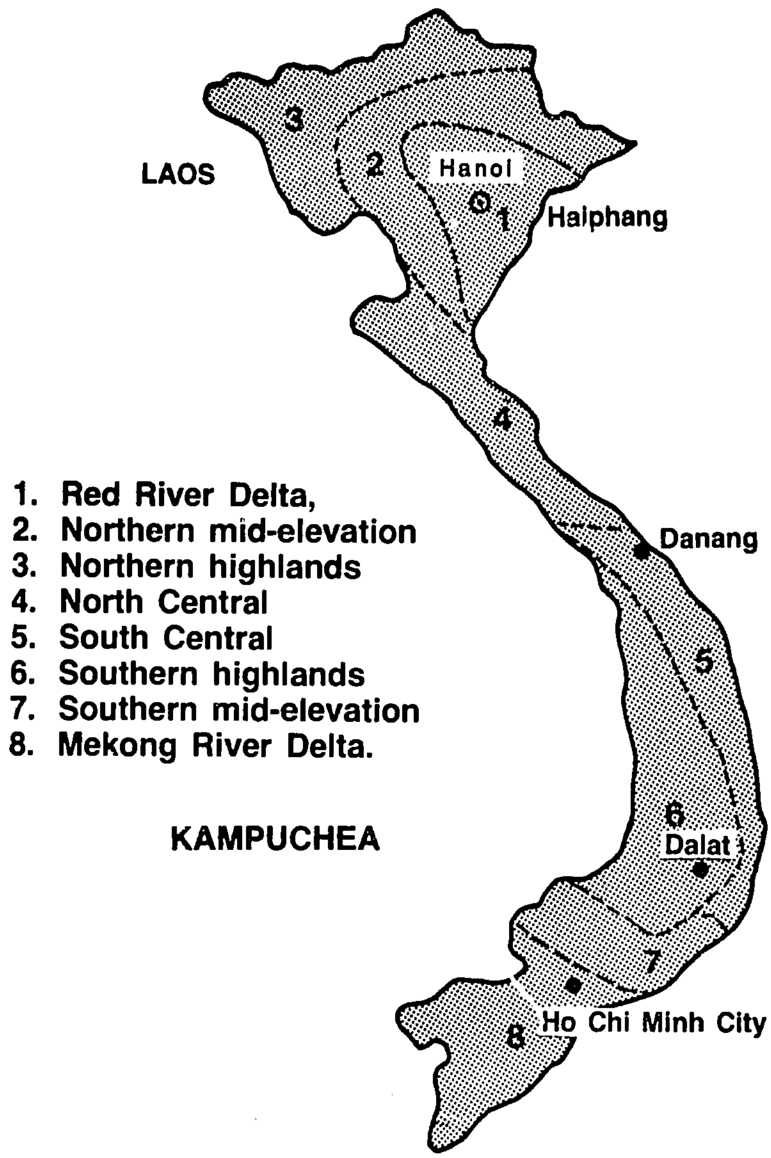

Fig. 1. Regions in Vietnam based on geography and climate.

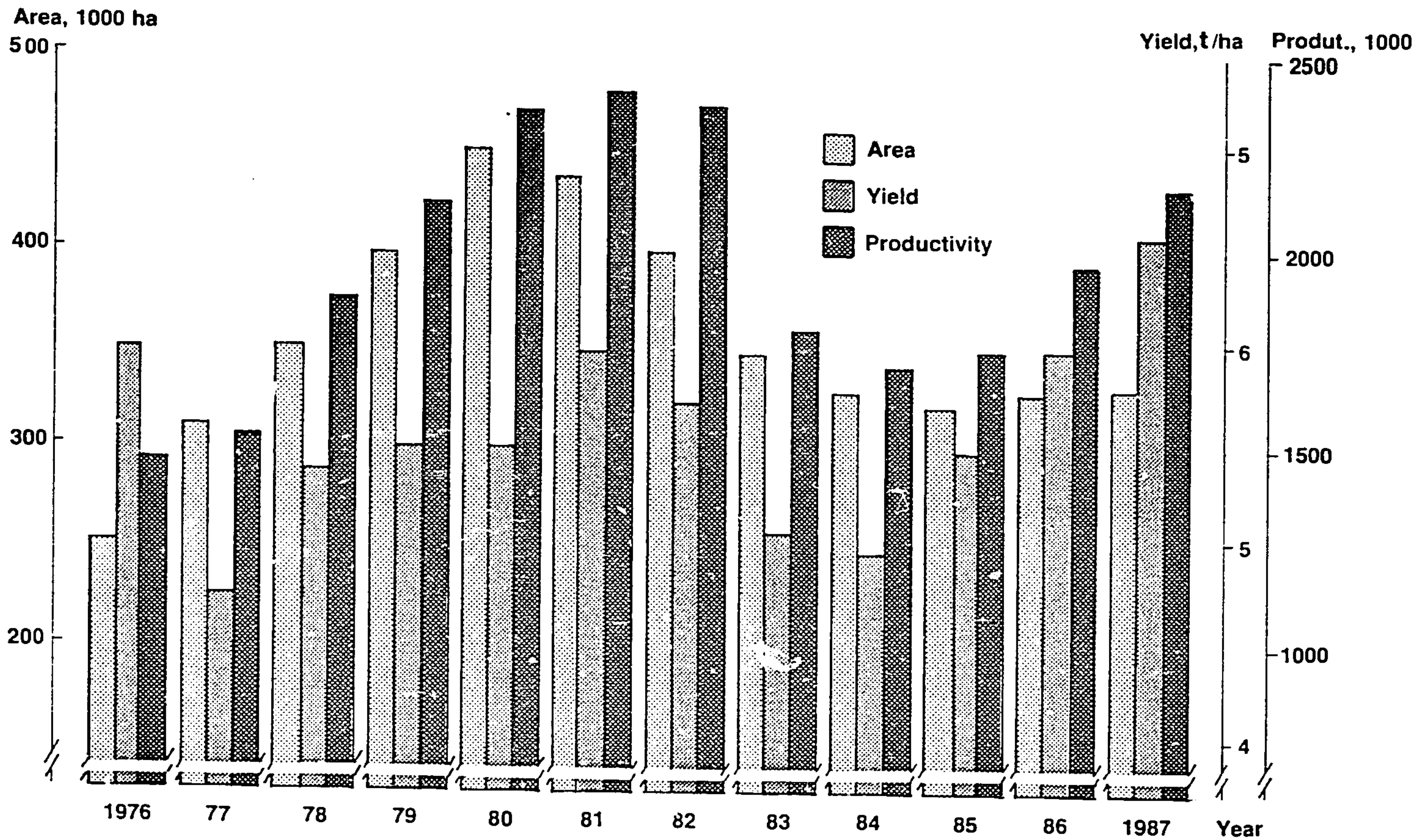

Fig. 2: Area, yield and productivity of sweet potato in Vietnam, 1976 - 1987.

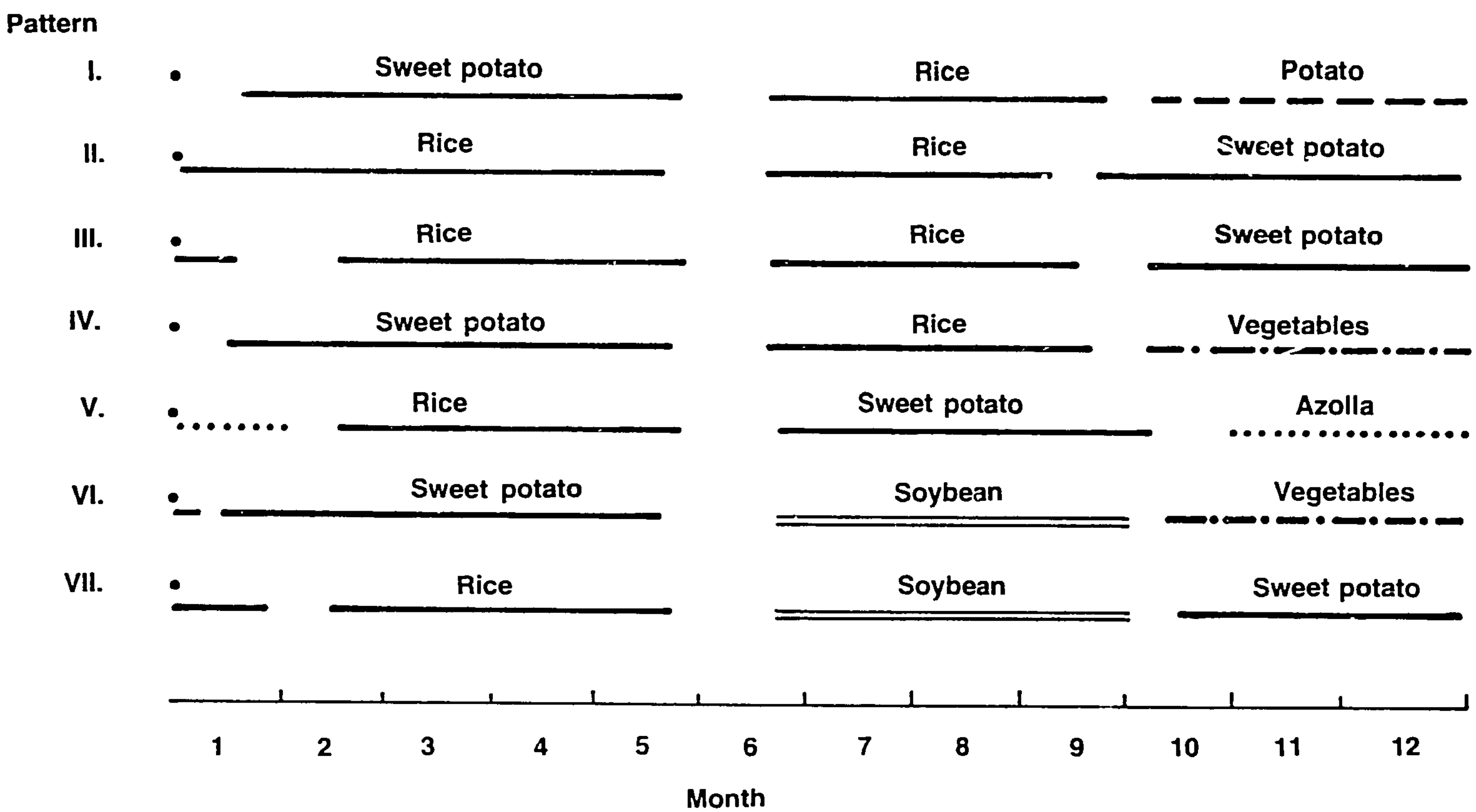

Fig. 3. Common cropping patterns with sweet potato in Vietnam.

DEVELOPMENT AND TESTING OF AN INTEGRATED PEST MANAGEMENT TECHNIQUE TO CONTROL SWEET POTATO WEEVIL

N. S. Talekar[1]

1. ABSTRACT

Screening of over 1,200 sweet potato accessions for resistance to the sweet potato weevil, *Cylas formicarius* (F.), failed to find any usable level of resistance for breeding purposes. Environment seems to play a dominant role in determining many sweet potato characters including weevil and host-plant interaction, making the use of weevil-resistant cultivar to control this pest potentially difficult. An integrated pest management (IPM) was therefore developed at AVRDC, which emphasizes the use of crop rotation, control of alternate *Ipomoea* spp. hosts from borders and surrounding empty areas, frequent hilling up of plants, and use of a female sex pheromone to continuously trap weevil males from planting to harvest. This IPM, which has been successfully tested on farmers' fields in Taiwan, is now being promoted elsewhere where the insect is a serious pest.

2. INTRODUCTION

Among over 300 species of insects and mites that infest sweet potato (*Ipomoea batatas* (L.) Lam) throughout the world (Talekar 1988a), two species of weevils; *Cylas formicarius* (F.) and *C. puncticollis* (Boh.) (Coleoptera: Curculionidae) are the most destructive. *C. formicarius* has two subspecies, *C. formicarius formicarius* (F.) and *C. formicarius elegantulus* (Summers). While the former is common in Asia, Africa and the Pacific, the latter occurs in North America and the Caribbean. *C. puncticollis* occurs only in Africa. Despite the taxonomic differences at species and subspecies levels, the nature of damage, ecology and host-plant relationship of the weevil species is practically identical. Hence, the control measures developed for one species are applicable to the other.

At the Asian Vegetable Research and Development Center (AVRDC), our research activities emphasize the development of an integrated pest management (IPM) package with major emphasis on the host-plant resistance. In this connection we screened our entire germplasm for resistance to sweet potato weevil (SPW), *C. formicarius formicarius*, and simultaneously developed an IPM based on the use of weevil-free planting material, control of alternate *Ipomoea* spp. hosts, and use of a female sex pheromone for monitoring and mass trapping of the insect. This paper briefly describes our host-plant resistance research and development and testing of the IPM on farmers' fields in Taiwan.

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3. HOST-PLANT RESISTANCE

During the past 50 years, numerous attempts have been made to find sources of resistance to SPW and incorporate the resistance in agronomic cultivars (Cockerham and Deen 1947, Cockerham and Harrison 1952; LSU 1970; IITA 1976, 1977, 1978, 1979, 1980, 1983, 1985; Han and Leuschnar 1981, Rolston et al. 1979; Mullen et al. 1980, 1982). However, these efforts met limited success due to the inconsistency in resistance from each season and from each location. As a result, until now not a single sweet potato cultivar has been bred utilizing any known sources of SPW resistance and which is grown over appreciable area for a period of time specifically to control this pest.

At AVRDC screening of sweet potato germplasm for resistance to SPW has been done continuously since 1974 (AVRCD 1975, 1976, 1977, 1978, 1979, 1981a, 1981b, 1982, 1984, 1985, 1987a, 1987b). Since the SPW infestation initiates in the field, our resistance screening methodology involved planting of test accessions, along with a susceptible check, in the field between SPW-infested "source" rows, a mode of infestation similar to the one encountered in nature. At harvest root samples of test accessions as well as the standard susceptible checks, are evaluated by cutting open all roots and recording the number of insects found inside the roots (Talekar 1982).

By the end of 1987, we had screened our entire germplasm consisting of 1,200 accessions. Like the other researchers, we found wide variations in resistance between seasons, locations and, at times, different replicates of the same accessions in a trial (Talekar 1982, 1987a). Similar variations are also common in other characters of sweet potato, such as carotenoid content (Ezel and Wilcox 1958), alcohol-soluble solids, total solids, reducing sugars (Austin et al. 1970), protein content (AVRDC 1975) and yield (Jong and Park 1975).

The progeny of crosses between _I. batatas_ and _I. trifida_ show considerable reduction in SPW damage (Iwanaga et al. 1986, Talekar 1987a). The resistance progeny, however, needs to be backcrossed to _I. batatas_ to improve yield and quality since most of the resistant progenies have fibrous or woody roots. Whether such manipulation will increase the susceptibility to SPW is now under investigation at AVRDC.

Host plant-insect pest interaction is based on the physiological status of the plant and the pest, the environment and on the interaction of both. In the case of interaction between sweet potato and SPW, the environment seems to play a very important role. Research on resistance should, therefore, be done over a wide range of environmental conditions. The screening methodology should emphasize field research. However, wide variations in resistance and the failure to breed it from identified resistance sources despite years of research, indicate that an adequate source of resistance to SPW may not exist in sweet potato germplasm (Talekar 1987b).

4. DEVELOPMENT OF AN IPM PACKAGE

Although SPW can infest practically all varieties of sweet potato, it can remain alive without food for several weeks (Kemner 1924), and its concealed feeding habit make it inaccessible to control by conventional means, there are several weak points in the biology of this insect that can be exploited in a control or possibly eradication of this insect. We used these weak points to develop an IPM to control this pest.

4.1. Host Plants

SPW feeds and reproduces on only members of genus *Ipomoea*. At least 26 *Ipomoea* species serve as the host of SPW (Sutherland 1986). Among the *Ipomoea* species, sweet potato is the most preferred host. The elimination of other *Ipomoea* species, all of which are perennial weeds that grow on borders around the cultivated areas, will deny the insect an alternate host during the off-season and considerably reduce SPW source for the infestation of subsequent sweet potato crop.

4.2. Flight Activity

SPW is a weak flier and cannot fly long distance (Sherman and Tamashiro 1954, Cockerham et al. 1954). The insect is carried from one location to the next via transport of the contaminated roots and stem cuttings which are used for planting. In the planting materials, the insect is transported in the form of adults hiding among the foliage, in addition to eggs, larvae and pupae that are present within the stems. The use of planting materials from SPW-free crop or cleaning the cuttings by dipping in a suitable insecticide solution will prevent the spread of SPW. In an experiment at AVRDC, dipping cuttings in 0.1% AI carbofuran solution reduced SPW infestation by 50 to 95% (Talekar 1983).

4.3. Mode of Infestation

Although SPW also feeds inside the sweet potato stems, its larvae do not tunnel through the stems to enter the roots. The adults search for exposed roots for oviposition through the soil cracks. Regular earthing up or mulching of the soil around the plants will help deny the weevil's access to the roots and reduce infestation (Talekar 1987c).

4.4. Survival in Soil

SPW can survive in the soil in sweet potato debris left over from the harvest of a previous crop. Avoiding areas planted to sweet potato in the previous season or incorporation of crop rotation, which in itself is a good agronomic practice, will help reduce weevil infestation. Previous studies at AVRDC showed beneficial effects of paddy rice rotation on SPW control (Talekar 1983, 1987c).

4.5. Sex Pheromone

Female SPW produces a sex pheromone chemical which attracts males for mating (Heath et al. 1986, Phoshold et al. 1986). This chemical is quite persistent and a 10-microgram sample can remain active in an open field for four to five months which is sufficient for one cropping season. Like in other insects, this chemical, which is now synthesized, has a potential in mass-trapping of male weevils before they mate, thus, reducing the subsequent SPW population.

Based on these points, AVRDC developed a package of IPM technology (Talekar 1988b) which is now promoted through the national programs of various countries in the tropics and subtropics. In a continuation of AVRDC's research and development activities, we attempted to implement this IPM in two localities on Penghu Island chain in Taiwan Strait.

5. TESTING OF IPM ON FARMERS' FIELDS

5.1. The IPM Technique

The IPM technique we developed consisted of the following components:

5.1.1. Crop rotation

Plant sweet potato after other crops in the previous season.

5.1.2. Destruction of alternate host

Uproot and promptly destroy alternate Ipomoea species hosts before planting sweet potato. During the season keep the surroundings free of any Ipomoea species.

5.1.3. Weevil-free cuttings

Use sweet potato cuttings from weevil-infestation free or dip the cuttings in a suitable insecticide solution for several hours immediately before planting of a new crop.

5.1.4. Sex pheromone

At a regular distance throughout the field, place female sex pheromone-baited traps to continuously trap weevil males from planting time up to harvest.

5.1.5. Soil management

When the roots start enlarging stir the soil around each plant to fill the cracks with soil to prevent adult weevil from laying eggs in sweet potato roots.

6. PROCEDURE

This experiment was conducted in two localities; Jungtwun and Husyi towns, Baisa prefecture, Penghu Island chain in Taiwan Strait during summer 1988. Sweet potato, ground nut and sorghum are the principal crops on Penghu Island. All three crops are rainfed and grown mainly between April and September. In October-November 1987, at the harvest of the preceding sweet potato crop, we surveyed the SPW damage in both locations.

In the 1988 cropping season (April to September), 39 farmers cultivating 3 ha sweet potato in 55 parcels in Jungtwun and 34 farmers cultivating 4 ha in 38 parcels in Husyi participated in this experiment. In both locations, before the initiation of planting, farmers were explained the details of the IPM in a public meeting specially organized for this purpose. This included control of Ipomoea weeds from borders and empty areas, practicing of crop rotation, dipping of the vine cuttings in 0.04% carbofuran solution for 30 minutes before planting to kill the weevil inside the cuttings around the plants.

Within two weeks after planting, depending upon the size of the field, each farmer was given one to five traps baited with 100 micrograms of SPW sex pheromone. The farmers were advised to change the location of each trap within the field as often as possible to cover the entire field, so that the native as well as the migrating male weevils can be trapped from the entire area before they could mate. We recorded the number of males trapped in each field during the season.

At harvest we surveyed the fields and sampled about 5 kg roots from each parcel of land. To achieve this we selected several plants at random and dug up just one root from each of the several plants when the crop was still standing in the field. We cut open each root in thin slices and recorded the number of SPW larvae, pupae and adults inside. The insect-damaged portion of the roots was weighed and the percentage of damaged roots was calculated.

7. RESULTS AND DISCUSSION

In both townships, farmers followed crop rotation with sweet potato being planted after either groundnut or sorghum in the previous season. All farmers in Husyi dipped the cuttings in carbofuran solution but some farmers in Jungtwun failed to do so. The Jungtwun farmers' noncompliance to this simple and useful procedure is especially significant because in the preceding two seasons this experiment was conducted only in Jungtwun, and the farmers were aware of the importance of this simple treatment.

Ipomoea species weeds were not a serious problem in Husyi and only minimum effort was required to keep them under control. Ipomoea weeds, however, were rampant in Jungtwun and some farmers did not pay attention to them despite repeated reminders.

During the season we trapped 21,129 male weevils in pheromone-baited traps in Jungtwun and 16,348 in Husyi. The results of the evaluation of SPW damage to sweet potato root in Jungtwun are summarized in Figure 1. The number of SPW per kilogram of roots ranged from 0 to 69.4 with a mean of 5.10 and insect damage from 0 to 46.4% with a mean of roots and 31 farms were weevil-free. This compares favorably with mean insect number of 14.5/kg root, damage of 11.6% and only 10 out of 62 fields weevil-free as observed in our 1987 study (Talekar 1988c).

The results of the evaluation of SPW damage to sweet potato root in Husyi are presented in Figure 2. The number of SPW per kilogram of roots ranged from 0 to 4 with a mean of 0.34. The percentage of damaged roots ranged from 0 to 4 with a mean of 0.45%. In this township 31 out of 38 sweet potato fields were free of weevil infestation. This compares very favorably with at least 80% plants having weevil infestation and, by implication, about 40% roots damaged in the preceding season before the introduction of IPM.

Some farmers in Jungtwun still continued to ignore the SPW control measures, although it has improved over 1987 level (Talekar 1988c). For example, two fields in this town had 49.3 and 69.4 weevils/kg of roots which was far higher than the rest of the fields. Those fields where all control measures were ignored acted as source of the insect to infest the rest of the area. On the other hand, all farmers in Husyi followed the control measures, in most cases rigorously. As a result, this insect did not pose much problem in this township.

8. TRANSFER OF IPM TECHNOLOGY

Based on the successful reduction in the weevil infestation in this and previous year's tests, we have printed a brochure which describes this procedure. We have distributed this brochure together with sex pheromone samples to various research and development organizations in the following countries: Fiji, Tonga, Western Samoa, Solomon Island, Vanuatu, Saipan, Tahiti, Caroline island, and other island in the South Pacific via the South Pacific Commission, Papua New Guinea, Australia, Japan, China. Taiwan, Philippines, Vietnam, Thailand, Malaysia, Brunei, Indonesia, India, Bangladesh, Cape Verde, Nigeria, Kenya, Sierra Leone, Jamaica, Guyana, Barbados and other island in the Caribbean via the Caribbean Agriculture Research and Development Institute (CARDI), Brazil, and the United States. All those who responded so far report excellent activity of the sex pheromone in trapping the weevil. We plan to continue this development activity in the future and do some basic research on the transport of the weevil from each location especially through cuttings.

9. CONCLUSIONS

Finding a reliable source of SPW resistance to breed resistance cultivar has proven to be extremely difficult. If at all possible, it will be a while before a truly resistant cultivar can be developed. Meanwhile, an IPM technology has been developed to control this pest. It is possible to reduce SPW infestation to below economically damaging level by adopting the IPM, which is based on the use of weevil-free planting materials, control of Ipomoea species weeds surrounding the sweet potato fields, ridging the plants frequently, and use of a sex pheromone to continuously trap males, presumably before they mate. Success of the IPM depends entirely on the willingness of all farmers in the community to strictly follow the IPM practice, as failure by one to cooperate reduces its overall effectiveness.

10. ACKNOWLEDGMENT

I thank the staff of the Penghu Substation of Kaohsiung DAIS for their help in carrying out the IPM project.

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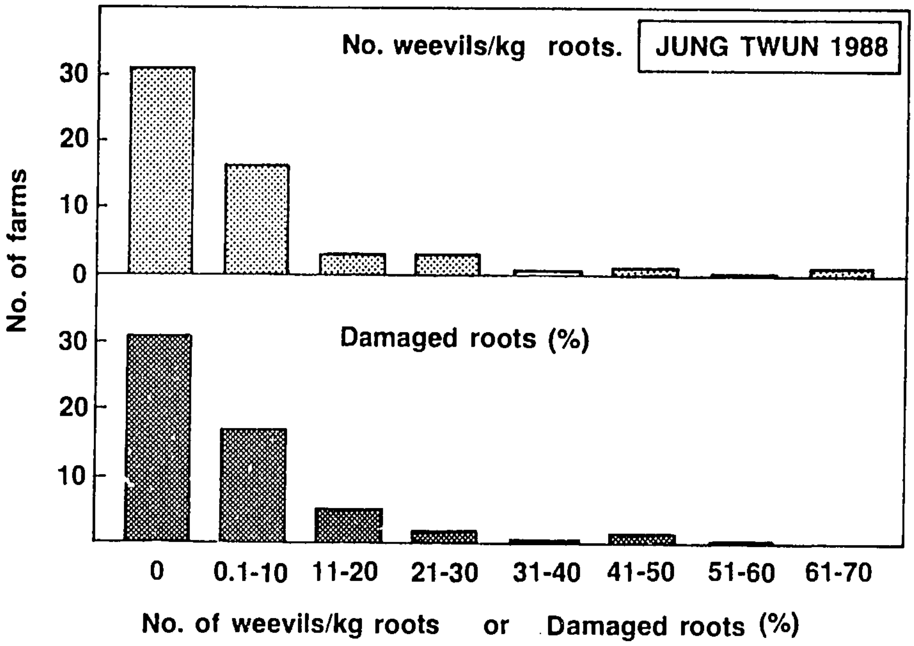
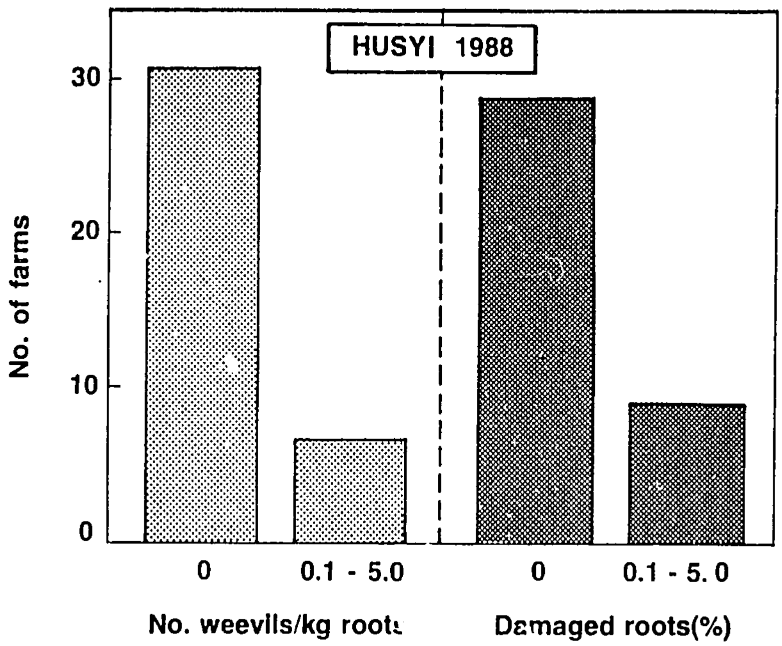
12. Figure captions

Figure 1. Distribution of SPW infestation in farmers' fields in Jungtwun.

Figure 2. Distribution of SPW infestation in farmers' fields in Husyi.





DIGESTIBILITY OF SWEET POTATO STARCH

Samson C. S. Tsou and Tuan-Liang Hong[1]

1. INTRODUCTION

The tuberous root of sweet potato, Ipomoea batatas (L.) Lam., is a traditional and inexpensive energy source in East and Southeast Asia. It is used as a supplemental staple food, feed or raw material for industry. The multi-usage of sweet potato is considered one of its desirable characteristics (19, 4).

Although sweet potato originated in the Americas and introduced to the tropical region of Asia, presently about 70% of world production is in China (22, 9). The spread of sweet potato cultivation in China was often associated with food crises since it was introduced as a survival crop (2). Sweet potato, however, has never become a popular staple food in China; when the crisis was over the sweet potato was used as feed or for other purposes. Sweet potatoes were used as a supplemental staple food in Taiwan, they comprised about 18% food energy of the Taiwanese diet during the period 1935-39 (14). However, more than 60% of the sweet potato production was used as feed and only 16% was consumed directly as food in the mid-1960s (15). The sweet potato utilization pattern in Chinese culture is characterized as being for multi-usage purposes. In order for the sweet potato to be an effective "survival" food, sufficient quantities of it must be available for human consumption during times of famine. One method to ensure the availability is for sweet potato to be utilized in as many manners as possible. The Chinese tend to utilize the sweet potato as a survival crop more effectively than many other cultures because of its use as a feed. A steady demands of sweet potatoes for other purposes provided additional incentives for farmers to grow the crop and provide additional; input for higher yield.

Concerning its utilization sweet potato-based feed for hog raising generally requires cooking for better feeding efficiency. This process requires not only additional labor and fuel but also limits the size of an animal farm. Thus, it can be used only under subsistence farming systems and is unsuitable for large-scale commercial production.

A series of experiments were conducted in Taiwan during the mid-1970s to asses the constraints of sweet potato as feed for hogs (6, 10, 13). Poor protein digestibility, thus lower feeding efficiency, was identified as one of the major constraints. On the other hand, the biological quality of purified sweet potato protein was found to be equal to the casein (21). The presence of trypsin inhibitors in sweet potato roots was suspected to be responsible for the low protein digestibility of uncook sweet potato feed (3, 16, 1, 23). However, this paper summarizes the result of research conducted

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at AVRDC which demonstrated that the starch properties may be directly associated with digestibility. Varieties with improved digestibility associated with starch properties were identified (18, 19).

2. EFFECT OF STARCH ON PROTEIN DIGESTIBILITY

It is known that starch of root and tuberous crops is not easily digested (11, 12). Studies on sweet potato starch-induced flatulence confirmed that it is less digestible than starches from cereal grains (20). Hog-feeding experiments, however, were not able to detect the difference in carbohydrate digestibility between sweet potato and corn based diets (6) (5). The lower feeding efficiency of the sweet potato diet was generally due to the lower protein digestibility (19). Cooking was found to be an effective method to improve the protein digestibility and thereby, the overall feeding efficiency of experimental rats (13).

Rat feeding experiments using sweet potato starch and casein as energy and protein sources were conducted to study the effect of sweet potato starch on protein digestibility. The results of a representative experiment are shown in Table 1. The protein digestibility of the uncooked sweet potato starch diet was found to be lower than that of the corn starch diet. A significant improvement in protein digestibility can be achieved through precooked sweet potato starch; the biological value of casein was not affected by the starch source. These results suggest that the property of the sweet potato starch may be partially responsible for the low feeding efficiency of the sweet potato diet.

Rat feeding experiments further revealed that the effect of starch on protein digestibility varied genotypically (Table 2). The diet prepared from starch isolated from sweet potato lines C 63-74 and CN 1232-9 had a protein digestibility comparable to that of the corn starch diet. This result implies that the feed quality of sweet potato starch can be improved through proper breeding programs. The difference in quality of sweet potato starches can not be detected by analyzing the residual fecal carbohydrate of experimental rat and hog (6).

3. SCREENING METHOD

Animal feeding experiments are the most direct method to evaluate the quality of sweet potato starch; however, they are time and labor consuming . A modified laboratory method based on CO_2 gas production by fermentation of sugars obtained from pancreatic digestion of starch was adopted (24, 12).

Instead of the manometric apparatus, a fermentation tube was utilized to estimate the CO_2 gas produced to simplify the procedure. A 675 mg sweet potato flour sample, ground in a cyclone mill, is first mixed with 202 mg of compressed Baker's yeast and 54 mg of pancreatic enzyme (Sigma Co.). The mixture is next placed in a fermentation tube with 14.5 ml of 0.002 N phosphate buffer (pH 6.9) and allowed to ferment at under 30° C for 2 hours. The volume of CO_2 gas produced expressed the starch digestibility (Fig. 1). Corn meal is used as the check and a blank test without pancreatic enzyme for each sample is also used to estimate the original sugar content. The method is relatively simple and large number of samples can be evaluate within a short period of time.

The susceptibility of selected sweet potato samples to pancreatic enzyme based on the above described method is listed in Table 3. Carbohydrate and protein digestibility data obtained from previous rat feeding trials are also listed. In spite of the limited sample number, one can still observe a trend that lines of higher digestibility generally have a higher CO_2 gas production. In addition, the fermentation method seems more sensitive than animal feeding trials. Based on fermentation method, the digestibility of CN 1232-9 was higher than other lines but lower than that of corn meal. However, this difference was not detected by feeding experiments (19).

4. SEASONAL EFFECT ON DIGESTIBILITY OF SWEET POTATO STARCH

It has been observed by farmers and consumers that sweet potato roots harvested in the wet season generally have poor eating quality, and are less digestible. In order to confirm this, the digestibility of sweet potato samples harvested from fall (dry) and summer (wet) trials was evaluated by the fermentation method. A distinct seasonal effect on digestibility was observed for all varieties tested (Table 4).

Sweet potatoes harvested during the wet season were found to be more resistant to pancreatic enzyme digestion. The percent reduction in susceptibility due to wet season varied from 18.7% to 75.3% with an average value of 48%. No clear relationship was observed between the digestibility of dry and wet season samples of the same cultivar which implies that feeding quality of sweet potato starch needs to be evaluated separately, according to the planting season. Besides CN 1232-9, two additional AVRDC improved varieties, CN 1108-13 and CN 1448-59, were found to be highly susceptible to pancreatic digestion. The CO_2 production obtained from these two lines is even higher than for the corn meal check. The variety CN 1108-13 is especially promising. The wet season sample of this line is more digestible than the dry season sample can be used only for primary screening, the actual feeding quality of these two promising lines needs to be further tested by the animal feeding method.

5. PROPERTIES OF SWEET POTATO STARCHES

There are three major sources of commercial starches. The first group are starches isolated from roots and tuber crops. The second group comprise starches from cereals. And the third group are known as waxy starches which are isolated from cereals but with properties similar to root starches. It is already known that there is variation in susceptibility to digestive enzymes among raw starches. Starches from roots and tuber crops are generally more resistant to digestion; the reasons are still unclear.

The sweet potato starch granule is polygonal in shape with a size of 5-25 µm in diameter. The major properties of sweet potato starch are shown in Table 5. Since the I_2 affinity of purified sweet potato amylose was found to be 20.3%, one may estimate the amylose content of sweet potato starch to be around 18% (4, 8). Selected properties of starches isolated from a few varieties were studied and the following observation made:

A varietal variation in amylose content was detected. The amylose content of sweet potato starches isolated from C 63-74 (27%) and CN 1232-9 (24%) is higher than that from other lines (14-19%). (2) Brabender viscogram studies have shown that starch of CN 1232-9 needs to be heated to a higher temperature before thickening begins than does the starch from Tainung New 31. (3) Certain starch, such as from C 63-74, was found to have a much higher retrogradation (set back) upon cooling the temperature of the paste from 95^o to 35^{o}C than other starches tested. (4) A higher gelatinization temperature of CN 1232-9 starch was further confirmed by differential scanning calorimatric (DSC) testing. The onset temperature (To) and peak temperatures (Tp) of starch isolated from the roots of CN 1232-9 and Tainung New 31 were found to be 71.0^o, 74.5^o, and 54.8^o and 61.7^{o}C, respectively. The enthalpy needed for gelatinization of these two starches was found to be comparable (around 13.2 J/gr of dry weight). (5) The phosphorous contents of sweet potato starch which is susceptible to pancreatic digestion was found to be slightly lower (0.015%-0.018%) than that of resistant lines (0.021%-0.024%).

The characteristics of lower phosphorous and high amylose contents may be associates with the susceptibility to digestive enzymes. This information obtained, however, does not provide a solid basis to explain the nature of the difference between starches which are susceptible and resistance to digestive enzymes. The findings of seasonal effects on starch digestibility introduced additional factors to this problems, rendering the problem more complex in nature. More detailed analyses of the properties of starch granules, as well was the starch molecule structure, are needed in the future in order to clarify these differences.

6. CONCLUSIONS

Sweet potato can be a more effective survival crop if utilization patterns, other than for human consumption, can be develop. One alternative utilization of sweet potato is for feed. Raw materials with easily digestable starches without cooking are one of the desired characteristics for feed purposes. A simple method to estimate CO_2 gas production based on fermentation sugars from enzymatic digestion was found to be acceptable for screening purposes. Genotypical and environmental effects on starch digestibility were observed. Several lines such as CN 1232-9, C 63-74, CN 1108-13 and CN 1448-59, have been identified as promising varieties for feed. Studies on chemical and physical properties of starch, however, were not able to provide a solid basis to explain the differences of digestibility between the resistance and susceptible lines.

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Table 1. Effects of sweet potato starch on protein digestibility[z]

Starch	TD[y]	AD	BV[y]	FE[y]
Corn	91 a[x]	85 a	73 a	35.1 a
Sweet potato (raw)	80 b	72 b	82 a	29.8 b
Sweet potato (cooked)	88 a	82 a	77 a	31.4 ab

[x]Means followed by the same letter are not significantly by Duncan's Multiple Range Test, 5% level.

[y]TD: True digestibility; AD: Apparent digestibility; BV: Biological value; FE: Feeding efficiency.

[z]Casein was used as the protein source for all treatments

Table 2. Protein digestibility of sweet potato starch diets.[z].

Starch	SD[y]	FN[y]	AD[y]	TD[y]	BV[y]
63-74	99.67 a[z]	1.83 b	83.02 a	85.46 a	85.05 ab
CN 1232-9	99.69 a	1.80 b	82.37 a	85.58 a	87.29 a
New 31	98.20 a	2.68 a	73.57 b	82.51 b	79.79 b
TN 18	99.51 a	1.93 b	79.70 ab	85.78 ab	83.60 ab
Corn	99.74 a	1.52 b	85.78 a	91.39 a	89.22 a

[x]Means followed by the same letter are not significantly different by Duncan's Multiple Range Test, 5% level.

[y]SD: Starch digestibility; FN: Fecal nitrogen; AD: Apparent digestibility; TD: True digestibility; BV: Biological value.

[z]Casein was used as the protein source for all treatments.

Table 3. Effect of sweet potato starch on digestibility.[z]

Starch	AD[y] (%)	CD[x] (%)	Fermentation Method ($cm^3 CO_2$/g DW)
CN 1232-9	73.97 abc[w]	94.74 a	8.68 b
CN 1038-16	70.23 bc	98.45 a	3.83 d
TN 57	70.80 abc	98.33 a	4.96 c
New 31	73.61 abc	91.83 b	3.44 d
CN 1219-1	68.40 c	94.14 b	2.86 e
Corn	77.47 a	99.01 a	9.80 a

[w]Means followed by the same letter are not significantly different by Duncan's Multiple range test, 5% level.

[x]CD: Carbohydrate digestibility.

[y]AD: Apparent protein digestibility (casein 10%).

[z]Data of AD and CD are adopted from AVRDC Progress Report (18).

Table 4. Varietal and seasonal effects on susceptibility of sweet potato starches to pancreatic enzyme.

Variety	Susceptibility ($cm^3 CO_2$/g DW) Fall season	Summer season
CN 1232-9	8.68 ± 0.08[z]	3.18 ± 0.12
CN 1489-89	4.21 ± 0.24	2.86 ± 0.21
CN 1489-43	4.71 ± 0.23	3.83 ± 0.09
CN 1028-15	3.59 ± 0.38	1.58 ± 0.16
CN 1108-13	11.40 ± 0.24	6.56 ± 0.24
CN 1448-59	10.31 ± 0.80	2.55 ± 0.32
Corn (check)	9.81 ± 0.25	- -

[z]Mean ±SD.

Table 5. Selected properties of sweet potato starch.

Properties	Observation
Protein content (%)[y]	0.06-0.2
Ash content (%)[z]	Trace-0.51
Crude fiber (%)[z]	0.02-0.10
P content (%)	0.02
I_2 affinity (%)	3.66
Gelatinized temperature(^{o}C)	58-63-69
Granular size (μm)	10 x 14
Brabender viscograms	Type B
Branch no. of amylose	7.9

[z]Source Ref. Lii, et al. (7) and Lii, et al. (8)
[y]Less purified commercial samples are included.

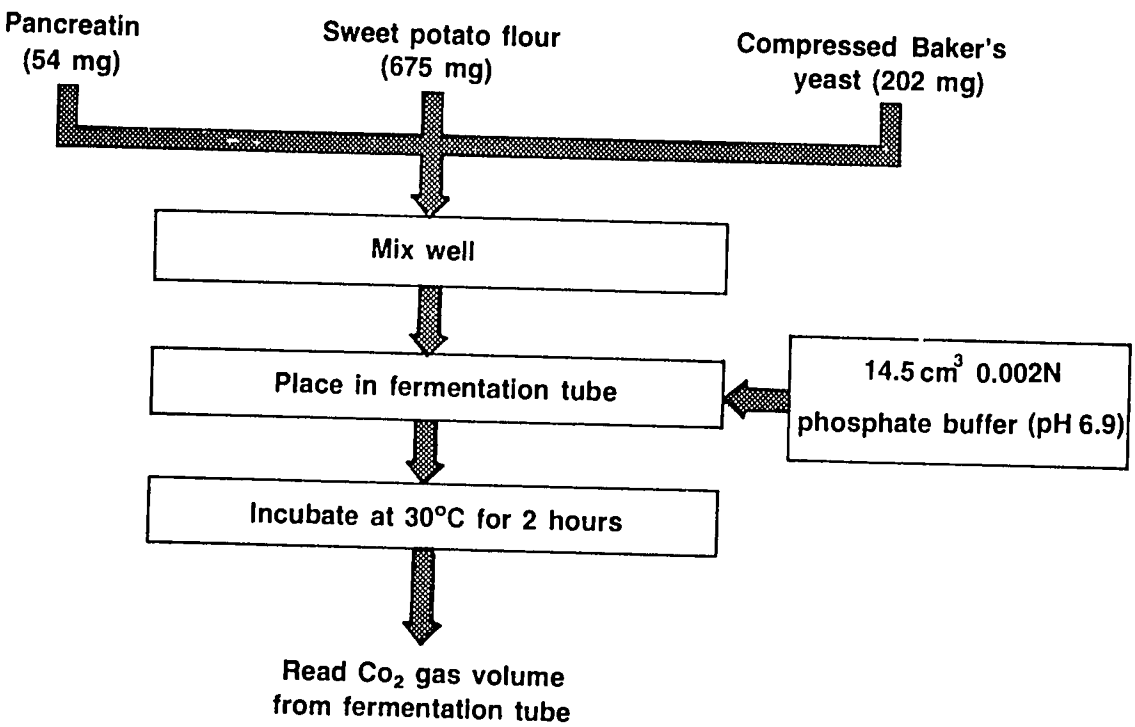

Figure 1. Fermentation method for estimating digestibility of sweet potato starch.

SWEET POTATO BREEDING IN JAPAN: ITS PAST, PRESENT AND FUTURE

Isao Tarumoto [1]

1. INTRODUCTION

The first sweet potato cultivar was introduced into Miyako Island (Okinawa, Japan) from China in 1597. Since then, many alien cultivars were introduced into the southern parts of Japan like Okinawa and Kyushu districts and the alien cultivars themselves which were adapted to the environment conditions cultivated in Japan and accepted as food by the people have been cultivated for table use by 1919 when the systematic breeding including hand-pollination was started at Okinawa, Japan. Under the system, several strains like Okinawa 100 were released as the results of cross breeding. The system was reorganized to be the Norin system in 1937, and since then sweet potato improvement and the preservation of genetic resources have been conducted under the Norin system.

The present report deals with the past, present and future activities of sweet potato breeding in connection to objectives, method, genetic resources and recent cultivar released.

2. SWEET POTATO CULTIVATION AND UTILIZATION

Sweet potato cultivation area of the world was 7.7 million ha in 1984. 93% of it is occupied by the Asian countries. The utilization of sweet potato mainly in Asia and Oceania countries are as shown in Table 1. The primary use is as human food and the second is as animal feed in many countries, but the raw material for industrial use occupied the second position in Japan and Korea.

Figure 1 shows the trend of consumption of sweet potato in Japan. The main use for sweet potato before the world War II was as food for farmers. During the War about 20% of total production was used as raw material for alcohol production. After the food shortage ceased around 1950 when the cultivation area was about 440,000 ha, the sweet potato was mainly used for industrial use like starch and alcohol production. About 50% of the total was consumed for industrial use in 1965 (260,000 ha). A drastic decrease of the acreage occurred in 1965-75 according to the increase of imported materials for starch production, and 65,000 ha of sweet potato cultivation was reported in 1986. At present, the figures for sweet potato consumption for marketing as table use and process food, industrial use and animal feed are 40, 38 and 13% of total production, respectively.

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3. BREEDING OBJECTIVES

From the above trend of consumption and cultivation of sweet potato in Japan, the current breeding objectives summarized in Table 2 are coming up.

3.1 Table food

As sweet potato was dealed with in the vegetable market, the food appearance is one of the most important traits. The good appearance is characterized by brilliant red-purple skin color and smooth skin after washing, long spindle shape without any bend, furrow and cleft, and uniform size of roots in the package box. Delicious taste (good eating quality) is also important and is characterized by very to moderate sweetness, very to moderate dryness, yellow to yellow-white color and good taste after steaming (mushi-imo), baking (Yaki-imo) and/or frying (Tenpura). Good storability is very important to keep freshness and eating quality well. Early tuberous and maturing abilities are necessary to improve the efficiency of land use and send to the market earlier.

3.2 Process food

There are various kinds of traditional type and modern type processed food. The breeding objectives are different according to the processing types, but the adequate root shape, root color and process quality are necessary for processing efficiently and making a good product according to the type.

3.3 Industrial use

The price of raw materials for the starch production per ton is settled by the starch content of a sweet potato cultivar. In the production of alcohol and distilled spirits, the higher starch content induces the better quality and the less cost of manufacture. The higher starch content becomes the most important objective. The higher starch yield calculated by root yield x starch content is important from the viewpoint of farmers' income.

3.4 Animal feed

Substandard tuber roots for table and industrial use are ordinarily used for animal feed. Besides those, green chop of vines is used for animal feed. Tsurusengan, released in 1981, is a cultivar with high vine yield.

For green animal feed, the earlier vine growth and regrowth abilities and high quality as feed are the breeding objectives.

3.5 Common objectives to the above four

The increase of yield per unit land is still the principal target for higher income. For increasing yield stability and decreasing the production cost, it is important to improve pests and disease resistance, specially to root knot nematode (*Meloidogyne incognita*) and soil rot (*Streptomyces ipomoea*).

4. THE NORIN SYSTEM FOR BREEDING AND GERMPLASM PRESERVATION

The so-called Norin system was established in 1937 for rising the effective of improving sweet potato breeding and resolving the demands of sweet potato improvement and the preservation of genetic resources in Japan have been conducted under the Norin system, though the minor changes have been done with the times.

At present time, as described in the above sentence, there are many demands of sweet potato growers and consumers which become the breeding objectives. In order to resolve the current problems, the present Norin system was organized and many efforts have been done.

4.1 Breeding system

Figure 2 shows the breeding system of sweet potato organized by MAFF, Japan. The activities and organizations concerned are as follows:

The collection, preservation and evaluation of sweet potato genetic resources are mainly done in National Agriculture Research Center (Tsukuba) and Kyushu Agricultural Experiment Station (Kumamoto), Ministry of Agriculture, Forestry and Fishery. In the above two, the choice of cross parents from the genetic resources including selected lines and the breeding of new cross parents by using the genetic resources were carried out.

Since it needs the skill and experience to get flowers by grafting with *Ipomoea nil*, to identify their incompatibility and to get seeds by hand-pollination, those works are separated from selection and are done in Kyushu A.E.S. (Ibusuki).

The selection of superior F1 individuals of which contents are morphological traits, yield, quality, pests and disease resistance and those environmental responses are mainly carried out in NARC (Tsukuba) and KAES (Kumamoto).

Adaptability and performance trials of the selected lines were done in various prefectural Agr. Exp Stations under the sponsorship and/or collaboration of MAFF's organizations.

The superior lines selected in the above steps will be registered in MAFF as Norin varieties.

Under the above Norin system, a total of 42 varieties was registered since 1942 in Japan, as shown in Table 3. The name, cross parents, main characters, and others of the representative Norin varieties are shown in Table 4.

4. Genetic resources

It is needless to emphasize the need for collecting and preserving a wide range of genetic resources as the source material for breeding in the past as well as at present. Since the artificial pollination was initiated in 1925 at Okinawa, the domestic cultivars were collected as the source of cross parents. After the second world war, the alien germplasm were initiated to collect in 1955 by I. Nishiyama, Kyoto University, and in 1969-61 from USA (USDA collection) and in 1969 from New Zealand (Yen collection) by MAFF, Japan. The above activities are positively maintained by the Norin system as follows:

The collection and preservation of sweet potato cultivars and breeding lines are mainly done in NARC (Tsukuba) and KAES (Kumamoto), MAFF. As shown in Table 5, the germplasm recently introduced from foreign countries is concentrated in NARC (Tsukuba) and the germplasm domesticated in Japan is mainly preserved in KAES (Kumamoto). The collection and preservation of wild relatives and selected interspecific crosses are done in KAES (Ibusuki).

Sweet potato cultivars and breeding lines are mainly preserved as the clones, of which plants are grown in the field in summer season and tuberous roots are stored in the special store facilities in winter season. The alien cultivars and wild relatives with low tuber ability are kept as vines or stocks in a green house, the temperature of which is more than 15°C. Recently, in vitro preservation is added to the above.

In NARC and KARS (Kumamoto), the morphological, taxonomic and agronomic traits were evaluated in field trials and in laboratory analysis. The chromosomal study and incompatibility test are done in KARS (Ibusuki). The above data is constracted to data base for effective use of genetic resources.

5. BREEDING PROGRAM IN FUTURE

Cultivated sweet potato, Ipomoea batatas, is an autohexaploid species and the chromosome number is $2n = 6X = 90$, and so it is highly heterozygous in its genetic background. It has very poor flowering ability under natural conditions and is divided into 16 groups of incompatibility with a few modifiers. The above characteristics cause the following three handicaps for effective breeding of superior varieties and gene accumulation into certain cross parents: 1) the artificial flower induction is needed, 2) the ideal combination of crosses is restricted, and 3) the rate of gene accumulation is very low in the F1 population resulted by hand pollination.

In order to overcome the above handicaps and improve the breeding efficiency, the scheme shown in Figure 3 is proposed. The main target of the scheme is how efficiently and effectively the genes concerned with objective traits are accumulated in the cross parents, because the higher percentage of emergency of objective traits in F1 population resulted by crossing should be most important. Also, it is needed to develop the new technologies like as anther or pollen culture for making haploid, cell fusion for removing the handicaps with poor flowering and incompatibility, and the simple evaluation for effective selections.

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Table 1. Utilization of sweet potato in several countries

Country	Percentage of utilization		
	Food	Feed	Industrial
Japan	38	18	35
Korea	56	5	36
Taiwan	11	73	16
Thailand	80	15	5
Philippines	80	10	10
India & Indonesia	90	10	
Sri Lanka	100		
Papua New Guinea	85	15	

(Lin, S.S. et al., 1983)

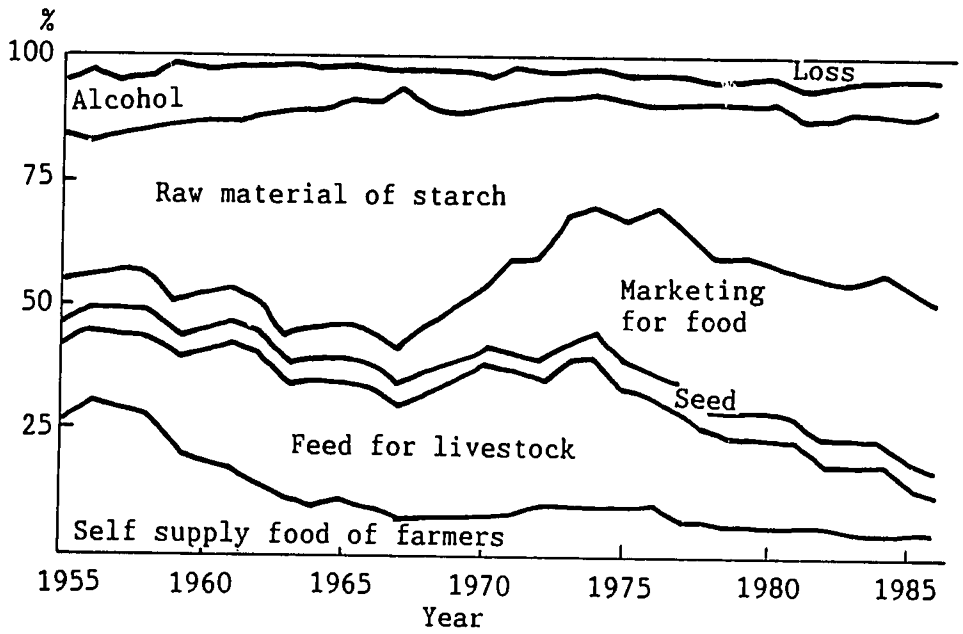

Figure 1. Consumption trend of sweet potato in Japan

Consumption rate

Table 2. Breeding objectives of sweet potato in Japan

Type of usage	Breeding objectives
Table food	Good appearance, delicious taste, good storability, early tuberous and maturing ability
Process food	Good shape, color & quality for processing
Industrial use	High starch content and high starch yield
Animal feed	Early vine growth & regrowth ability, high quality
Common for the above	High yield, high resistance to pests & diseases

C,P,E of Genetic resources, and Breeding & choice of cross parents ← Nat. Agr. Res. Center (Tsukuba) & Kyushu A.E.S. (Kumamoto)

↓

Compatibility test and crossing ← Kyushu A.E.S. (Ibusuki)

↓

Selection of superior F_1 individuals ← NARC (Tsukuba) & KAES (Kumamoto)

- Yield & environmental responses ← Ditto
- Disease & insects resistance ← Ditto
  - Black rot ←← Nagasaki Pre. AES
  - Southern root knot nematodes ←← Miyasaki Pre. AES
- adaptability trials ← Saitama, Ehime, Nagasaki, and Kagoshima Pre. AES

↓

Performance trials ← Various prefectural A.E.S.

↓

Registration, propagation, distribution ← NARC, KAES and others, MAFF

Figure 2. Sweet potato breeding system in Japan

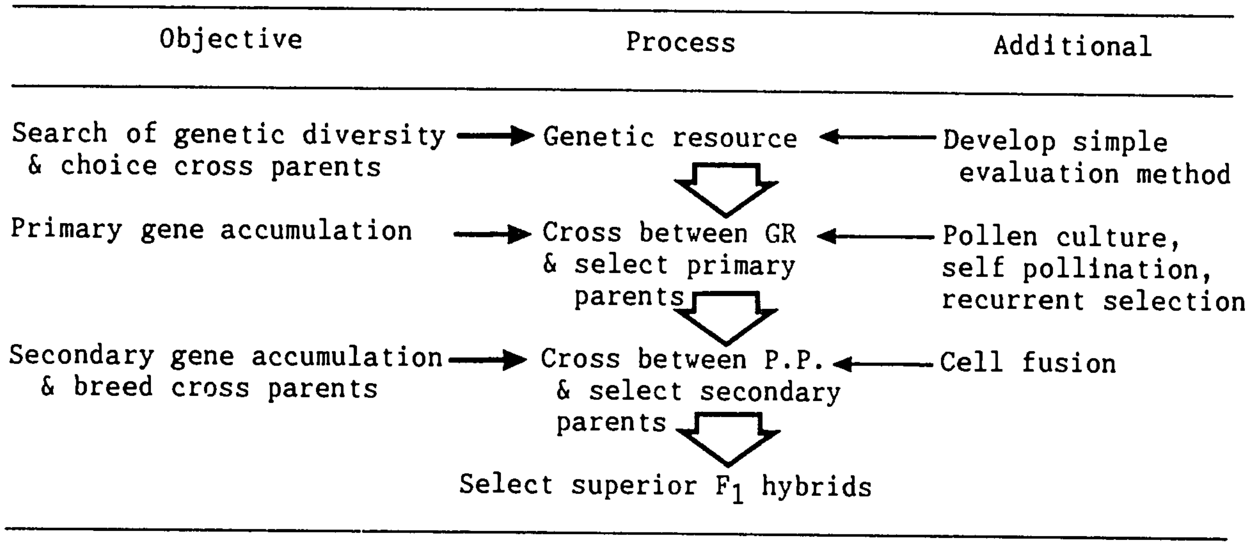

Figure 3. Proposal for improving breeding efficiency in sweet potato

Table 3. "Norin" varieties registered in MAFF, Japan

	Year of registration		
	1940 - 1954	1955 - 1969	1970 - 1988
Table food	8 (5) (Norin 1, 5, 10)	5 (Benikamachi)	1 (Beniazuma)
Process food	0 (1) (Shirosengan)	0 (1) (Tamayutaka)	2 (Benihayato, Satumahikari)
Industrial use	7 (4) (Norin 2)	9 (3) (Koganesengan)	3 (Shirosatsuma, hi-starch)
Animal feed	3 (1)	2 (3)	1 (Tsurusengan)
Total	18 (Norin 1 - 18)	16 (Norin 19 - 34)	7 (Norin 35-41)

Table 4. List of leading cultivars of sweet potato in Japan during the 1980s.

Cultivars (alias)	Name of institute and year of release (or approval)	Use	Main attributes	Acreage in 198! (ha) (*Putative, in 1!
Houkei 14 Katobuki 1 Tosabeni Narutokintoki	Kochi. Pref. Agric. Expt. Sta. 1945	Table	Red sking, early maturity, good taste, good keepability	24,900
Beniaka (Kintoki)	Traditional local cultivar ca. 1900	Table	Red skin, good taste, high cooking quality	4,700
Norin 2	Kagoshima Pref. Agric. Expt. Sta. 1942	Starch	Yellowish white skin, tolerance to poor soil productivity	2,800
Tamayutaka (Norin 22)	Kanto-Tosan Agric. Expt. Sta. 1960	Processing (dried chips after steamed)	White skin with red tips, high yielding, good quality for chips	1,800
Koganesengan (Norin 31)	Kyushu Nat'l, Agric. Expt. Sta. 1966	Starch, table	Yellowish white skin, high yielding, high starch content (22-24%), good taste	17,600
Benikomachi (Norin 33)	Cent. Agric. Expt. Sta. 1975	Table	Red skin, good taste	2,300
Minamiyutaka (Norin 34)	Kyushu Nat'l. Agric. Expt. Sta. 1975	Starch	Brown skin, high yielding but late maturity, tolerant to nematodes, 1/8 kinship of _Ipomoea trifida_ in its pedigree	3,900
Beniazuma (Norin 36)	Nat'l. Agric. Res. Centre 1984	Table	Deep red skin, high yielding, tolerant to diseases	1,400
Benihayato (Norin 37)	Kyushu Nat'l.Agric. Expt. Sta. 1985	processing, cooking	Red skin, high vitamin A (12-14 mg%)	100*
Shiroyutaka (Norin 38)	Kyushu Nat'l. Agric. Expt. Sta. 1985	Starch	Yellowish white skin, high yielding and high starch content (24-26%), high quality of starch grain, tolerant to nomatodes	5,000*
Shirosatsuma (Norin 39)	Nat'l. Agric. Res. Centre 1986	Starch	Yellowish white skin, high yielding and high starch content (24-26%), good keepability	1,000*
Satsumahikari (Norin 40)	Kyusyu Nat'l.Agric. Expt. Sta. 1987	Processing, cooking	Red skin, no B-amylase activity resulting in non-sweetness, high yielding	30*
Hi-starch (Norin 41)	Nat'l.Agric.Res. Centre 1988	Starch	Brown skin, ultra high starch content (28-32%	

(After Kukimura, 1988)

Table 5. Numbers and kinds of genetic resources of sweet potato preserved in Japan

Organization	Numbers	Kinds of genetic resources
Nat. Agr. Res. Center (Tsukuba)	932	Domestic 48, Alien 474, Registered 41, Selected 383
Kyushu Nat.Agr.Exp.Sta. (Kumamoto)	1178	Domestic 278, Alien 203, Registered 38, Selected 628
Kyushu Nat.Agr.Exp.Sta. (Ibusuki)	358	Alien 81 (wild relatives), Selected 277 (interspecies)
Kagoshima & Unzen Field, MAFF	420	Double preservation of the above

RECENT STUDIES ON DRY MATTER PRODUCTION PHYSIOLOGY

Makoto Nakatani

1. CHARACTERISTICS OF DRY MATTER AND YIELD PRODUCTION OF SWEET POTATO AND CLIMATIC INFLUENCE

Marked features of dry matter production in sweet potato plant compared with cereal crops are as follows: 1) Maximum value of crop growth rate (CGR) is not so high, 2) relatively high values of CGR are regarded during growing time, 3) dry matter partitioning ratio, harvest index is high (Tsuno & Fujise, 1965; Toyoda & Shikata, 1986). Recent studies in growth analysis of sweet potato plant (Agata & Takeda, 1982; Komeichi et al., 1986) show that the growth of sweet potato is regarded as two growth phases (Fig. 1). The first growth phase is the stage of leaf area index (LAI) increase and the second growth phase is that of maintaining matured LAI. Dry matter production during the first growth phase depends on LAI, and LAI value is closely related to air temperature. On the other hand, dry matter production and tuber growth rate (TGR) during second growth phase depend on net assimilation rate (NAR), and NAR values are closely related to solar radiation. The effect of air temperature on the dry matter production during second growth phase varied among the experimental location. In Kanto area, the northern limiting region of economic production positive correlations were found between the air temperature and TGR. On the other hand in Kyushu area, southern part of Japan it was reported that the air temperature negatively correlated with NAR; CGR or TGR (Fig. 2). Under the favorable conditions high temperature, especially high night temperature inhibits the tuber growth (Nakatani et al. 1984: Fig. 3).

Shimotsubo et al. (1986) have reported that the number of defoliated leaves correlates negatively with tuber dry weight during the second growth phase (Fig. 4). It is suggested that the leaf defoliation is a competitive sink against the tubers. And Fujise (1983) has proposed the favorable characteristics of top growth as follows: 1) Moderate stem elongation, 2) longer leaf longevity.

2. TUBER SINK POTENTIAL AND SOURCE-SINK INTERRELATION

It has been recognized that one of the most important factors determining the yield and dry matter production of cultivars is tuber sink potential in sweet potato (Hahn, 1977; Hozyo et al., 1971; Wilson, 1967). Tuber sink effects on the dry matter production were found in values of NAR and source-sink interrelation. Tuber sink potential affects the source photosynthetic activity (Hozyo & Park, 1971), leaf longevity (Shimotsubo et al., 1983a) and the translocation speed of assimilates (Kato & Hozyo, 1974). Nakatani et al. (1988a) showed that there was no relation between

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[1]National Agricultural Research Center, Japan.

photosynthetic activity and tuber dry weight before or immediately after tuber formation by the grafting experiment. However, the photosynthetic activity in a scion changed with kind of stock cultivars and related with tuber dry weight after it amounted to about 10g/plant (Fib. 5). Thus the tubers were found as the dominant sink and controlled the photosynthetic activity after their dry weight reached about 10g.

These regulation of photosynthetic activity were regarded with the control of leaf carbohydrate content, since the leaf carbohydrate content were regarded in closely related with phosynthetic activity (Hozyo & Park, 1971; Shimotsubo et al., 1983b, Nakatani et al., 1988c). Chonan et al. (1983) showed that the large starch grains deposited in the chloroplasts destroyed the granum structure and inhibited the photosynthetic activity in the grafts with non tuber forming stock.

3. ESTIMATION OF TUBER SINK POTENTIAL

Tuber sink potential of cultivars has been estimated by using the grafts (Hozyo et al., 1971; Hahn, 1980; Nakatani et al., 1986). Both of the sink and source can be changed by grafting. Ideally speaking source potential and sink strength other than tubers should be uniform for the estimation of tuber sink potential. There are some problems in the use of usual grafts for estimation of sink potential. Source amount may be different between stocks even with same scion. To solve this problem Nakatani et al. (1986b) have used the single leaf grafts (Fig. 6). In the system of single leaf grafts, leaf area and photosynthetic potential can adjust uniform easily. The photosynthesis depends on the mesophyll resistance of CO_2. And mesophyll resistance depends largely on the tuber sink potential (Fig. 7). The matter production in the single leaf grafts, therefore, depends largely on the tuber sink potential. By using this system tuber sink potential can be estimated under the ideal condition.

4. PHYSIOLOGICAL FACTORS RELATING TO TUBER SINK POTENTIAL.

Although the relationship between the tuber yield and/or sink potential and several physiological factors has been investigated, physiological factors controlling the tuber sink potential are still not clear.

Tsuno & Fujise (1965) have found that K_2O/N ratios of tubers correlate positively with the tuber yield in six cultivars. Siga et al. (1985) have also reported same tendency among many cultivars in Japan. However, no correlation was observed between tuber dry weight and K_2O/N ratio in the field grown and single leaf grafts (Nakatani et al., 1988c:Table 1) and among the lines in Yen collection (Sweet Potato Breeding Lab., NARC, personal communication). From this facts, it is suggested that tuber K_2O/N ratio is the result of "Source-Sink interrelation," but it is not the regulatory factor of sink potential.

The activity of cell division is an important factor in determining the sink potential. The callus forming ability of tuber tissue was assumed to be an indicator of the activity of cell division. Hozyo (1973) and Yamaguchi (1978) have found the varietal difference in the callus forming ability of tuber tissue and requirement of hormones for callus formation. However, the callus forming ability in two kinds of medium containing the different level of 2,4-D and BA was not correlated with tuber fresh weight and sink potential (Nakatani et al., 1988c: Table 1). Thus it is suggested that the callus forming ability _in vitro_ is not favorable indicator of the activity of cell division _in situ_.

Generally plant hormones play an important role in the regulation of the growth. The secondary growth of radish and carrot roots is controlled by auxin and cytokinin (Torrey, 1976). In potato, specific tuberization substance is identified (Koda et al., 1988). In sweet potato, however, the hormonal mechanism in the regulation of tuber thickening is not so clear.

Akita et al. (1962) have shown that the cessation of tuber thickening by the light exposure is related with the decrease in the endogenous auxin level and the activation of IAA oxidase. The requirement of auxin for the normal development of tubers is not reported.

Major cytokinin in sweet potato tuber is zeating riboside (ZR) (Matsuo et al., 1983). And the endogenous level of cytokinin in the tuber achieves maximum at the stage just after tuber formation (Matsuo et al., 1983; Hozyo, 1973), and higher than that in other organ (Koda et al., 1985). Root cytokinin level is reported higher in sweet potato than in the non-tuber forming wild type (Oritani et al., 1983). Applied cytokinins increase the number and weight of tubers (Spence & Humphries, 1972; McDavid & Alam, 1980). From these facts it is suggested that cytokinins play some role for tuber formation and/or thickening. However, tuber ZR content of single leaf grafts did not correlated with tuber sink potential at the late growth stage (Nakatani et al., 1988c: Table 1). On the other hand tuber ABA content of them correlated with sink potential significantly (Nakatani et al., 1988c: Table 1). Oritani et al. (1983) reported that the ABA content of roots at the stage of tuber formation was higher in the cultivar than in non-tuber forming wild type and assumed that high cytokinin and ABA content might relate with high sink potential. Further investigations were still needed to clarify the hormonal regulation of tuber formation and thickening.

It is thought that the activity in the starch synthesis may relate with sink potential. And tuber starch content is one of the most important factors for the industrial use. As the other crops in sweet potato starch is synthesized from ADP-glucose by starch synthase (Murata & Akazawa, 1968). However, starch synthase do not suggest to be a key enzyme controlling the starch accumulation (Murata, 1970; Nakatani et al., 1988c: Table 2). The starch accumulation, therefore, is thought to be regulated by the enzyme before the ADP-glucose synthesis. Nakatani & Komeichi (1988) showed the significant correlation between tuber ADP-glucose pyrophosphorylase activity and starch or dry matter content (Table 2). It is assumed that the starch accumulation in sweet potato tuber may regulate roughly by this enzyme.

For the improvement of sweet potato the physiological studies should provide the strategy and method to the breeder and/or agronomist. Especially for the application of bio-technology to the improvement of sweet potato, physiological and/or biochemical mechanism regulating the yield and matter production should be clarified.

Table 1. Correlation coefficients between tuber K_2O/N ratio, calluse forming ability, ZR and ABA content and tuber sink potential.

		r
Field grown grafts	K_2O/N ratio immediately after tuber formation	-0.054
	K_2O/N ratio at harvesting time	0.059
	Calluse forming ability (Miller)	0.116
	Calluse forming ability (Miller + 2, 4-D, KIN)	0.011
Single leaf grafts	Zeatin riboside (ZR) content	-0.419
	Abscicic acid (ABA) content	0.558

*: Significant at 5%.

Table 2. Correlation coefficients between the activity of starch synthase and ADP-glucose pyrophosphorylase and dry matter content in tubers.

	Correlation coefficient
Starch synthase	0.167
ADP-glucose pyrophosphorylase	0.689[a]

[a]The activities were based on gFW tuber.

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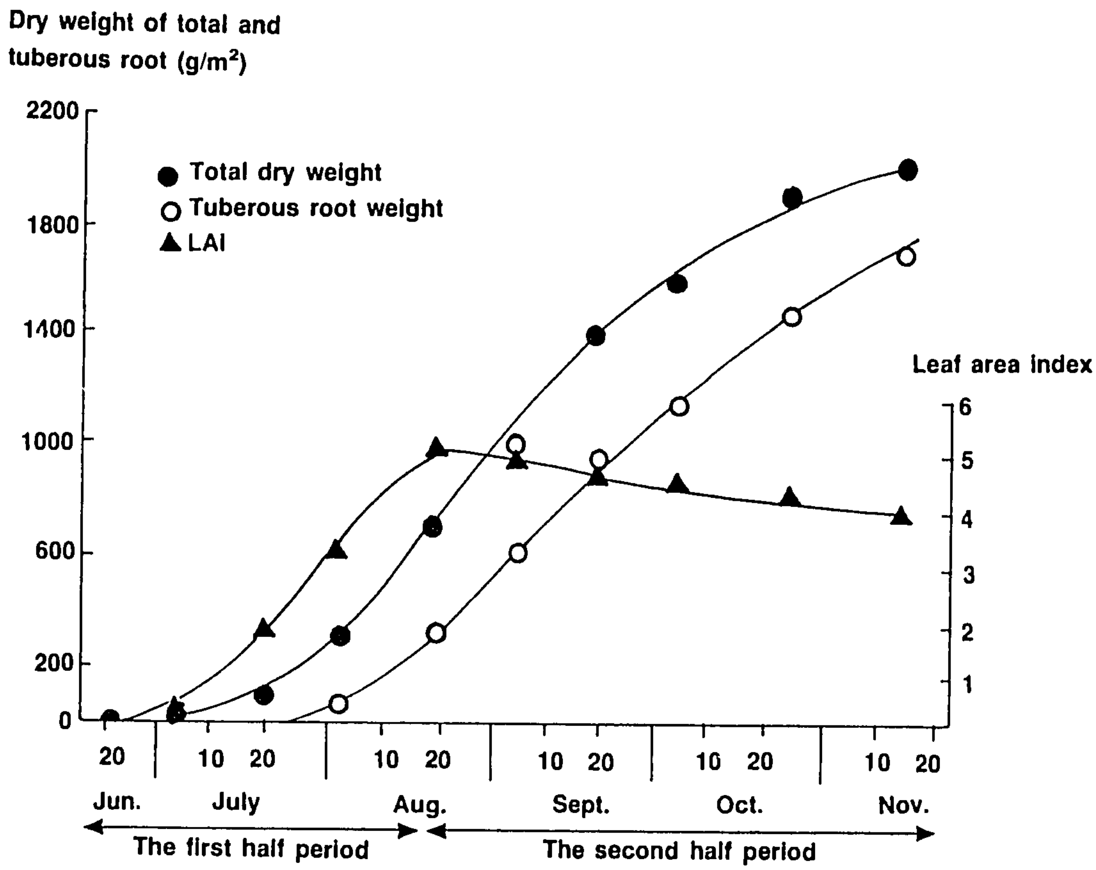

Figure 1. Changes of total dry weight, tuberous root dry weight (yield) and leaf area index (LAI) with growing time under field conditions (cultivar: Koganesengan).

(Agata & Takeda, 1982)

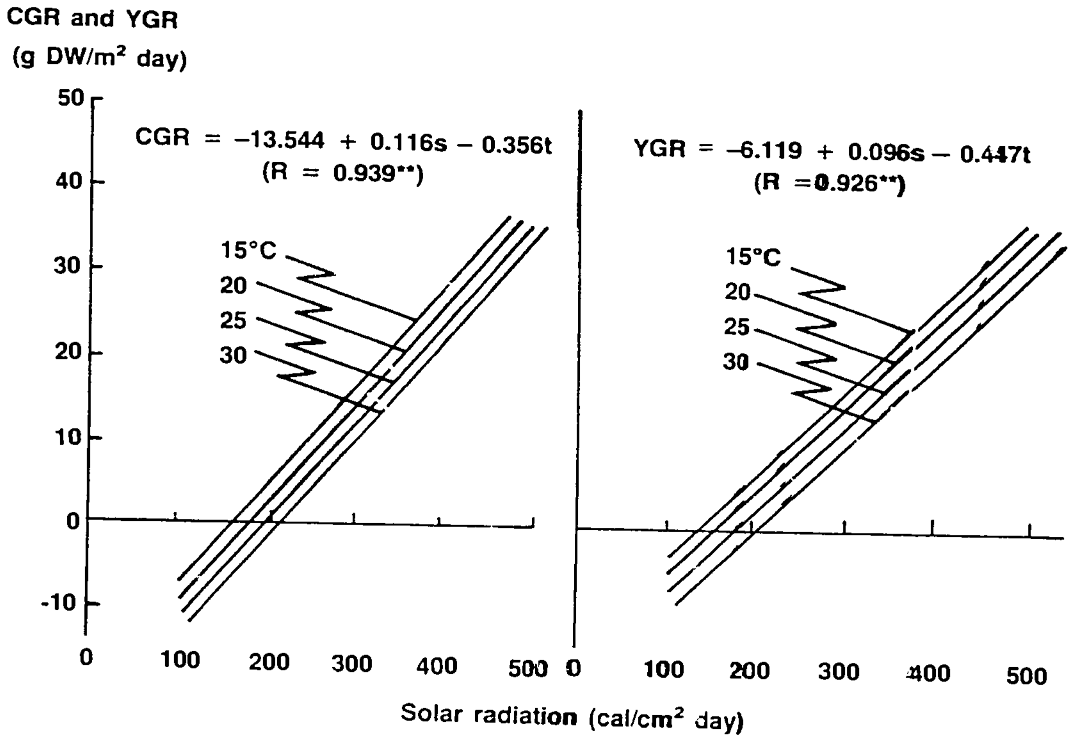

Figure 2. Effects of solar radiation (s) and ir temperature (t) on crop growth rate (CGR) and tuberous root growth rate (YGR) in the second half of growth period. The analysis was made by mixed data of Koganesengan and Minamiyutaka.

(Agata & Takeda, 1982)

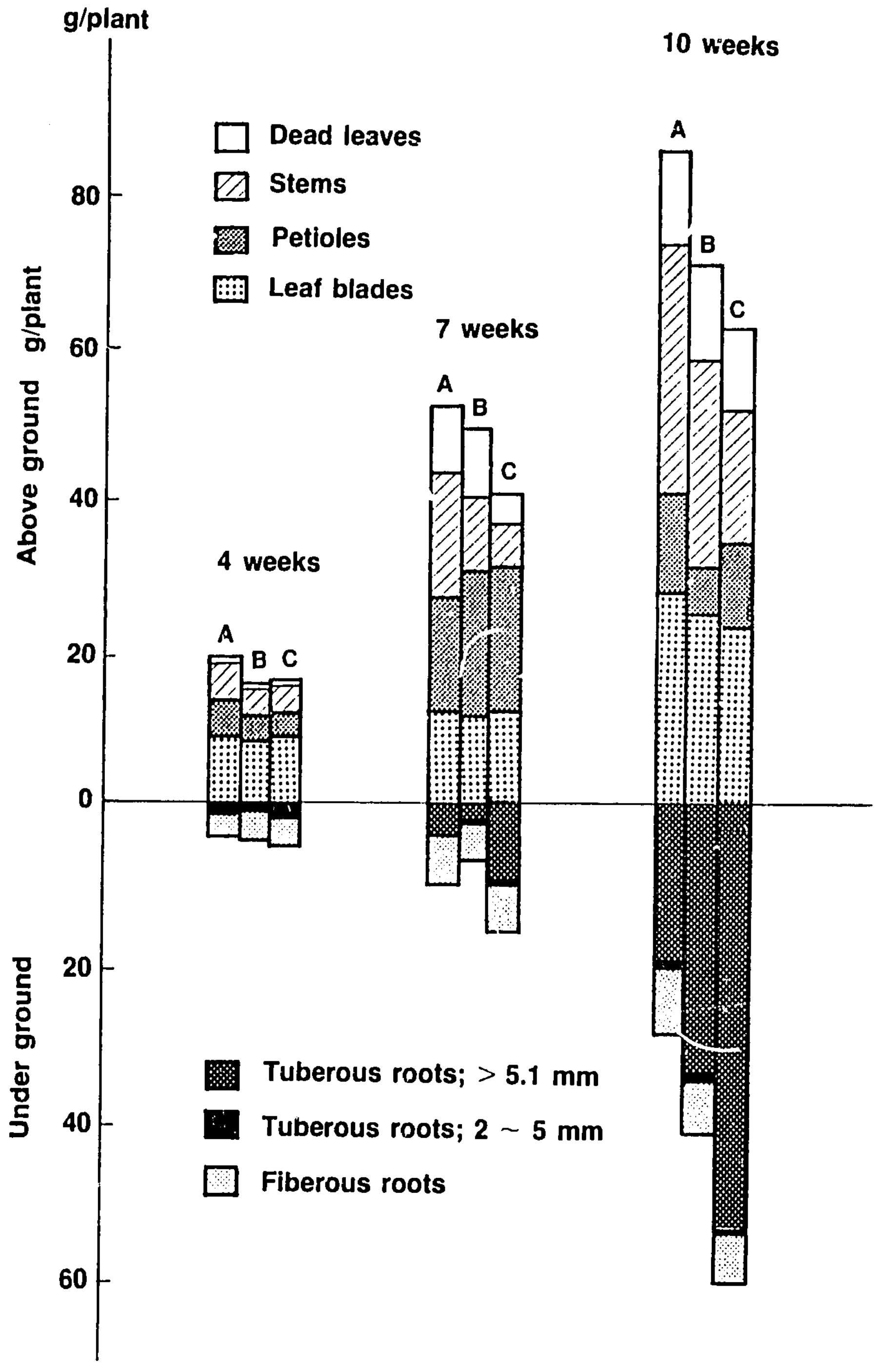

Figure 3. Successive partition of dry matter in each organ.
A:28/28°C, B:28/24°C, C:28/20°C

(Nakatani *et al.*, 1984)

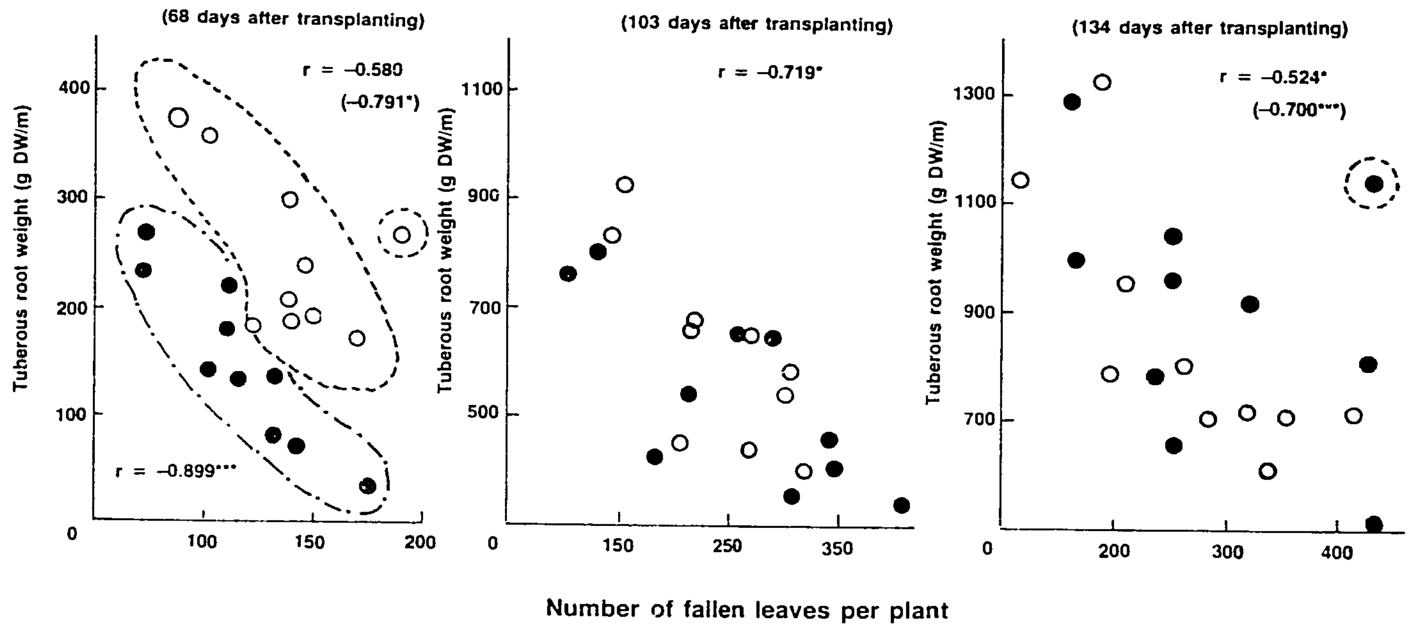

Figure 4. Relationship between dry weight of tuberous roots and number of defoliated leaves in grafts with Koganesengan stocks (○) and Norin No. 1 stocks (●).

(Shimotsubo *et al.*, 1986)

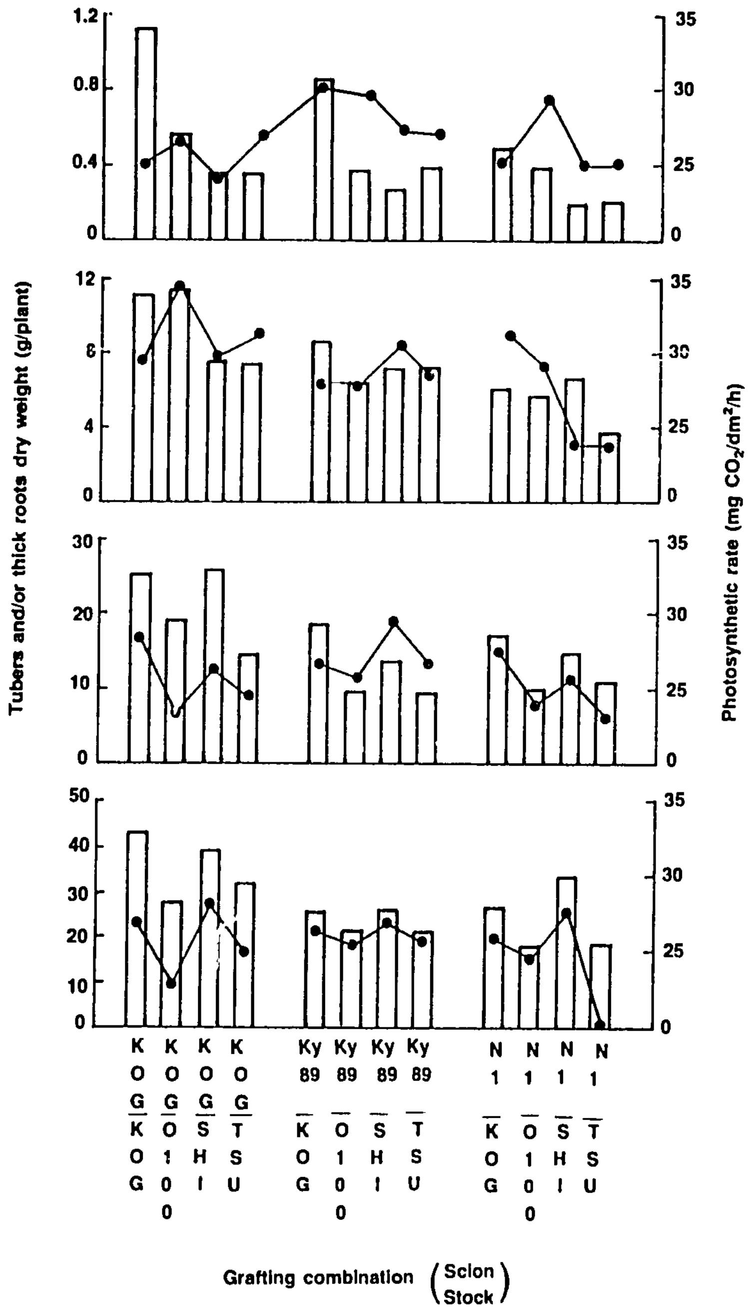

Figure 5. Tuber dry weight (□) and photosynthetic rate (●) of grafts at 5 (upper), 7 (2nd), 9 (3rd) and 10 (lower) weeks planting in 1986.

(Nakatani *et al.*, 1988)

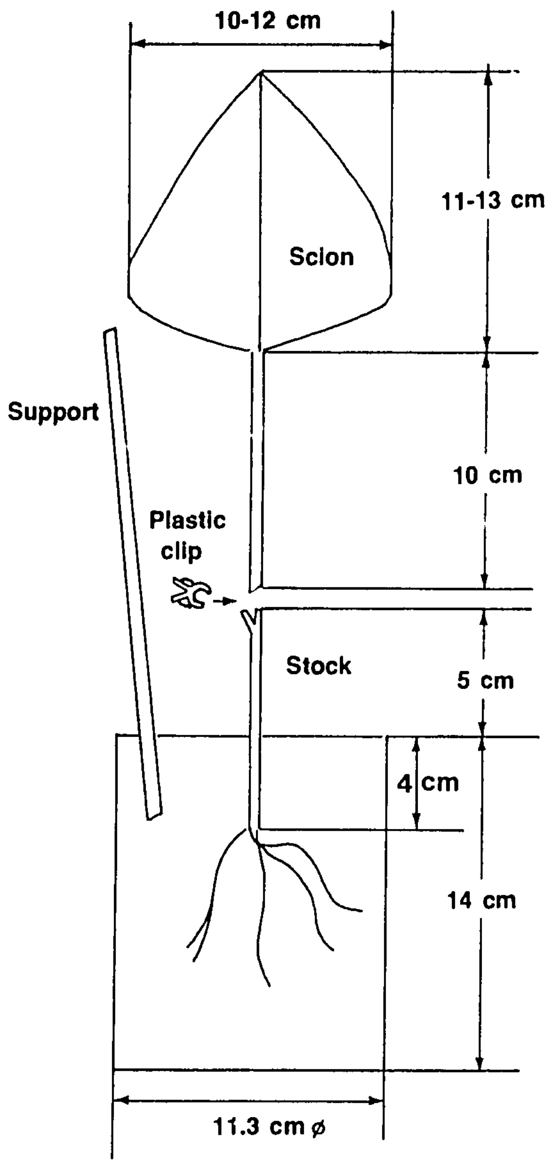

Figure 6. Grafting of single rooted leaf.

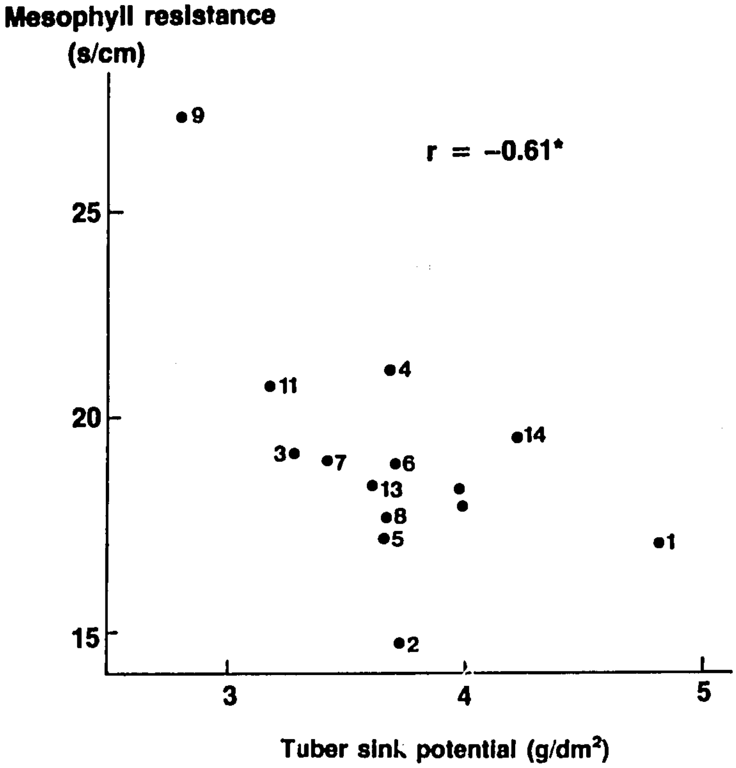

Figure 7. Relationship between tuber sink potential and mesophyll resistance of single leaf grafts.
The numbers in the figure show cultivars of stock as follows:
1: Koganesengan, 2: Kokei 14, 3: Beniaka, 4: Okinawa 100, 5: Norin 1, 6: Fukuwase, 7: Chugoku 25, 8: Minamiyutaka, §: Tsurusengan, 10: Kyushu 89, 11: Shiroyutaka, 12: Beniazuma, 13: Kanto 92, 14: Shirosatsuma.

SWEET POTATO ADAPTATION STUDIES AT NORTH CAROLINA STATE UNIVERSITY

Wanda W. Collins[1]

1. INTRODUCTION

The sweet potato breeding program at North Carolina State University has as its primary goal the development of commercial cultivars for the State of North Carolina as well as all other states in the United States which grow sweet potatoes. The type of sweet potato which is commercially successful in the U. S. is a moist-textured, sweet, orange root with a very precise size and shape. It is quite different from the type of sweet potato consumed in the world which is usually dry-textured, non-sweet or only slightly sweet, and white to yellow or very light orange. The precise sizes and shape requirements of the U. S. consumer are not as important in other parts of the world.

The climate in which sweet potatoes are grown is similar to more tropical growing areas. Sweet potatoes are planted in the spring when soil temperature is above 15C. Air temperature ranges from 15C-22C. As the season progresses, soil and air temperatures gradually increase. Mid summer air temperature may be as high as 35-37C. Length of growing season is almost always shorter than in tropical growing areas. The preferred growing season is 120 days or less. Harvest is seldom delayed past 135 days.

Sweet potatoes grown on a wide range of soil types with the preferred types being sandy loam or loamy sand. These soils in N.C. are usually low in fertility. They may be well-drained or poorly drained. Aluminum toxicity may be a problem. Many of these soils are similar to tropical soils.

Diseases that are most important in North Carolina include root-knot nematode and Fusarium wilt.

2. GOALS AND OBJECTIVES

Recently studies at N. C. State have on adaptation of N. C. germplasm and development of new germplasm for increasing yields, food quality and disease resistance of sweet potatoes for tropical growing conditions.

The potential of sweet potato as a food source has not yet been reached in developing countries. Part of the season for this is the lack of

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researchers working with the crop as compared to cash crops. In addition, germplasm may not be available to provide the genetic diversity to develop cultivars suited to specific environments and with resistances to diseases and pests unique to those environments. Many local cultivars are low in dry matter with poor storability and few disease resistances. An adaptation and development program at N. C. State University offers the unique ability to work with promising material in an environment that closely parallels environments that may be found in developing countries that need improved germplasm.

Specific goals of this program at North Carolina State are:

- to develop clones with high levels of resistance to *Fusarium* wilt and root-knot nematode (*Meloidogyne incognita*) and the particular food quality characteristics needed in different areas;
- to develop a long-term, random mating population with a wide genetic base which will form the basic for a recurrent selection program to change gene frequencies and increase the potential levels of the characters mentioned; and
- to propagate the selected material, in vitro and pathogen free, for distribution to anyone requesting.

3. 1988 RESULTS

Almost 300 clones were tested for internal root quality characters in 1987. A group of the most promising clones were tested in replicated tests in 1988 for:

- yield
- dry matter
- protein
- carotene
- sugars
- starch.

Roots of the clones were also cooked and evaluated by a small, untrained taste panel for taste, texture, flavor and color. They were then grouped loosely and subjectively into 3 groups: staple types, supplemental staples and luxury types. Results are shown in Table 1 and 2.

The clones selected for replicated study were also tested for *Fusarium* wilt and root-knot nematode resistance. However, those tests have just been harvested and data are not analyzed.

The clones listed have been cultured in-vitro and virus indexed.

4. 1989 STUDIES

Several clones will be selected out of the group mentioned above in order to test their production potential and food quality characters under minimum input fertility conditions.

5. SUMMARY

Results from the first year of study show that the range in the characteristics listed are significant. A good breeding and selection program for types adapted to tropical conditions should provide valuable germplasm to other breeders.

Table 1. Internal Root Quality Characteristics of Fresh Roots of Selected Sweet Potato Clones[z]

Clone	Origin	Flesh Color	Carotene (mg/100g)	% DM	% Total Sugar	% Starch	% Protein DWB	% Protein FWB
Group 1. Staple Types								
1582	P. Rico	White	0.12	29.2	12.3	63.4	5.6	1.6
J-2	Japan	White	-	31.8	13.3	63.5	4.6	1.5
1761	US	Pale Yellow	1.10	26.7	9.2	63.9	4.7	1.2
273-5A	US	Yellow	1.70	30.8	10.5	58.9	5.8	1.8
1525	Nigeria	Purple	1.12	23.1	10.9	52.9	5.1	1.2
1554	Brazil	Purple	0.13	33.3	11.4	66.7	5.9	2.0
Group 2. Supplemental Staple Types								
1508	Brazil	White	0.20	25.6	8.6	62.5	5.2	1.3
WI90	US	White	0.00	39.9	10.1	66.9	4.3	1.7
262W	US	Pale Yellow	0.32	25.5	9.8	60.7	6.5	1.6
1135	US	Pale Yellow	0.73	21.0	19.4	52.5	6.2	1.3
1560	Nigeria	Yellow	0.62	22.4	13.1	58.7	8.1	1.8
196-20	US	Yellow	0.40	26.7	13.7	58.7	5.6	1.5
239.12	US	Deep Yellow	4.53	27.2	18.3	54.9	4.6	1.2
239-4	US	Deep Yellow	1.87	26.3	10.7	59.5	5.3	1.5
NC17	US	Orange	5.30	24.6	11.8	54.7	6.7	1.6
Group 3. Luxury Types								
Jewel	US	Orange	8.80	22.5	14.2	63.0	6.6	1.5

[z]Assignment to Group 1, 2, or 3 based on taste (mostly sweetness) and appearance after cooking.

Table 2. Yield Characteristics of Selected Sweet Potato Clones[z]

Clone	Yield mt/ha	Dry Matter kg/ha	Dry Matter kg/ha/d[y]	Protein kg/ha	Protein kg/ha/d[x]	Growing Days
Group 1. Staple Types						
273-5A	48.8	15030	105.1	872	6.1	143
J-2	40.9	13006	89.7	598	4.1	145
1503	38.3	11330	82.1	634	4.6	138
1761	34.0	9078	66.8	427	3.1	136
1554	33.5	11156	78.0	658	4.6	143
1582	31.6	9196	66.6	543	3.9	138
1525	29.9	6907	50.1	352	2.6	138
Group 2. Supplemental Staple Types						
1135	60.7	12751	89.2	791	5.5	143
262W	50.1	12776	92.6	830	6.0	138
1560	48.8	10931	79.2	885	6.4	138
239-12	46.1	12539	86.5	576	4.0	145
196-20	44.2	11801	81.4	661	4.6	145
NC317	43.4	10676	78.5	716	5.3	136
239-4	42.8	11256	78.7	597	4.2	143
1508	41.8	10701	77.5	556	4.0	138
W190	37.2	14843	102.4	638	4.4	145
Group 3. Luxury Types						
Jewel	34.3	7718	55.9	509	3.7	138

[z]Assigment to Group 1, 2, or 3 based on taste and appearance after cooking.

[y]FAO average= 22kg/ha/day

[x]FAO average= 1 kg/ha/day

NUTRITIONAL ASPECTS OF SWEET POTATO ROOTS AND LEAVES

J. A. Woolfe[1]

1. INTRODUCTION

The basic purpose of all the people gathered at this meeting, whatever their discipline, is an improvement in the quality of human life through the greater provision of food supplies. More specifically we hope to provide more food and a higher nutritional status in many countries through the improvement of sweet potato as a crop and an increased recognition by consumers of its nutritional value. Both these goals require great efforts to achieve. But does the sweet potato really have nutritional advantages over other major crops, which make these efforts worth while?

To answer that question, we can examine the nutritional value of the sweet potato in two ways, both of which compare the sweet potato with other major crops grown and widely used in the tropics.

Firstly, we can examine how effective sweet potato is, compared with other crops, at feeding the individual consumer. Roots and leaves will be described separately. The quantity of 100 gram has been chosen for purposes of comparison of roots with other food crops both for convenience, and the fact that it is a modest quantity which even a young child could eat in one sitting. Secondly we can look at the total numbers of people per unit area per unit time the sweet potato can support in comparison with other crops.

2. HOW SWEET POTATO NOURISHES THE INDIVIDUAL

2.1. Roots

2.1.1. Energy and protein

If we look first at the energy and protein contents of cooked and other cooked staples in Table 1 it can be seen that sweet potato is a moderately good supplier of energy, being greatly superior in this respect to potatoes and cereal noodles and porridges. As would be expected it supplies less energy than drier foods such as bread.

It is less impressive in terms of protein content. The NDpE% of sweet potatoes is below even the adult requirement as shown in Table 2. This means that sweet potato is not well balanced in terms of energy and protein and even if enough is eaten to supply all energy needs, the quantity of protein eaten will be insignificant. The calculation of NDpE% includes both the quantity and quality of the protein. The quality can be appreciated better if the chemical scores for any particular human age group are calculated as shown on Table 3. The table demonstrates that sweet potato protein quality is moderately good for the lower age groups and very good for school children and adults. Techniques for the improvement in the quality and quantity of sweet potato protein have been much discussed. What would an improvement mean to the most vulnerable age group, that is a 1-2 year old? Figure 1 shows the greatly decreased quantity of sweet potato which would have to be eaten to satisfy all of the child's daily essential amino acid requirement if the chemical score could be increased to 100% combined with an improved average protein quantity of 2.0% (at the top of the observed range of actual values). In fact it is a very rare child who would be fed only on sweet potato, but the diagram also indicates that if equal quantities of the three types of sweet potato were eaten the most highly improved type would require less addition of other protein-rich, relatively expensive supplements.

2.1.2. Vitamins and minerals

It is perhaps in the content of vitamins that the comparative advantage of sweet potato can best be seen. Table 4 compares sweet potato with other staples. It has a similar B-vitamin content to the other staples, but is virtually the only one with potentially high levels of both pro-vitamin A carotenoids and ascorbic acid. So how does it compare with other roots and tubers in the contents of these two vitamins? Most have similar contents of ascorbic acid but all other roots and tubers apart from sweet potato are lacking in carotene as seen in Table 5. The range of carotene in sweet potato cultivars is very wide. At the top of the range come the very dark orange-fleshed cultivars which are not popular with many consumers in tropical countries. However, there are many cultivars with yellow flesh and a more modest carotenoid content which could still supply a very high percentage of the daily vitamin A requirement.

We are accustomed to thinking of vegetables such as tomatoes, carrots and so on, rather than roots, tubers or cereals, as suppliers of vitamins. Sweet potato is, however, used by many as a vegetable accompaniment to a meal rather than as a staple. So how does it compare to other commonly eaten vegetables in terms of vitamins? Table 6 shows that it compares very favorably. Sweet potato has similar or superior quantities of B-vitamins to the other vegetables except soybean sprouts. Surprinsingly it is superior to all but peppers in ascorbic acid content. Even more surprisingly perhaps, it is potentially a richer source of pro-vitamin A than vegetables such as carrots and tomatoes which consumers are accustomed to thinking of as the richest sources.

Why is the presence of pro-vitamin A carotenoids in sweet potato so important? The condition of xerophthalmia (a term which can be used to encompass all the manifestations of severe vitamin A deficiency) is a problem of public health magnitude in some countries, particularly the rice-dependent countries of Asia, and is of seasonal or occasional occurrence in others. It has been estimated that about 250,000 children in the world suffer from severe xerophthalmia and go blind each year. In Bangladesh alone it was calculated in 1986 that about 12,000 rural pre-school children are surviving blind at any one time, about 45,000 have serious loss of sight in one or both eyes and approximately 750,000 pre-school children have some degree of xerophthalmia. The condition is also prevalent in some parts of Indonesia, India, Philippines, and is serious in Afghanistan, Nepal, Sri Lanka, Haiti, the sugar-growing area of N. E. Brazil and parts of West Africa. The use of carotenoid-rich cultivars of sweet potato for feeding the youngest and most vulnerable age groups, who are also the ones least likely to reject moist, sweet-tasting cultivars, should be strongly encouraged. However, we need to know more about child-feeding habits as well as the degree of absorption and utilization of the carotene from sweet potato in the presence or absence of other constituents of local diets. Carotenoids may be poorly absorbed when ingested with too little fat, for example.

In addition to vitamins, sweet potato roots contain modest amounts of iron, magnesium, manganese, copper and molybdenum. They are quite a good source of phosphorus and have a high potassium to sodium ratio.

2.1.3. Contribution to daily nutrient needs

Even a small quantity of sweet potato root such as 100 gram can supply a significant part of some daily nutrient requirements as shown in Figure 2. It is assumed that the sample shown contains 4 mg/100 g B-carotene. A cultivar with a moderate level of 2 mg/100 g of B-carotene could supply all of a child's and 50% of an adults daily vitamin A requirement. Richer sources might enable a child to store several days supply. The same quantity of sweet potato supplies almost a child's ascorbic acid and over 50% of the adult's needs, whilst also fulfilling about 5% of their B-vitamin requirements.

2.1.4. Postharvest changes

Among the nutrients, vitamins are those most susceptible to losses as a result of postharvest handling. Figure 3 shows approximate retentions of vitamins under ideal conditions of storage. Though sweet potatoes are seldom stored in the tropics, the storage which does occur is usually in uncontrolled conditions conductive to high nutrient losses. These have hardly been investigated and are in need of greater research efforts to promote simple improved storage methods.

Cooking also leads to losses. Table 7 shows that retentions of vitamins are greatest when the sweet potato is cooked in its skin or if the cooking water is retained and utilized in a soup or stew. An encouraging fact is that retention of pro-vitamin A carotenoids is high both during storage and normal cooking. The same cannot be said for ascorbic acid which is vulnerable to both heat and oxidation.

If we compare different methods of cooking, baking in the skin confers some nutritional advantages over boiling. Losses of nutrients are similar, but loss of moisture during baking means that remaining nutrients are concentrated. For example, baked sweet potato provides a child with about 20% more energy than an equal weight of boiled sweet potato.

2.2. <u>Leaves</u>

Sweet potato and other tropical leaves have previously been neglected by researchers who are now recognizing their worth. Though temperate vegetables introduced into the tropics may have a higher status in the eyes of consumers, leaves such as those sweet potato have the advantage of being adapted to local conditions and can continuously harvested over a period of time making them suitable for back-ya cropping. They are also among the cheapest vegetables found in the market. Compari sweet potato leaves on an equal weight basis with other tropical leaves and with sc popular temperate leafy and non-leafy vegetables, we can instantly see in Table 8 t many nutritional advantages of tropical leaves.

2.2.1. Protein

The protein content of sweet potato leaves not only is twice that in the roots, b also much higher than in all the temperate vegetables. Turning back briefly to Table we can see that the quality of leaf protein is on average similar to that of the root Very few complete amino acid analyses of sweet potato leaves have been done, but least one analysis indicates that they may be a very rich source of lysine. Th should be further investigated.

2.2.2. Vitamins

Table 8 shows a variable but high ascorbic acid content and a favorable level beta-carotene. One very interesting finding is that sweet potato leaves are relative rich in riboflavin which is low in many Asian diets. One may compare the avera riboflavin content of sweet potato leaves shown in Table 8 with that of milk (0. mg/100 g), beef (0.24 mg/100 g), chicken meat (016. mg/100 g) and white fish (0. mg/100 g).

2.2.3. Minerals and oxalate

An examination of some minerals in sweet potato leaves indicted that they a potentially richer sources of calcium and iron than the roots (see Table 9). Howeve it should also be noted that their oxalate content is considerably higher than that most temperate vegetables with the exception of spinach. This is a disadvantage that oxalate can bind and render unavailable minerals such as calcium and zinc Cultivars low in oxalate content could be sought to overcome this. It has also bee found that iron absorption from sweet potato leaves is very low. The reason for thi is not known and should be investigated so that ways can be found to maximiz absorption.

2.2.4. Contributions to daily nutrient needs

The final diagram shows the percentage of daily nutrient requirements fulfilled b 85 gram leaves (the quantity estimated by one researcher as the average serving size) It is clear that sweet potato leaves can supply very high percentages of the dail needs of many nutrients for both children and adults. However, ways should be sough to maximize retention of vitamins (which are liable to high losses on cooking), an absorption of minerals.

3. SWEET POTATO CAN FEED LARGE NUMBERS OF PEOPLE

The second way of judging the value of sweet potato is by examining the numbers of people which it is capable of feeding per unit area in one day and comparing this with the numbers fed by other major crops. Table 10 shows that, even with the present low average tropical yield of sweet potato in terms of tones per hectare, it produces more food per hectare per day than any of the other major crops listed. This is because it has a greater fresh weight yield than legumes or cereals and a shorter time to harvest than other roots and tubers. If the experimental yields, shown at the bottom of the table (or even something approaching them) could be achieved on-farm, very large quantities of food indeed could be produced from either sweet potato roots or leaves.

If we examine, in Table 11, the number of people which one hectare of sweet potato can provide with various major nutrients in one day, we again have some very impressive figures, especially if both roots and leaves could be harvested with the sort of yields shown in the table. Indeed among the crops shown, only sweet potato has the potential to provide large numbers of people with vitamin A and ascorbic acid.

The sweet potato yields two highly nutritious commodities from a single plant. The improvements in yield, disease and pest resistance, storage methods and production of food products and overall quality which are being urgently sought means that the sweet potato will receive the recognition it has so long been denied - that of a crop capable of nourishing the greater populations of the world.

Table 1. Energy and protein in cooked plant foods (per 100 g edible portion)

	Moisture %	Energy kcal	Protein g
SWEET POTATO			
Roots (boiled)	71	115	1.5
Cassava (boiled)	69	124	0.9
Potato (boiled)	80	76	2.0
Rice (boiled, white)	68	135	2.3
(noodles)	79	88	1.0
Maize (porridge)	81	76	1.8
(tortilla)	48	210	4.6
Wheat (bread)	33	278	8.7
(pasta)	66	132	4.1
Beans (boiled)	69	118	7.8

Table 2. Net protein energy as percent of total energy (NDpE%)

Food	NDpE%
Breast milk	8.0
Oats	7.0
Potatoes	6.0
Wheat	6.0
Rice	4.9
Maize	4.5
Sweet Potato	3.4
Cassava	<1
Requirement for:	infant 8.0
	1-year old 6.0
	adult 4.0

Table 3. Amino acid scores of roots and leaves

	Infant		Pre-school		School child		Adult	
	Score	LAA	Score	LAA	Score	LAA	Score	LAA
Roots	57	Met	70	Lys	92	Lys	>100	-
Leaves	52?	Try?	66	Lys	86	Lys	>100	-

LAA = Limiting Amino Acid

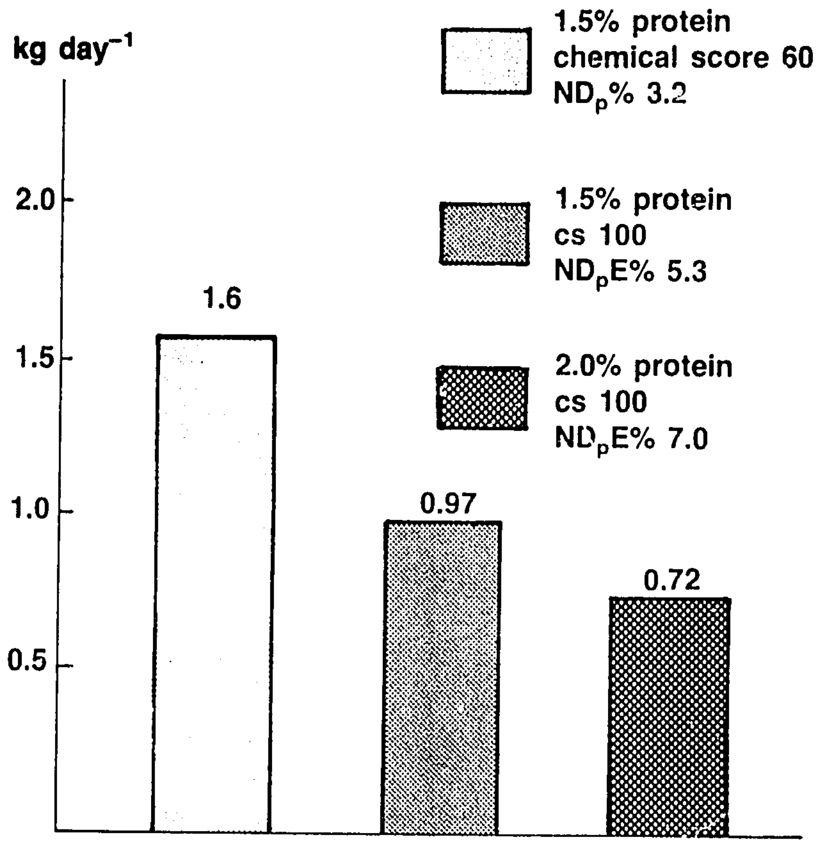
$$\text{Score} = \frac{\text{mg amino acid in sweet potato protein}}{\text{mg amino acid in human requirement pattern}} \times 100$$

Table 4. Vitamins in sweet potato roots and other staples (cooked, per 100 g).

	B-carotene mg	Thiamin mg	Riboflavin mg	Niacin mg	Ascorbic Acid mg
Sweet potato (boiled)	0 - >20	0.10	0.06	0.6	17
Rice (boiled white)	0	0.02	0.01	0.4	0
Maize (cob, boiled)	0.24	0.12	0.10	1.4	9
(porridge)	Tr	0.06	0.01	0.5	0
Bread (white)	0	0.09	0.05	1.0	0
Spaghetti (boiled)	0	0.01	0.01	0.3	0
Beans (boiled)	Tr	0.11	0.06	0.7	0

Sweet potato also contains folic acid,, pantothenic acid and Vitamin B_6

Figure 1. Improvement of sweet potato protein.



Quantity of "normal" and "improved" sweet potato which would have to be eaten by a 2-year old child to satisfy 100% of their essential amino acid requirement. Calculations assume 100% bioavailability (A 2-year old only needs to eat 1.2 kg sweet potato to fulfill its energy needs. In other woods at ND_pE% 3.2, can't fulfill protein needs at this quantity).

Table 5. Carotene and ascorbic acid in roots and tubers (raw, per 100 g)

	B-carotene mg	Ascorbic acid mg
Sweet potato	0 - >20	30
Cassava	0 - 0.1	32
Potato	0 - Tr	25
Yam	0.10	20
Cocoyam	0.04	15
Giant taro	0	17
Plantain (ripe)	0.4 - 1.0	20

Table 6. Vitamins in sweet potato roots and other vegetables (raw, per 100 g).

	B-carotene mg	Thiamin mg	Riboflavin mg	Niacin mg	Ascorbic Acid mg
Sweet potato	0 - >20	0.10	0.06	0.6	30
Carrots	12	0.06	0.05	0.6	6
Onions	0	0.03	0.05	0.2	10
Tomatoes	0.6	0.06	0.04	0.7	20
Peppers	0.2	Tr	0.03	0.7	100
Pumpkin	1.5	0.04	0.04	0.4	5
Soybean sprouts	0.025	0.19	0.15	0.8	10

Table 7. Percent retentions of vitamins during cooking

Treatment	B-carotene	Ascorbic acid	B-vitamins
Boiled in skin	90	80	90 -- 100
Boiled peeled	85	20 -- 80[a]	50 -- 100[a]
Baked in skin	75 -- 100	80	90 -- 100
Baked peeled	?	50	80

[a]Highest retentions: water retained
Lowest retentions: water discarded

Table 8. Sweet potato leaves and other vegetables (per 100 g)

Vegetable	Protein mg	B-carotene mg	Riboflavin mg	Ascorbic acid mg
Tropical leaves				
Sweet potato	3.0	1 - 7	0.35	55 (20 - 136)
Amaranth	3.5	5 - 7	0.22	65
Cassava	7.0	8 - 12	0.27	300
Temperate leafy & non-leafy				
Cabbage	1.9	<1	0.05	45
Carrot	0.7	12	0.05	6
Onion	0.9	0	0.05	10
Lettuce	1.0	1	0.08	7
Spinach	3.2	5	0.17	46
Tomato	0.9	0.6	0.04	20

Figure 2. Percent nutrient needs met by 100 g boiled sweet potato.

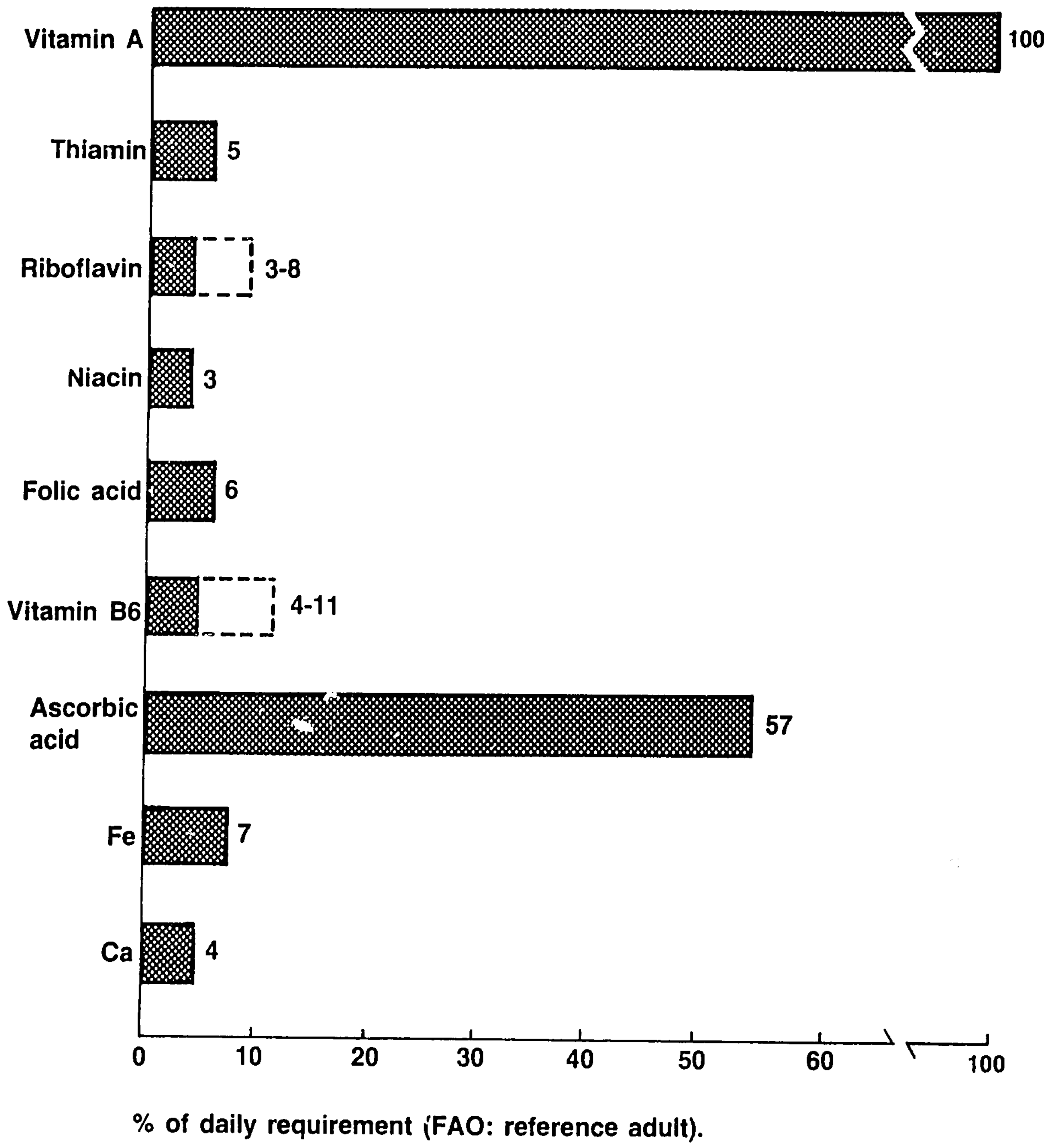


Figure 3. Approximate retentions of major vitamins after 3 months storage at temperatures above 10°C.

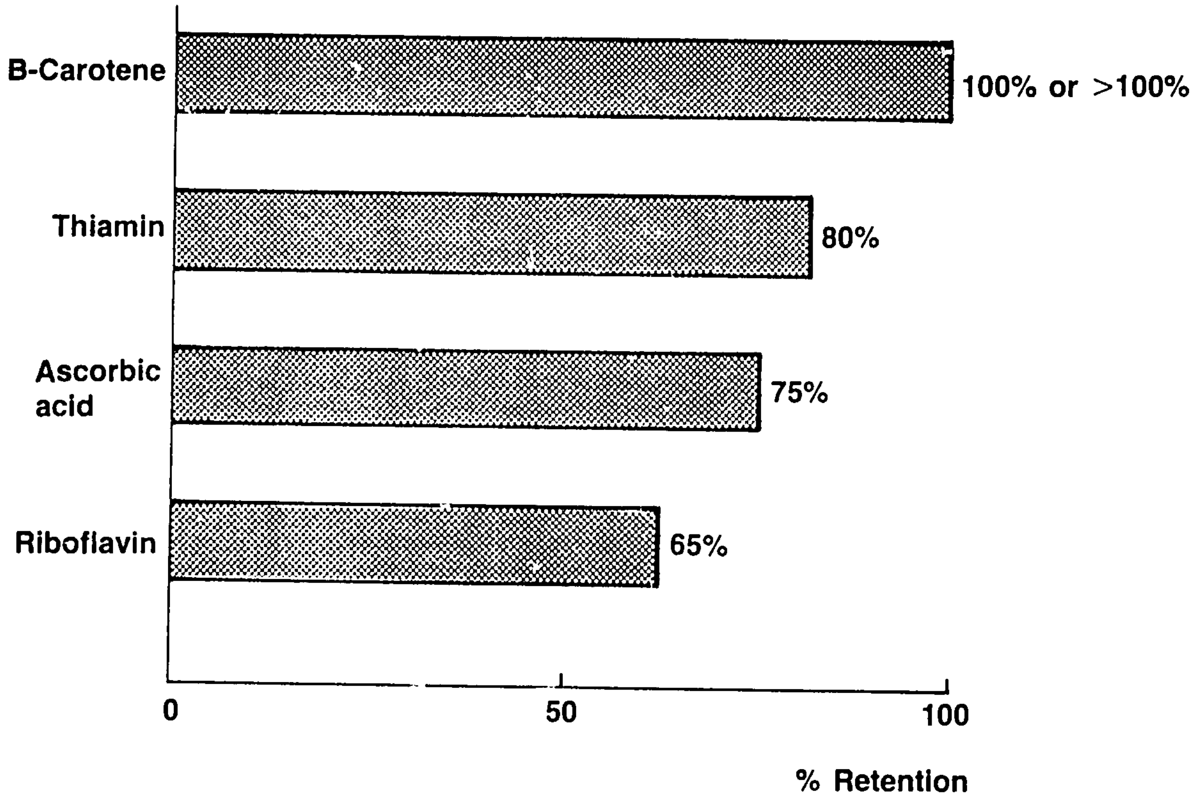
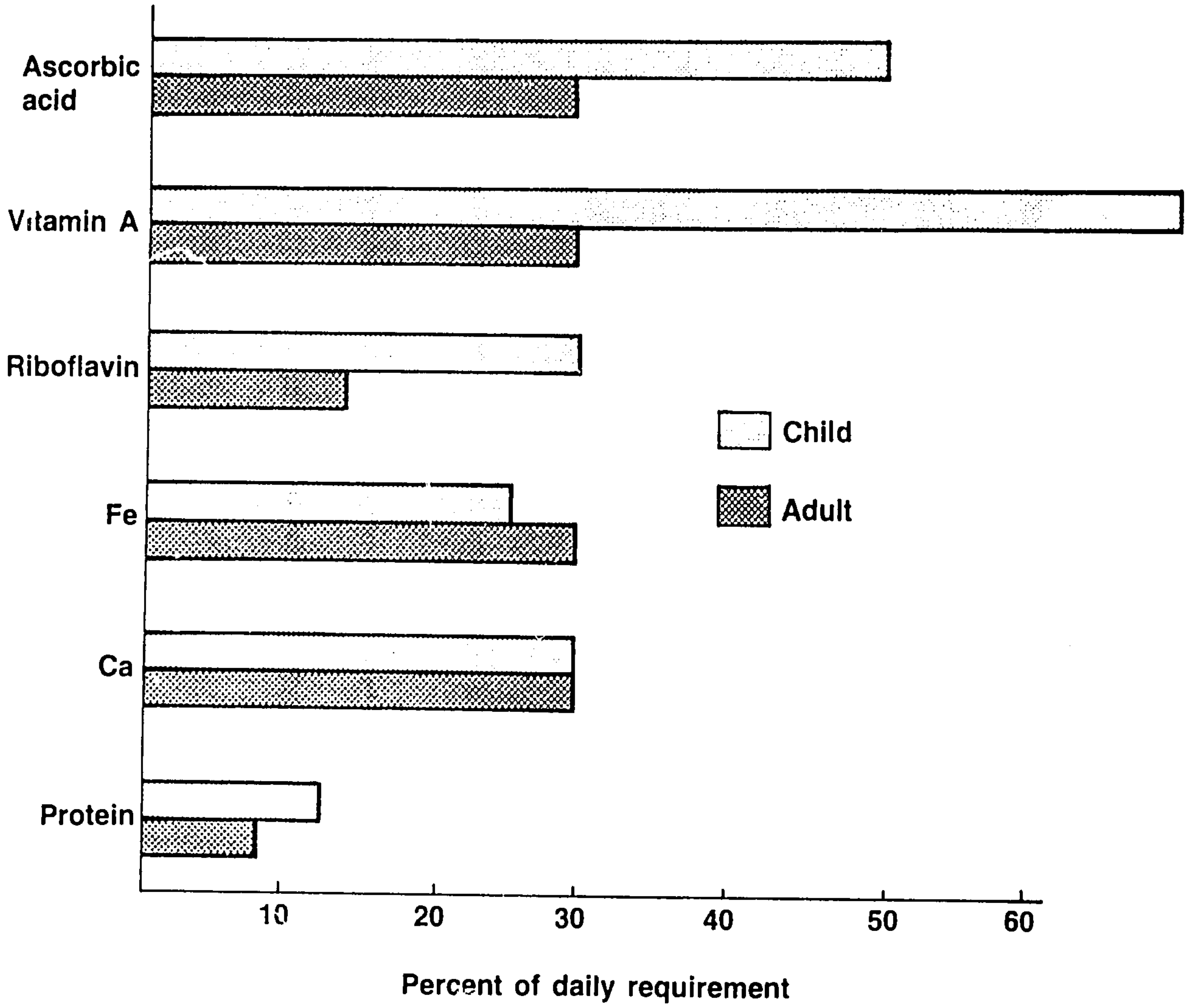


Table 9. Minerals and oxalate in leaves and other vegetables (per 100g)

Vegetable	Ca mg	Fe mg	Zn mg	Oxalate g
Tropical leaves				
Sweet potato	183	3.0	0.5	0.37
Amaranth	176	2.8		0.83
Cassava	160	2.4		0.52
Temperate leafy & non-leafy				
Spinach	93	3.1		0.73
Cabbage	44	0.4	0.3	0.003
Carrot	48	0.6	0.4	0.014
Onion	31	0.3	0.1	0.002
Lettuce	23	0.9	0.2	

Figure 4. Percent daily nutrient needs met by 85 g cooked sweet potato leaves.



Ascorbate may be very low in wilted, badly-cooked leaves.
Fe absorption may be less than 10%.
Ca availability may be reduced by oxalate content.

Table 10. Yields of sweet potato and other major crops

Crop	Average Tropical Yield t ha^{-1}	Days to Harvest	Average Yield kg ha^{-1} day^{-1}
Roots/Tubers			
Sweet potato	6.5	140	46.4
Cassava	8.7	330	26.4
Yam	7.0	280	25.0
Legumes			
Beans	0.6	120	5.0
Soybeans	1.3	100	13.0
Cereals			
Rice	2.0	140	14.3
Maize	1.2	130	9.2
Sorghum	0.8	110	7.3
Experimental Yields			
Sweet potato roots	30.0	140	214.3
Sweet potato leaves	13.0	120	108.3

Table 11. Number of people which one hectare can support per day in terms of major nutrients

Crop	Energy	Protein	Vitamin A	Ascorbic acid	Iron
Sweet potato roots (6.5 t/ha)	20	20	0 - 1856	387	30
(30 t/ha)	92	92	0 - 8565	1786	138
Leaves (13 t/ha)	23	93	542	1444	325
Roots + Leaves (14 t/ha + 13 t/ha)	63	63	542 - 4532	2276	390
Cassava	13	7	0	264	29
Beans	6	27	0	0	38
Soybeans	19	130	0	0	85
Rice	14	31	0	0	14
Maize	13	26	12	0	20

SWEET POTATO RESEARCH STRATEGY[1] AT THE INTERNATIONAL POTATO CENTER (CIP)

Peter Gregory, Masaru Iwanaga and Douglas Horton[2]

For decades, worldwide research on sweet potato has been seriously underfunded: in 1983, the sweet potato ranked only 19th among commodities supported by the CGIAR. Relative to the value of production, funding for sweet potato research was lower than that for any other commodity. But recent action by the Consultative Group for International Agricultural Research (CGIAR) - which supports 13 international agricultural research institutes, including the International Potato Center (CIP) - has helped to improve the situation. The Group recognized that funding was inadequate and encouraged CIP to make a major commitment to sweet potato research.

By 1993, sweet potato research will account for 40% of CIP's activities. This is a natural move for CIP, since many priority areas for sweet potato research are similar to those for potato. Both of these crops originated in Latin America and are asexually propagated. Thus, CIP's research experience and potato germplasm distribution and evaluation system also can be used for sweet potato. The goal is to build upon the years of research progress by institutions in developed and developing countries around the world, and by the International Institute of Tropical Agriculture (IITA), the International Board for Plant Genetic Resources (IBPGR), and the Asian Vegetable Research and Development Center (AVRDC).

Despite past inadequate funding, strong research accomplishments are reflected in proceedings such as those from an international sweet potato symposium held at AVRDC (AVRDC, 1982), another at Visayas State College of Agriculture (VISCA) in the Philippines (VISCA, 1987), and in of the seven symposia of the International Society for Tropical Root Crops (ISTRC) published between 1967 and 1987.

1. DETERMINING RESEARCH PRIORITIES

CIP's strategy has been to interact with sweet potato scientists from developing and developed countries and from IARC's to help determine research priorities. In February 1987, CIP's first planning conference on sweet potato research was held to determine priority global needs and to assess CIP's comparative advantages in exploration, maintenance and utilization of sweet potato genetic resources. The conference involved active participation

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1 This paper is based on Gregory, Iwanaga, and Horton (1989).

2 Director of Research, Geneticist, and Economist, respectively, International Potato Center (CIP), Apartado 5969, Lima, Peru.

of 18 invited scientists from developed and developing countries and from IITA and AVRDC. The conference and recommendations for action were published in a CIP report (CIP, 1987).

Further priorities were set during two sweet potato workshops: in Africa (CIP, 1988a) and in Latin American (CIP, 1988b). The objectives of these workshops were similar to today's, including (i) gathering knowledge, country by country, on production, marketing, utilization, and constraints affecting the crop; (ii) learning about existing research, training institutional frameworks, public versus private sector involvement and international collaboration; (iii) developing collaborative research and training workplans involving various country programs and CIP; and discussing the feasibility of creating country networks in which the comparative advantages of individual countries of a region are used to help others. Scientists from 7 African countries and Latin American participated, as well as scientists from CIP, IITA, CIAT and AVRDC.

During the Planning Conference and the two previous workshops, many issues were discussed in depth and numerous detailed recommendations and collaborative workplans were made. In each case, priorities reflected country needs, as expressed by scientists from the countries, and the comparative advantages of CIP versus other institutions around the world. Detailed discussions of all issues that arose, country by country, is beyond the scope of this paper, however, some of the highest priority issues are discussed below. Our current workshop will be invaluable in creating a more detailed picture of the Asian situation *per se*.

1.1 Socioeconomics

Participants noted the extreme scarcity of reliable, well analyzed information on patterns and trends in sweet potato production. Better information on who grows and consumes sweet potato, and on how and why they do so, is needed to set priorities for generating new potato production and post-harvest technologies. Information also is needed on the potential contribution of new technologies to expanding sweet potato production and use. Socioeconomic studies on several aspects of sweet potato production and utilization were recommended as a high priority. Since national research institutions have few social scientists with field-orientated diagnostic skills, it was recommended that initial studies should receive strong support from international agricultural research centers that have experience in this type of research.

1.2 Genetic Resources and Breeding

Genetic erosion is a major problem with sweet potato, as with many other crops. CIP is rapidly completing its collection of cultivated and wild sweet potatoes. This collection, which is being transferred to *in vitro* conditions, is already the largest collection in the world, with 1967 accessions of *Ipomoea batatas*, 814 wild *Ipomoea* accessions, and 359 breeding lines. National programs now should be strongly supported in their efforts to build up their own collections of wild and cultivated sweet potatoes and to characterize, evaluate, and maintain them. Such support is progressing well, as exemplified by CIP's sweet potato research contracts made recently in China with the Xuzhou Institute of Sweet Potato (XISP) and at the Guangdong Academy of Agricultural Sciences (GAAS). The contracts are designed to assist with evaluations of the sweet potato collections at XISP and GAAS, with emphasis on characters that are important in reducing production and utilization constraints in China. The collections are the largest in China, and both institutions have excellent track records in sweet potato research, including successful variety development. Xuzhou is in a temperate region, and GAAS is subtropical. In an integrated approach, XISP and GAAS are collaborating with more than a dozen other Chinese institutions in evaluating collections for a wide range of resistances to diseases and pests. They are also evaluating tolerances to environmental stresses, and quality factors related to processing and for agronomic characters. The ultimate goal is to utilize selected germplasm in the development of breeding materials for export through CIP's global network, and for China. In China and elsewhere, scientists are being encouraged to characterize and evaluate their collections for important agricultural traits using a new descriptor list developed by IBPGR and modified by CIP. Standardization will facilitate easier information exchange. Many materials in the CIP collection already have been characterized using this list.

To realize the enormous potential of sweet potato collections, further steps must be taken to minimize pathogen spread from one country to another. Regional tissue culture facilities for cleanup and redistribution should be established, and national programs should be helped to set up their own tissue culture facilities for maintaining and distributing the pathogen-tested germplasm. Identification of sweet potato viruses is an urgent need, as is the development of virus testing methods for use in cooperating countries. Action in this area should remove a major block to progress in sweet potato improvement. CIP, in collaboration with North Carolina State University, is giving strong emphasis to identification and detection of sweet potato viruses. A routine method is being sought that can be applied to a wide range of sweet potato genotypes for eradication of viruses. A position paper on sweet potato virus indexing published recently by Salazar and Moyer (1988) will serve as a useful guide in this crucial area of research.

In estabishing breeding priorities, the planning conference determined that CIP has a comparative advantage in exploiting its germplasm collection for improvement of various traits of global and/or regional importance, many of which have already been identified in the collection. These traits include agronomic characteristics such as yield potential, earliness, tolerances to several environmental stresses (including excess moisture, drought, heat, salt, shade and cold); resistances to pests (including weevils, stem borers and root-knot nematodes), resistances to viruses, and food quality and storage attributes. As with the virus research, CIP's breeding work is being complemented by a research contract with North Carolina State University.

National programs are being encouraged to provide CIP with information on varieties, climatic parameters, and abiotic stress factors. CIP will use this information in the development of methodologies for the evaluation of genetic material with tolerance to stresses such as cold, heat, excess water, drought, salinity, and low fertility. It was recommended that CIP develop methodologies to evaluate resistances to pathogenic fungi, insects and nematodes, particularly at the seedling stage. Adaptation of CIP's genetic material for long-day photoperiod conditions was suggested as an important issue, and it was recommended that CIP collaborate with national programs breeding better adapted materials for long-day areas.

1.3 Networks and Human Resource Development

All groups in the planning conference and the workshops indicated that training was an important part of each topic discussed. Training also was considered as a necessary complement to each research recommendation.

Similarly communications was seen as a crucial element for the overall success of sweet potato improvement. Efforts should be made initially to collect existing information on priority post-harvest issues. A systematic approach should be developed for disseminating updated research results to researchers and extensionists in national systems. It was recommended that a directory of sweet potato researchers, educators, and extensionists should be developed for the purpose of establishing linkages and for promoting the flow of information related to sweet potato improvement.

Efficient collaboration among scientists working on the same commodities in different countries has been important in global agricultural research: international agricultural research centers have played a key role in linking such scientists. Establishment of networks is particularly important for sweet potato researchers, who generally work in isolation. Very few countries can afford a comprehensive sweet potato research and development program. Networking can allow individual countries to concentrate on areas where they have a comparative advantage, and to share skills, research data and other information with their neighbors. Networks may be used to build cells of expertise in specific countries that provide regional services.

Asia, the present center of sweet potato production and utilization, has widely diverse languages; thus useful information is not widely distributed to scientists in other countries. For example, China has many sweet potato scientists involved in large research projects, but their experiences often are not known to other country scientists. Japan and Korea share this difficult problem.

Sweet potato's high productivity, even under sub-optimal conditions, offers great promise for more production in resource-poor African countries. The Asian and Latin American experiences should be extremely useful to African scientists. A global network is needed to link scientists of Latin America (the center of genetic diversity), to Asia (the center of present use), and Africa (the center of future use).

Some regional networks need to be reinforced. Dr. F. Martin has organized the Caribbean Sweet Potato Working Group, which includes persons interested in developing sweet potato agriculture, mainly in the Caribbean basin. AVRDC has interacted with many Asian countries for development of technologies and human resources. Similarly, IITA has been involved in helping African countries to solve problems in sweet potato production. The Australian government has assisted several South Pacific nations in developing the capability for germplasm exchange. The Southeast Asian Program for Potato Research and Development (SAPPRAD), which has successful activities in potatoes, has included sweet potatoes as an additional crop for the network's member countries. Canada's International Development Research Center (IDRC) has shown a strong interest in helping Asian countries improve root and tuber crop production and utilization, as demonstrated by their support for organizing the International Sweet Potato Symposium, held at VISCA, Philippines in May, 1987. A global network is urgently needed to link and fortify these regional activities, which now tend to be fragmented. Part of CIP's strategy is to help catalyse the formation of such a network.

2. CONCLUSION

New efforts are being made on a global scale to better realize the enormous global potential of sweet potato as a foodcrop, livestock feed, and raw material for industry. The of information and the greater exploitation of many previous advances made by national and local institutions around the world and by IARCs. We are on the right track. This workshop will help us to keep moving along it to better serve the ever increasing needs of the hungry and the poor in Asia and the rest of the developing world.

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RESEARCH ACTIVITIES IN CIP ON SWEET POTATO VIRUS DISEASES

L. F. Salazar[1]

Work on virus diseases of sweet potato has been considered among the priority projects in CIP research.

Sweet potatoes free of viruses are needed for commercial production, international exchange of germplasm and for research purposes. Previous Planning Conference and symposia on sweet potato reached a consensus on two overall objectives in virus research. First, sweet potato virus investigations should emphasize identification, detection, geographic distribution and importance of virus diseases. Secondly, every effort should be made to establish a standard set of guidelines based on current information for virus-testing of sweet potatoes.

1. STATUS OF THE RESEARCH ON VIRUSES AND VIRUS DISEASES

Many "virus" diseases have been described in the literature but the etiology of many of these diseases has not been determined. Some of the better know viruses are shown in Table 1. This table only attempts to simplify a complex situation and by no means can be taken as a definitive list of virus diseases in this crop species. The complexity of the knowledge on virus diseases seems to be caused by some of the following facts:

a. Many "virus" diseases have been reported but characterization of viruses was not done or was incomplete.

b. Tolerance to viruses appears to have improved production but it has made diagnosis difficult and in some areas resulted in an underestimation of the importance of virus diseases.

c. Many virus diseases are the result of synergistic action among viruses, notably between SPFMV and other agents. This is the case of SPVD which is caused by the synergistic interaction of a strain of SPFMV and the white-fly transmitted agent. Diseases similar to SPVD such as Georgia mosaic and yellow dwarf have been reported in U.S.A. And sweet potato veinclearing virus from Israel also induces symptoms similar to SPVD.

d. SPFMV is frequently isolated from naturally infected sweet potatoes, obscuring detection of associated viruses.

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e. On the identification of viruses in the past there has been no possibilities of using a standard set of sweet potato cultivars or indicator hosts. This precluded more direct comparisons between viruses isolated in different geographic areas and in some cases led to wrong identifications.

f. Due to an increased amount of phenolic compounds and other substances sweet potato is not an "easy" plant for virological studies.

Table 1. Virus diseases and viruses identified from sweet potatoes.

Virus or disease	Virus	Virus characteristics	Transmission	Distribution
Feathery Mottle, Virus A	SPFMV	Flexuous, 850 nm	Aphids non-persistent	Worldwide
Vein Mosaic	SPVMV	Flexuous	Aphids non-persistent	Argentina
Latent	SPLV (SPVN)	Flexuous	Unknown	Taiwan
Mild Mottle, Virus B, SPV-T	SPYDV	Flexuous	Mechanical? <u>Bemisia tabaci</u>	East Africa
Yellow Dwarf	SPYDV	Flexuous	White-flies	Taiwan
Caulimo like virus	SPCLV	Isometric	Unknown	Puerto Rico N. Zealand other
SPVD, Yellow dwarf? Georgia mosaic?		SPFMV + White-fly transmitted agent	Aphids + white-flies	Africa USA?

Conscious of all these, and other related problems, CIP encouraged and develop a collaborative work on identification of viruses and developed of methods of diagnosis rather than undertaking alone the enterprise. In the aspect a research contract with Dr. J. Moyer at the North Carolina State University, Raleigh, and the collaboration of Dr. A. Brunt, Glasshouse Crops Research Institute, Littlehampton, U.K. is giving excellent result. Collaborative arrangements have also been made with Prof. G. Loebenstein, The Volcani Research Institute, Israel, Mr. Cai Shaohua, Academy of Agricultural Sciences, Beijing, China, and Dr. C. Clark, Louisiana State University, Baton Rouge, L.A. New collaborative arrangements are being sought for other parts of the world.

1.1. Other Viruses Isolated from Sweet Potato

At least three viruses which have broad host ranges, such as tobacco mosaic virus (TMV), cucumber mosaic virus (CMV) and tobacco streak virus (TSV) have been isolated from sweet potato. Recently at CIP, sweet potato cv. Paramonguino was shown to be infected by sap inoculation with Potato spindle tuber viroid (PSTV), but no symptoms have been yet recorded.

1.2. Other Virus-like Diseases of Unknown Etiology

Many other symptoms resembling viral infection have been observed on sweet potatoes. Most of the times mosaics were the predominant symptoms.

Chlorotic leaf distortion (SPCLD) is another sweet potato disease of unknown etiology. It was recently described in Lousiana, U.S.A. (C. A. Clark, unpublished) and has been observed throughout the Southeastern United States. The diagnostic symptom of SPCLD is a bright chlorosis of the young leaves of affected plants. A viroid etiology for this disease is suspected.

1.3. Virus-testing of Sweet Potatoes

As a result of the First Planning Conference on sweet potatoes, held at CIP, Lima, Peru, February 23-27 1987, some guidelines for virus-testing of sweet potatoes were developed (J. W. Moyer and L. F. Salazar, submitted for publication). These guidelines were intended to serve as a framework that will accommodate current as well as future information that will facilitate testing of sweet potatoes for specific viruses. A flow chart of the procedure in use at CIP is shown in Fig. 1. Certainly, modifications might be required in the scheme as other viruses become identified. For instance, inoculation of sweet potato clone already infected with a mild strain of SPFMV.

Seed transmission of sweet potato viruses is a major concern. However, no virus infection has been confirmed as a result of seed transmission. This is one area of active research at CIP, meantime monitoring seedling closely for evidence of seed transmission is the best approach we can use.

1.4. Other Virus Research Activities at CIP

The identification of several viruses isolated from diseased sweet potato plants is one of the major activities in Virology. A large number of field isolates of SPFMV are being compared against known strains (common, russet crack and yellow vein), by means of serology, host ranges and symptoms, and nucleic acid relationships.

Probes for detecting SPFMV have been already prepared with the collaboration of Dr. R. Hammond and R. A. Owens at Beltsville, MD, U.S.A.

One of the most important lines of research in Virology is the search for resistance to SPFMV among CIP's germplasm collection. Several accessions have not been infected after 3 grafting attempts with SPFMV-infected scions. Final inoculation are underway.

2. CONCLUSIONS

We at CIP recognize that our ability to certify plants free of viruses is far from being complete. The problem is most severe where it involves the international exchange of germplasm because of the absence of mutually acceptable standards. Elucidation of etiology of more important virus diseases should receive the major emphasis, and this knowledge should be immediately used to develop appropriate methods of detection. At least we feel that knowledge on SPFMV is enough at present to undertake other studies aimed to control this disease such as searching for genetic resistance.

All this work, however, can be accelerated through international collaboration and therefore, we encourage the continuation of ongoing research and stimulate the initiation of new projects in this area.

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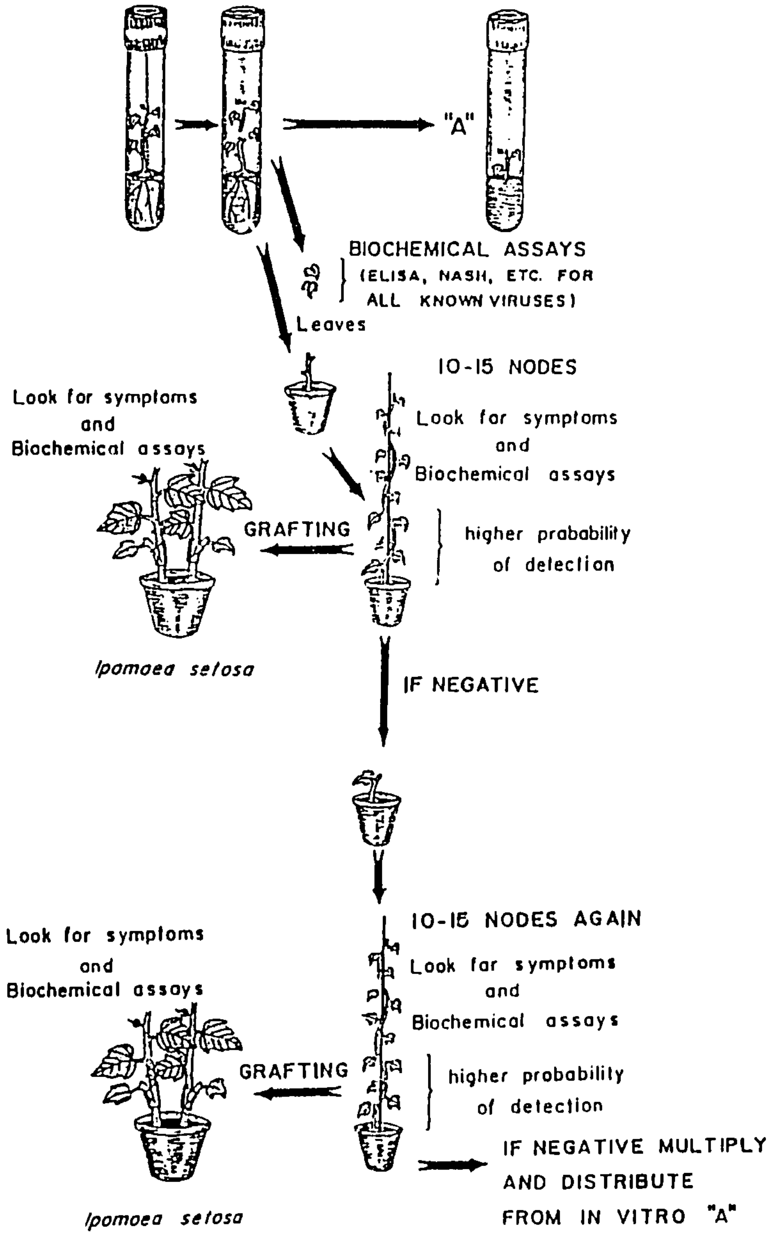
Fig. 1. INDEXING PROCEDURES FOR SWEET POTATO VIRUSES★



★ EFFECTIVE FEBRUARY 1988

IN VITRO SWEET POTATO GERMPLASM MANAGEMENT

By John H. Dodds

1. PROPAGATION

Sweet potato is normally field propagated by the use of stem cuttings, however under in vitro conditions a wide range of methods are available for micropropagation.

1.1 Propagation by Single Node Cuttings

Sweet potato germplasm can be introduced into in vitro culture in the form of a nodal cutting. When placed onto an appropriate culture medium the axillary bud is induced to grow and the result in the development of a new in vitro plantlet. It is important to note that this type of propagation involves the growth of an existing morphological structure, the axillary meristem. The hormone/nutrient conditions of the medium simply play a role in breaking the dormancy of the axillary bud and promoting its rapid growth. Several laboratories have developed media for single node propagation of sweet potato (1,2,3). Care must be exercised however that the culture conditions do not allow the formation of callus and subsequent de novo regeneration of plantlets, as will be shown in a later section this has been shown to affect the genetic stability of the genotype (4,5).

Most laboratories grow in vitro plantlets under long day (16 hrs light 3000 lux) conditions at 25-28°C. Under these conditions in vitro propagation rates are rapid and a single node cutting will have grown the full length of the culture tube and be ready for subculture after 6 weeks.

Several laboratories have shown that in vitro plantlets of sweet potato produced from single node cuttings can easily be transferred to non sterile conditions, for example transplant to jiffy pots, and in some cases plantlets have been transplanted directly to the field.

1.2 Propagation in Liquid Culture (Stem Segments)

From experience gained with other crops, especially potato, it is known that under certain conditions the speed and labour requirements for propagation by single node cuttings limit the potential production. As in potato, it is possible to micropropagate sweet potato in flasks (250 cm^3) containing liquid culture medium. Whole stem segments 5 to 8 nodes long are prepared by removing the apical tip and roots. This stem segment is then inoculated into the flask so as to be bathed by the culture medium. The liquid medium contains gibberellic acid to break the dormancy of all the axillary buds along the length of the stem segment. Shoots develop from this and in 3-4 weeks the flask is full of vigorously growing sweet potato shoots, (6). The flasks containing shoots can be a source of plant material either for preparation of single node cuttings of stem segments depending on the needs or the program.

1.3 Propagation by Plantlet Regeneration

The sweet potato is developmentally a highly "plastic" plant. It has been possible to regenerate *de novo* in vitro plantlets from almost all plant parts when placed into culture. Several scientists have been able to successfully regenerate plantlets of sweet potato from cultured stems, petioles, roots and leaf discs, (7). In all cases the first step is the formation of callus at the cut surface, the size and type of callus varies between treatments and genotypes. When given an appropriate hormonal stimulus it is possible to induce the *de novo* formation of meristems within these calli which then eventually form a regenerating plantlet.

A number of disadvantages exist to using this method as a standard propagation method. Firstly the labour involved in dissecting off these individual plantlets would make the method cost ineffective within a production program. Secondly, callus derived plantlets are likely to have undergone minor or major genetic aberrations during the callus stage, (8) thus, the regenerated plantlets would not be genetically the same as the original genotype. In a clonally propagated crop these types of genetic changes would probably be unacceptable to the producer or program.

1.4 Somatic Embryogenesis

Plantlet regeneration *de novo* can take place through two possible routes, organogenesis, that is direct organ formation as described in the preceding section or by embryogenesis, the direct formation of embryos from somatic cells. The induction of somatic embryos has been reported in many plants (9). In a few cases somatic embryos are being encapsulated to form 'synthetic' or 'clonal' seeds.

Somatic embryogenesis has been reported in one genotype of sweet potato (10). However, to my knowledge no analysis has been made as to the genetic stability of these embryos.

Since they are also derived from a callus/cell suspension there is a high probability that the plantlets are not all genetically identical.

2. THE IMPORTANCE OF ANALYSIS OF GENETIC STABILITY IN IN VITRO PROPAGATION (AND CONSERVATION) PROGRAMS

This section of this review is equally important both to propagation and conservation. In a clonally propagated crop it is important to know that each propagule is 'true to type', even small modifications could accumulate in the crop from one generation to the next and may affect uniformity and yield. In the case of conservation of clonal germplasm a detailed analysis of genetic stability in culture is vital. Clonal germplasm storage involves the maintenance of specific gene combinations (genotypes). If a plantlet should come out of storage with a different gene combination to that which it entered with, then the validity of the storage method must be questioned.

Our ability to detect genetic changes during propagation and storage are however only as good as the detection methods available.

Many germplasm collections evaluate the stored genotypes routinely on the basis of morphological characters of the plantlets when grown under controlled conditions. If the plants show different morphological characters, ie. leaf form, tuber or storage root color change, then we know some genetic change has probably taken place. However, if the plants appear the same this does not mean that no change has occurred, it means we cannot detect it. For example a change in a virus resistance gene could not be detected on the basis of morphology.

A number of biochemical methods are currently used in both potato and sweet potato to study genetic stability, these being soluble protein patterns and isoenzyme analysis. Although these are highly effective methods for looking for variation in gene products they do not look for changes in the genes themselves. Novel methods such as restriction length polimorphism analysis is now being investigated as a more sensitive way of looking for genetic changes. It is important that major germplasm repositories and seed programs use the most sensitive methods available to determine the genetic fidelity of their storage and propagation systems. In the case of CIP, morphological, soluble protein and enzyme analysis is routinely performed on both potato and sweet potato collections. If and when a more sensitive restriction enzyme method for gene analysis becomes available its inclusion in CIP's routine methods should be considered.

3. IN VITRO CONSERVATION OF SWEET POTATO GERMPLASM

A number of clonal in vitro sweet potato collections exist in many national programs and international organizations (11,12). There are many advantages to placing vegetatively propagated germplasm in an in vitro rather than field maintained form and these have been described previously (13).

A number of techniques exist for in vitro conservation, each with certain advantages or drawbacks.

3.1 Limiting Growth Media

Many years of research has gone into the development of propagation media for sweet potato where the objective has been to optimice rapid in vitro growth. In the case of conservation the objective is to limit growth to a minimum while maintaining viability of the cultures. By this means it is possible to maximice the time between transfers (sub cultures) of the in vitro plantlets. At CIP, for example, in the case of potato in LTS (long term in vitro storage) transfers are needed only once per year by most clones and in some cases only once every three years.

Experiments to limit sweet potato growth in vitro, in our own and in other laboratories have depended on the use of hormonal growth retardants, ie. ABA (Abscisic acid), growth inhibitors ie. B995, CCC (chloro choline chloride), or osmotic regulators such as high sucrose concentrations or the addition of osmotic sugars such as mannitol or sorbitol (14). The difficulty with these types of studies is that different genotypes will react differently under these conditions. When a large germplasm collection has to be maintained in vitro the objective of the studies must be the development of a conservation medium that is widely applicable to a broad range of genotypes. Several storage media have been reported for sweet potato, however again it should be emphasized that storage media should not allow induction of callus that may lead to genetic aberrations.

3.2 Reduced Temperature Storage

The growth rate of in vitro plantlets can obviously be restricted by reducing the incubation temperature. The optimal growth temperature for sweet potato in vitro appears to be between 28-30°C. If the cultures are moved to a temperature of 8°C we have found that survival time is less than 1 month. The optimal reduced temperature for genotypes studied to date would appear to be 15°C, but this needs further confirmation. As in the case of other crops maintained in vitro, ie. cassava, potato, yams, etc., it is possible to apply both reduced temperatures and osmotic/hormonal growth retardants at the same time. At the present time I believe the use of osmotic stress and reduced temperature (5°C) to be the most realistic and cost effective way to maintain a large sweet potato germplasm collection.

4. CRYOPRESERVATION

In the last decade there has been much interest in the use of cryopreserving (-196°C) plant materials in liquid nitrogen as a way of conserving germplasm (15,16).

This type of cryo-conservation is used routinely for storing animal cells and bacteria. The situation with plants is however more complex. It has been possible to freeze and thaw in viable condition plant cells from many plants, however these single cells then pass through a callus to regenerate whole plants causing genetic aberrations. If intact plant structures such as meristems or embryos are frozen, their size (multicellular) leads to a problem of ice crystal formation within the tissue. Survival rates of frozen multicellular structures are low and little or no study has been made on the stability of the regenerated plant (with the exception of cassava). The concept of cryopreservation is one that would revolutionize plant germplasm storage and as such deserves more investigation. However, in the short to medium term I do not see this as a viable option to sweet potato clonal in vitro repositories.

5. PHYTOSANITARY STATUS OF SWEET POTATO GERMPLASM COLLECTIONS

The successful introduction of a sweet potato plant to in vitro culture would imply that the plantlet is probably free from bacterial, fungal and mycoplasma infections. The plantlets may still however be infected with viruses or viroid. The maintenance of the plantlets in vitro (rather than in the field) does, however, limit further viral degeneration of the collection that could result from cross contamination. It is therefore possible to enhance the phytosanitary status of a collection by in vitro introduction. It is also beneficial to virus/viroid eradication programs to already have the germplasm in in vitro. When germplasm is to undergo evaluation is in obviously optimal phytosanitary status is required.

6. MANAGEMENT OF SWEET POTATO IN VITRO GERMPLASM COLLECTIONS

The size of any given germplasm collection will vary and the problem of managing a collection of several thousand accessions are distinct from those with fifty accessions. However, with any in vitro germplasm collection care and consideration must be given to the following points: 1) How many replicates should be kept of each accession. 2) Should duplicate accessions be held by another institution. 3) What safeguards can be made against errors in data maintenance. 4) How often should the collection be checked. 5) Which accessions are the most valuable in case of emergency. In the case of CIP a computer data base is being established on the sweet potato collection. This should allow us (using the potato collection as a model) to maintain continual records of the in vitro collection and make the maximum amount of information and material available to developing country national programs. It should also facilitate inter-centre information flow on the status of any or all in vitro accessions.

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STRATEGIES TO DEVELOP SWEET POTATOES WITH WEEVIL RESISTANCE IN DEVELOPING COUNTRIES.

K.V. Raman [1]

1. INTRODUCTION

Sweet potato is an important vegetable crop in the tropics, sub-tropics and temperate regions. It is considered the sixth most important crop in the world, after wheat, rice, corn, potato and barley (Vietmeyer, 1986). However, about two-thirds of the world production is utilized in one country, China (Villareal, 1982). It is a low input crop that almost always yields, and can be harvested at almost anytime from four to six months after planting. It is versatile in its uses and highly nutritious. The storage roots are an important staple food and may also be processed for starch, glucose or alcohol, whilst vines and leaves are used as animal fodder. In some countries of Africa and Asia, shoot tips are consumed as a vegetable. Sweet potatoes do not store well and are usually harvested gradually, thereby contributing to associated pest problems.

Insect pests cause major losses to sweet potato production in developing countries; over 300 species of insects and mites infest sweet potato throughout the world (Talekar, 1988). The most serious insect pests are complex of weevils, commonly called "sweet potato weevil" which attack the storage roots. Losses due to sweet potato weevils usually range from 5-80% depending on the time during which the crop remains in the ground. Recently, the International Potato Center (CIP), in collaboration with national programs of Latin America and Africa have identified research priorities for sweet potato improvement and utilization. Details of the recommendations made in these various workshops and planning conferences are reported in CIP 1987, 1988a and 1988b. At the end of these workshops the sweet potato weevil complex was identified as a major constraint to sweet potato production in developing countries, thus the development of integrated pest management (IPM) for this pest should receive high priority.

2. MAJOR SWEET POTATO WEEVIL SPECIES, DISTRIBUTION, BIOLOGY AND DAMAGE

Sweet potato weevils appear to be the most destructive pest of sweet potato throughout the tropics and sub-tropics, and in several areas they are the major limiting factor in successful sweet potato cultivation. Their damage is especially significant because they attack the storage roots directly and even slight damage by these pests make them unfit for human consumption due to an off-flavor and the presence of insects. Several weevil *formicarius* (F.), *Cylas formicarius elegantulus* (Summers), *Cylas puncticollis* (Boh.) and *Euscepes postfasciatus* (Fairmaire) (Coleoptera:Curculionidae), are significant in terms of their damage over wider areas. Despite their taxonomic differences, the mode of infestation and nature of damage by these pests are quite similar. Hence control measures devised to combat them are also practically identical. Details on the biology of these four weevil species has been reviewed by Talekar (1988). The damage caused by *E. postfasciatus* and *Cylas* spp. is similar. Adults feed externally on the vines or roots, mostly on roots. Damaged roots have a few small pits and numerous

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holes in which several weevil adults feed. The larvae bore down into the roots or stems from the oviposition site. The insect grows in winding tunnels which are packed behind solidly with frass or feces. A characteristic terpene odor, similar to the one caused by C. formicarius is also found in E. postfasciatus damaged tissues. Damaged vines darken from normal green to brown or black and damaged main stem becomes swollen, malformed and cracked. C. formicarius formicarius is distributed mainly in Asia, Africa and the Pacific. C. formicarius elegantulus is found in North and Central America, the Caribbean islands and Hawaii. On Okinawa island in Japan, both subspecies of C. formicarius occur (Messenger, 1954). Recent report indicates that C. formicarius elegantulus also occurs in Philippines (Bernardo and Esguera, 1984). In both cases, the insect appears to have been introduced from outside, most likely Hawaii. C. puncticollis is confined to several countries in Africa only. E. postfasciatus is reported to occur in the Caribbean, Hawaii, Fiji, Tonga, Okinawa island in Japan, New Zealand and Peru. Details on the geographic distribution of these four major sweet potato weevil species has been reported elsewhere (Talekar, 1988). Figure 1 summarizes the worldwide distribution of the sweet potato weevil complex. Apart from these four main species, several other weevil species are known to occur. The exact number of species of Cylas attacking sweet potato and their distribution in developing countries and pest status remains to be determined.

GEOGRAPHIC DISTRIBUTION OF SWEET POTATO WEEVIL SPECIES

Cylas puncticollis

1. Kenya
2. Nigeria
3. Senegal
4. Uganda
5. Zaire
6. Cameroon
7. Zimbabwe
8. Cape Verde island
9. Chad
10. Congo
11. Guinea
12. Malawi
13. Mozambique
14. Sierra Leone
15. Somalia
16. Sudan
17. Tanzania

Euscepes postfasciatus

18. Japan
19. Tonga
20. Fiji
21. Carolines Islands
22. Peru
23. Antigua
24. Barbados
25. Bermuda
26. Guadeloupe
27. Dominican Republic
28. Jamaica
29. Puerto Rico
30. Virgin Islands
31. Brazil
32. Surinam
33. Hawaii
34. Granada
35. St. Kitts
36. Papua New Guinea
37. New Zealand

Cylas formicarius elegantulus

38. Japan
39. Australia
40. U. S. A.
41. Barbados
42. Cuba
43. Haiti
44. Dominican Republic
45. Guyana
46. Jamaica
47. Hawaii
48. Puerto Rico
49. Mexico
50. Venezuela

Cylas formicarius formicarius

51. Fiji
52. Australia
53. Solomon Island
54. Tahiti
55. Guam
56. Papua New Guinea
57. Madagascar
58. Mauritius
59. Seychelles Islands
60. India
61. Bangladesh
62. Sri Lanka
63. China
64. Philippines
65. Indonesia

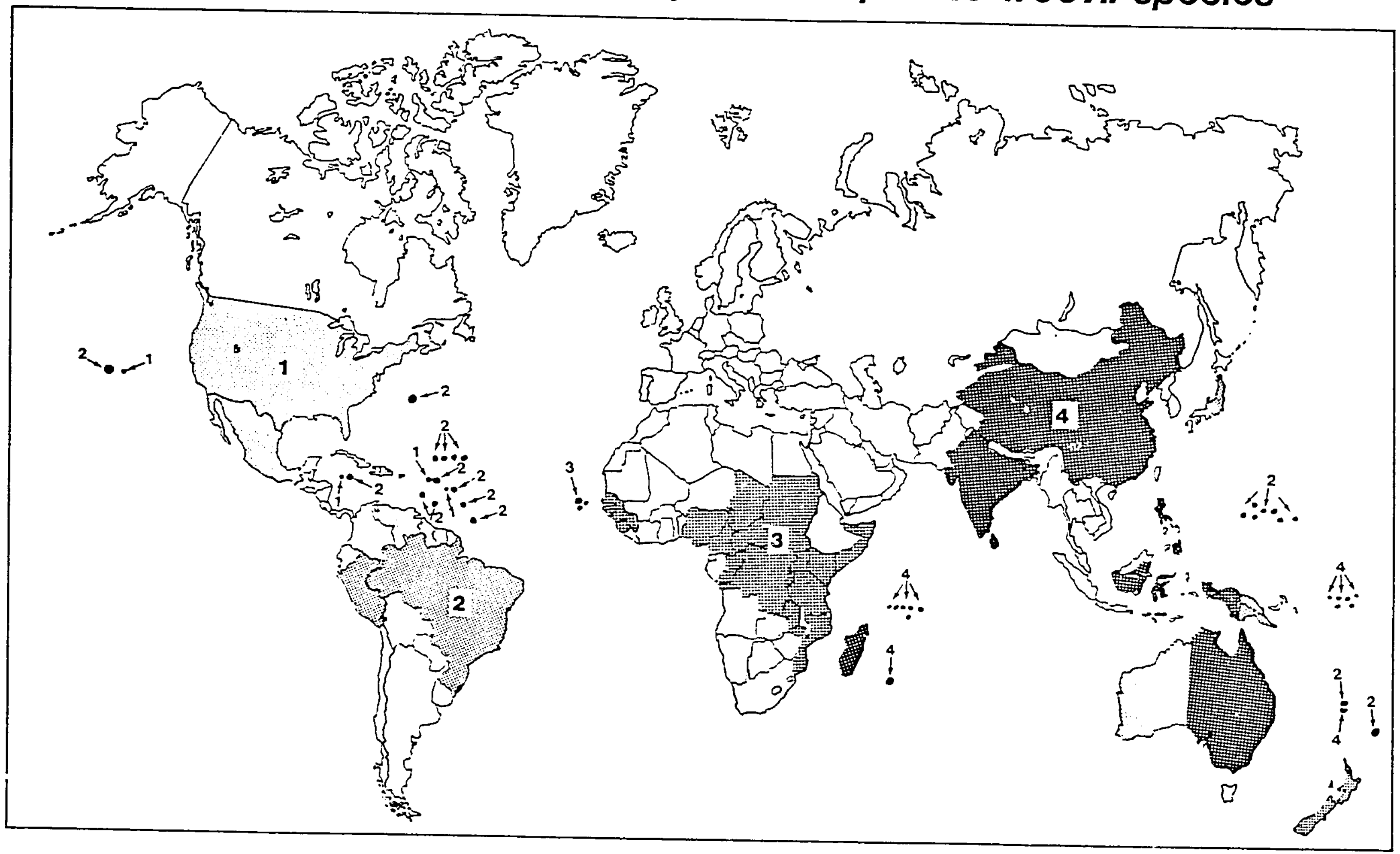
3. HOST PLANT RESISTANCE (HPR)

Collins (1988) has dealt in detail current research programs devoted to HPR research. In the U.S.A., screening for resistance to C. formicarius elegantulus has been conducted in Charleston, South Carolina, Florida and Mayaguez, Puerto Rico. After several years of research in Puerto Rico, low levels of resistance were identified and screening for identification for weevil resistance was thought to be difficult. In South Carolina, after nearly five years of research, two resistant cultivars, Resisto and Regal were identified. Their resistance lasted for four years, but recently in Florida, these cultivars were found to be susceptible when challenged to very high weevil population. In Georgia, currently there is a research program to identify chemical factors responsible in weevil resistance. In the U.S., at present no breeding program exists for developing varieties resistant to sweet potato weevil. The Asian Vegetable Research Development Center (AVRDC) located in Taiwan, the College of Agriculture (VISCA) in Philippines and the Central Tuber Crops Research Institute (CTCRI) in India have been conducting screening for resistance to C. formicariu formicarius. At AVRDC, screening of sweet potato germplasm for resistance has been done continuously since 1974. By the end of 1987 the entire germplasm of AVRDC consisting of 1,200 accessions were screened and no usable level of resistance was found in this population. Progeny of crosses between I. batatas and I. trifida has shown considerable reduction in damage. More research is now underway using this population. At VISCA, low levels of resistance have been encountered after several field and laboratory tests. A polycross scheme using these clones to increase the levels of resistance is being investigated. CTCRI has screened nearly 127 genotypes. After several tests, two clones, a pentaploid 5x45 and a germplasm entry S3 were found moderately resistant. The International Institute of Tropical Agriculture (IITA) located in Nigeria concentrated research on resistance identification and utilization with the African weevil C. puncticollis. Clones TIS 2534, TIS 3017, TIS 3030, TIS 3053 were identified and used in breeding program. At CIP, Lima, Peru, resistance identification to E. postfasciatus began in 1986. Nearly 1,000 clones have been screened using the closed container test and several clones have been identified with high levels of antibiosis. These clones are now being field tested in farmers' fields. Presently, no breeding is conducted for developing resistant varieties to this pest.

4. STRATEGY TO DEVELOP SWEET POTATOES FOR RESISTANCE TO SWEET POTATO WEEVIL

Currently screening for resistance to sweet potato weevil is based on field screening using natural weevil populations or with boosted infestation where laboratory reared weevil populations are released in field. Both these methods are quite expensive. In the case when natural weevil populations are used, the infestations may fail to develop to desired magnitude owing to absence of pest or impact of environmental mortality factors. When boosted infestations are used, moderately resistant clones may loose their resistance and be evaluated as susceptible. Under laboratory conditions, various techniques have been used, and in most cases it is difficult to compare results between countries as tests were not standardized. The problem of screening is further complicated due to the regional occurrence of different weevil species. Current resistance evaluation in Asia, Africa and U.S. has been with a very limited number of accessions; the germplasm collected at CIP has not yet been evaluated to any of the Cylas spp. Based on my personal experience, the following strategy is recommended for developing sweet potato cultivars with resistance to sweet potato weevil.

Geographic distribution of major sweet potato weevil species



1 Cylas formicarius elegantulus

2 Euscepes postfasciatus

3 Cylas puncticollis

4 Cylas formicarius formicarius

4.1 Development of a database

A data base on sweet potato weevil, with emphasis on germplasm identified for resistance in developing countries; screening methods used in laboratory, field or store; species used for resistance identification; mechanisms of resistance; environmental factors affecting resistance; research personnel available for resistance studies needs to be compiled.

4.2 Collection of germplasm

Sweet potato germplasm with some level of resistance to Cylas spp. and E. postfasciatus has been identified in the Caribbean, U.S., South America (Peru), Philippines, China, India and Nigeria. An international effort should be made to collect all reported sources of resistance. This germplasm should then be evaluated systematically (see Figure 2) for international cooperation in developing sweet potato cultivars for resistance to sweet potato weevils. The approach suggested here in Figure 2 could be modified to include countries such as Dominican Republic in Caribbean, with both Cylas and Euscepes. The germplasm currently maintained at CIP needs to be screened for resistance to Cylas spp.

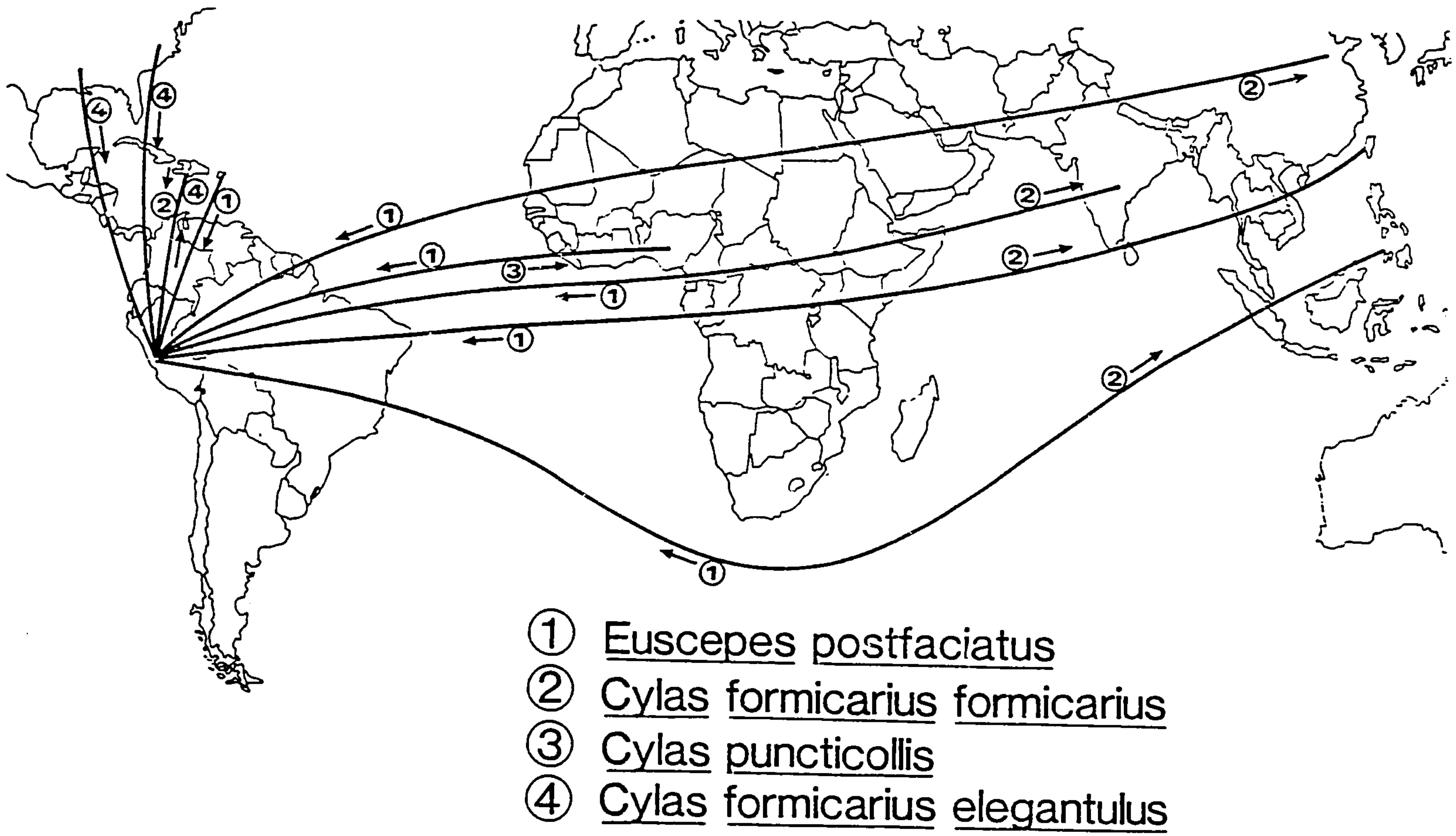
4.3 Weevil species and germplasm evaluation

As stated earlier, present knowledge worldwide indicates that there are four main weevil species. The CIP world collection could be effectively evaluated for the species occurring in South America and Caribbean, E. postfasciatus. The accessions identified from this collection after repeated lab and field tests should be tested in regions where Cylas spp. are important. Correlations on resistance identified in Peru for E. postfasciatus with resistances to Cylas spp. occurring in Asia and Africa should be an important research priority. Also, existing germplasm for resistance to C. puncticollis in Africa; C. formicarius formicarius in Asia and E. postfasciatus in South America needs to be evaluated using standardized techniques so that results can be compared between countries.

4.4 Screening methods

Biology and damage of the four main weevil species are quite similar. It should therefore, be possible to develop screening methods which are applicable to all the four species. When dealing with thousands of progenies, a laboratory test should be used to rapidly and systematically discard the susceptibles. The promising selections identified in laboratory should be multiplied and then tested in field (see Raman, 1988; and Talekar, 1982, for laboratory and field testing procedures). Other resistance contributing factors eg. high latex varieties in farmers' fields are less damaged (G. Watson & M. Potts, Personal Communication, Indonesia). Similarly researchers at University of Georgia, U.S., have found chemical ovipositional stimulants. Such characters might aid in rapid selection if further correlations could be established with resistance to weevils. More research along these lines is justified. Other mechanisms as escape through early maturity, deep rooting, and high dry matter should be further investigated.

International Collaboration in Testing for Sweet Potato Weevil Resistance



4.5 Utilization of resistance

At the present time no breeding is being done to incorporate resistance to *E. postfasciatus*. Some research has been done with *Cylas* spp. where in both antibiosis and non-preference resistance mechanisms have been transferred (see Collins, 1988). An interdisciplinary team comprising at least of an entomologist and breeder should be enlisted if extensive effort is going to be placed on developing varieties with resistance to weevils. It appears that only low or moderate levels of resistance are available and such resistance is usually lost when high weevil populations occur in field. Collins (1988) mentions strategies on how resistance levels could be increased through breeding. Both short and long term strategies have been recommended. It is very likely that only moderate or even low levels of resistance may occur in the germplasm. Such resistance would be a very essential component in the development of a total integrated pest management (IPM) program for these pests worldwide.

5. CONCLUSIONS

From earlier reported work, it appears that even after several years of research, no consistent sources of resistance to weevils has been obtained. An international effort to screen additional germplasm to identify even moderate levels of resistance for inclusion in an IPM program for weevil control is highly justified. More research is needed in developing standardized techniques for screening in field and lab. Some of the useful characters namely early maturity, high dry matter, which breeders are interested in sweet potato improvement, should be carefully evaluated. Resistance alone may not solve the problem of this pest, and should be considered as one of the important components in IPM development.

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IMPORTANT NEMATODE PARASITES OF SWEET POTATOES AND THEIR MANAGEMENT

P. Jatala

Sweet potato is considered as one of the most important food crops produced by many countries. However, it is generally grown in smaller volumes in more developing countries than any other root crop (1). Even though sweet potato is a native of tropical America and widely cultivated in tropical and warm temperate regions, China produces the largest percentage of this crop. Although in the diverse habitats of sweet potato production a large number of important plant parasitic nematodes affect a diversity of plants, food and fiber crops, only a few are of major importance to sweet potato production. Following is a brief description of the most important nematodes of sweet potatoes, their habitat and methods of control:

1. ROOT-KNOT NEMATODES (*MELOIDOGYNE* SP.)

On the global scale, the most important nematode species attacking sweet potato is *Meloidogyne incognita* which occurs in the areas where sweet potato is well adapted for cultivation. This nematode seems to do well in light, friable soils such as sandy loams which happens to predominate and constitute the major portion of the world's sweet potato growing area. *M. incognita* requires a warm temperature for completion of its life cycle and on sweet potatoes generally undergoes 4 to 5 generations per growing season (4). Therefore, it is capable of increasing its population to a level of economic importance in a rather short period (2). *Meloidogyne hapla* also attacks this crop, but its distribution is limited to the cooler temperate regions of the world. Therefore, the economic loss due to this nematode is rather restricted and not of major concern. Although *M. javanica* attacks the roots system of sweet potatoes quite readily, it cannot complete its live cycle on this crop (2).

Therefore, if the initial soil population is high, they cause a pruning effect which will be overcome by the vigorous growth and excessive lateral root production. Root-knot nematodes in addition to exerting a direct pressure on the root system, such as the root pruning effect, galling and root necrosis and splitting of the storage roots, they play an important role in production of disease complexes. *M. incognita* interacts with *Fusarium* sp. and causes severe wilting and premature plant death. Although there are cultivars resistant to *Fusarium* species, their resistance will be broken in the presence of *M. incognita*. Therefore, it is of outmost importance to either search for dual resistance or incorporate the resistance to these two organisms. Many cultivars developed in the USA and Japan carry various degrees of resistance to root-knot nematodes.

In the United States the major emphasis in developing *Meloidogyne* resistant cultivars was initiated in 1953 at the Oklahoma State University and Louisiana State University and many resistant cultivars were developed by 1985. Similar efforts were made by the breeders in Japan and as a result, the number of resistant clones or cultivars are significant. Studies showed that several clones of the CIP germplasm collection from Peru also have resistance to M. incognita. Distribution of resistance in some of the germplasm collected from various Peruvian geographical departments is given in Table 1. Data indicate that 2.5% of the clones from 7 Departments were highly resistant, and with the largest number of highly resistant clones originated from the Department of Lima. The same proportion of resistant clones was found from the same Department. Although the number of resistant clones originating from each Department varied, 21.4% of the total evaluated clones were found to be resistant (3). Data on the reaction of some CIP sweet potato germplasm collection obtained from various parts of the world is given in Table 2. The frequency of resistant clones from Peru and the United States was high and the clones from Peru constitutes the largest portion of resistant material available in the CIP germplasm collection. This high percentage of resistant material is due to the breeding efforts as well as selection pressure exerted by farmers throughout the past centuries.

The above information indicates that utilization of the available resistant cultivars in developing progenies with resistance to Meloidogyne incognita and perhaps to other important plant pathogens should not constitute difficulties, and development of multiple resistant progenies should receive high priority.

2. ROTYLENCHULUS RENIFORMIS

Another nematode of major importance is Rotylenchulus reniformis which is rather widely distributed in the warm tropical regions of the world. This nematode also interacts with Fusarium species in development of disease complexes and can become a limiting factor to sweet potato cultivation. Limited information is available on the resistance of sweet potatoes to R. reniformis. Unless the global importance of this nematode on sweet potatoes is well established, screening and breeding for resistance to this nematode should be on a limited scale.

3. PRATYLENCHUS SPECIES

Pratylenchus species also attack sweet potatoes and are widely distributed in the warm tropical regions of the world. Like root-knot nematodes, these parasites attack a large number of plant species, restricting the use of rotation crops in the cropping system. They also interact with other plant pathogens in development of disease complexes. Little is known about the resistance of sweet potato to these nematodes. The wide distribution of the species of this nematode in the tropics where the sweet potatoes are grown makes it imperative to search and develop resistance to these nematodes.

4. DITYLENCHUS DESTRUCTOR

Potato rot nematode Ditylenchus destructor may also attack sweet potatoes. Data indicate that in China this nematode can become a limiting factor to sweet potato production. (Personal communication, Dr. Song Bo Fu). Information regarding the action of this nematode on sweet potatoes is not readily available and studies are warranted to investigate the role of this nematode in damaging sweet potatoes.

The edible roots of sweet potatoes can serve as reservoir for the above mentioned nematodes and can be a source of nematodes spread to non-infested areas. Results of potato tuber treatment indicate that the nematodes within tubers can be killed by chemical dips immediately after harvest (5). Similar tests need to be conducted for sweet potatoes to determine the efficiency of such treatments in eliminating nematodes from the storage roots.

So far, in addition to limited available resistant cultivars, the major effort for controlling nematodes has been placed on the use of nematicides. However, recent development in the field of biological control indicate the possibility of using this method of control. Integration of cultural practices, together with the use of chemicals, resistance and biological entities in an appropriate management system should be considered in strategies for the control of nematodes on sweet potatoes.

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Table 1. Reaction of some Peruvian Sweet Potatoes Germplasm to *Meloidogyne incognita*

Department	Reaction to *M. incognita**				
	Highly resistant	Resistant	Moderately resistant	Susceptible	Total
Ancash	1	15	16	52	84
Arequipa	1	2	4	10	17
Cajamarca	1	16	17	53	87
Huanuco	1	4	7	20	32
Ica	4	19	8	8	38
Lima	4	26	22	58	110
Piura	-	2	6	26	34
Others[1]	3	29	15	84	131
Total	14	113	95	311	533
Percent	2.6	21.2	17.8	58.4	100

* Ayacucho, Amazonas, Cuzco, Lambayeque, La Libertad, Loreto, Puno, Tacna, Tumbes

Table 2. Reaction of some CIP Sweet Potato Germplasm to *Meloidogyne incognita*

Origin	Reaction				
	Highly resistant	Resistant	Moderately resistant	Susceptible	Total
Brazil	-	2	3	-	5
Peru	27	200	53	920	1200
S. Africa	1	1	-	-	2
USA	-	14	-	13	27
Venezuela	-	-	-	2	2
Others*	-	2	-	7	9
TOTAL	28	219	56	942	1245
Percent	2.2	17.6	4.5	75.7	100

*Argentina, Australia, Bolivia, Chile, Ecuador, Japan, Mexico, Puerto Rico and Taiwan

CONSTRAINTS TO SWEET POTATO PRODUCTION AND USE

Douglas Horton

As CIP initiates its research on sweet potato, four mechanisms are being used to gather information on constraints to sweet potato production and use: literature review, workshops and planning conferences, questionnaire surveys, and field studies. Questionnaire surveys have been used in two settings. Questionnaires have been mailed out to sweet potato experts in Asia, Africa, and Latin America. Questionnaires have also been filled out by participants of sweet potato workshops and planning conferences. In the future we plan to have participants in all CIP's sweet potato training activities fill out questionnaires as a standard procedure. Training courses can be excellent venues for obtaining information and the perceptions of national researchers.

To date, five sweet potato workshops and planning conferences have been held:

- International Planning Conference, Peru (Feb., 1987)
- Asian Symposium, Philippines (May, 1987)
- Latin American Workshop, Peru (June, 1987)
- African Workshop, Kenya (Oct. 1987)
- Asian Workshop, India (Oct. 1988)

Country representatives at the Trivandrum workshop provided information on 39 production zones within 12 countries: Bangladesh, China, India, Indonesia, Korea, Laos, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand, Vietnam.

The questionnaire used contained 43 questions grouped under 10 headings. For each question, the respondent was asked to indicate how important each constraint was, on a scale from 0 to 3:

0 = not present
1 = of little practical importance
2 = somewhat important
3 = very important

In general, respondents believe that post-harvest and marketing problems are more serious that pre-planting or field production problems (Figure 1 and Table 1). This is particularly interesting in light of the fact that most participants were breeders or production specialists; very few post-harvest specialists or marketing people were present at the workshop. Marketing was considered the most important constraint to sweet potato production and use. Among the field production problems, two aspects were emphasized: insects (weevil and stem borers), environmental problems (drought, poor soil fertility and soil structure).

In descending order of magnitude, the most important specific constraints were: unstable supplies and prices (with and average score of 2.4), lack of processed products (2.0), weevil (Cylas) (1.9), poor storage design (1.8), transport problems (1.8), drought (1.8), low soil fertility (1.7), and high marketing costs (1.5) (Table 2).

Some imitations of the survey should be noted. First, the results reflect researchers' perceptions rather than farmers' perceptions or information gathered through field visits. Second, standard deviations are high relative to the average scores. This may reflect that constraints to sweet potato production and use vary greatly among locations, or that information provided by reseaichers is not very accurate.

The two logical next steps in our work on constraints are to group responses according to agro-ecological zones and production systems, and to carry out field studies that complement researchers' perceptions with the views of producers, market intermediaries, and consumers and with direct observations and measurements.

Irrespective of the present study's limitations, the data provided by Asian sweet potato researchers offer much food for thought and several hypotheses for further study.

Figure 1. Sweet Potato Constraints

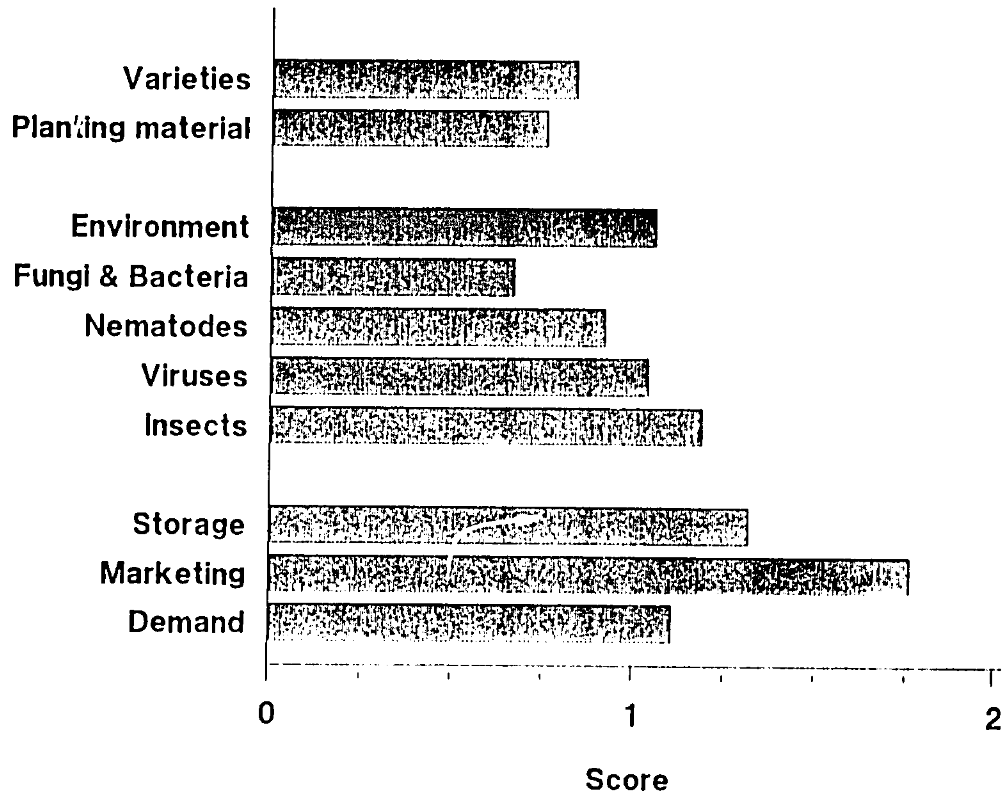

Table 1. Constraints to sweet potato production and use
Trivandrum Workshop.
No. Surveys = 13
No. Zones = 39

	No. Obs	Average	Standard Deviation
A. Pre-planting Problems:			
1. Inadequate varieties	116	0,84	1,05
2. Poor supply of planting material	121	0,76	0,80
B. Field Production Problems:			
3. Fungal and bacterial diseases	79	0,67	0,69
4. Nematodes	26	0,92	0,69
5. Virus diseases	27	1,04	0,52
6. Environmental problems	328	1,06	0,88
7. Insects	96	1,19	1,15
C. Post-harvest Problems:			
8. Storage	220	1,32	0,83
9. Marketing problems	125	1,76	0,96
10. Limited consumer demand	231	1,11	1,01

Table 2. Constraints to sweet potato production and use Trivandrum Workshop.
No. Surveys = 13
No. Zones = 39

	No. Obs	Average	Standard Deviation
A. Pre-planting Problems:			
1. Inadequate varieties:			
a. Not suited for livestock feeding?	31	0,42	0,67
b. Too late maturing?	27	0,56	0,97
c. Not suited for processing?	22	0,82	1,05
d. Poor market/consumer acceptance?	36	1,44	1,13
2. Poor supply of planting material:			
a. Scarcity?	35	0,94	0,91
b. Poor health?	32	0,81	0,82
c. Poor physiological condition?	28	0,68	0,61
d. High cost?	26	0,54	0,76
B. Field Production Problems:			
1. Fungal and bacterial diseases:			
a. *Erwinia*?	21	0,43	0,51
b. *Fusarium* wilt?	26	0,73	0,78
c. Scab (*Elsinoe*-*Sphaceloma*)?	32	0,78	0,71
2. Nematodes:			
a. Root-knot (*Meloidogyne* spp.)?	26	0,92	0,69
3. Virus diseases	27	1,04	0,52
4. Environmental problems:			
a. Low soil pH?	32	1,03	0,93
b. Aluminium toxicity?	15	1,13	0,52
c. Low soil fertility?	39	1,67	0,90
d. Drought?	34	1,74	0,86
e. Poor soil structure?	25	1,28	0,84
f. Weeds?	38	1,11	0,69
g. Excess soil moisture?	32	0,84	0,72
h. Low light energy (cloudiness)?	33	0,76	0,79
i. Soil salinity?	29	0,66	0,72
j. Cold, frost, or hail?	31	0,65	0,84
k. Heat?	20	0,40	0,50

5. Insects:			
a. Weevil (Euscepes)	15	0,33	0,72
b. Diabrotica?	16	0,50	0,52
c. Stem borers?	27	1,07	0,92
d. Weevil (Cylas)?	38	1,89	1,23
C. Post-harvest Problems:			
1. Consumer demand is limited by:			
a. Lack of processed products?	34	2,00	1,02
b. Lack of variety with good processing?	32	1,31	1,03
c. Lack of a variety with good eating quality?	36	1,06	0,89
d. Sweet potato not in traditional diet?	35	0,94	1,00
e. People don't like to eat sweet potato?	32	0,94	0,76
f. Price too high?	33	0,82	0,88
g. Sweet potato not available?	29	0,62	0,94
2. Storage:			
a. Poor store design?	27	1,81	0,88
b. High storage costs?	24	1,38	0,92
c. Storage problems due to:	150	1,24	0,80
i. Diseases (rots)?	36	1,67	0,68
ii. Insects?	31	1,26	1,03
iii. Rodents?	32	1,03	0,69
iv. Sprouting?	22	0,77	0,75
v. Shriveling, dehydration?	29	1,28	0,53
d. Insufficient storage capacity?	19	1,16	0,69
3. Marketing problems:			
a. High handling losses?	26	1,38	0,90
b. High marketing costs?	33	1,52	0,87
c. Transportation problems?	39	1,77	1,04
d. Unstable supplies and prices?	27	2,41	0,69
Total/average	1369	1,11	0,95

SWEET POTATO PRODUCTION AND CONSUMPTION SURVEYS: VARIABILITY AND VARIETIES

G.A. Watson[1]

ABSTRACT

The diversity of sweet potato varieties (1) has contributed to the crop's widespread use under a range of environmental conditions, cultivation practices, and dietary customs. National statistics provide information on average production and consumption, but may overlook the logic and preferences for sweet potato utilization by the producer and consumer. Sweet potato research must address the concerns of its clients; that is, those targetted farmers, merchants and home consumers who produce, market and eat specific types of sweet potato. This suggests that producer and consumer surveys be increasingly oriented to identify the reasoning, practice and demands of their client constituent, and to understand preferences which make varietal choices important.

1. INTRODUCTION

Sweet potato accounts for about 28% of underground crop yields of Asian nations where production is reported. Per capita production can be substantial, although production per hectare is generally low, averaging 16 tons per hectare in 1985 (12 t/ha excluding China). Most nations in Asia primarily use sweet potato for human consumption. Malaysia and Taiwan utilize most of their crop as animal feed. Japan and the Korea Republic process over 25% of their yields. This production and utilization data are presented in Table 1 (Horton 1988).

Statistical data and national institutional priorities provide an overview for research and extension, Country-wide figures and national policies focus on average yields, hectarage and large-scale development perspectives. However, farmers' and consumers' preferences for sweet potato are much more variable within and among populations, regions, and over time. Sweet potato research and extension programs will become more appropriate to these people the more their concerns are addressed.

An increase in sweet potato production presupposes farmer adoption or incorporation of new varieties, new or more intensive cultivation practices, or other technological inputs. Increased yields can affect farm-gate prices, the use of the sweet potato in fresh or processed forms, and the marketing networks that absorb this production. Increases in sweet potato yields and utilization are based on the acceptance of new techniques or products by target producers and consumers as compared to other crop or food options.

Producer and consumer surveys are a logical extension of national research at the local and regional level, and can be used to assess people's ideas and behaviors. Research focussing on a "users' perspective" (Rhoades 1988) in client-oriented research

1/International Potato Center, Indonesia

(Ewell 1988) can help direct investigations and tailor resulting technologies to target producer and consumer groups. We need to know who these people are, what types of sweet potato they utilize, and how, where, when and why they do so. Sweet potato producers and consumers provide the "market" for national and international research efforts (2).

2. FARMERS AND SWEET POTATO PRODUCTION

Farmers cultivate sweet potato with a wide range of methods for both subsistence and commercial purposes. The environmental adaptability of individual varieties make sweet potato one of Asia's most widely grown crops. It is grown from sea level to 2,850 m. in the tropics; in subtropical and warm temperate climates; and under rainfall conditions ranging from 1,500 to 5,000 mm. a year. By adjusting sweet potato's microclimate through mounding and drainage techniques, farmers can cultivate varieties on such diverse soils as heavy clays, peats or sandy loams, with pH ranging from 4.5 to 6.5.

Farmers do not grow sweet potato or any other crop simply due to its environmental suitability, however. Rather, sweet potato varieties are cultivated and consumed because they fit into the wider context of the cropping, farm and food systems of the producer. By understanding farmers' logic in their selection of the sweet potato as compared to other crops or activities, researchers can identify farmer priorities in their use of resources. This gives farmers and researchers a baseline to address the potential utility of new sweet potato varieties or techniques.

2.1 The sweet potato in the farming context

There are numerous reasons farmers choose to grow sweet potato. Its low and flexible labor requirements can provide farmers with the "free time" necessary to pursue other on or off-farm activities. Sweet potato's low fertilizer and pesticide demands make it an attractive crop to resource-poor farmers, or where inputs are scarce or unavailable. More intensive cultivation and higher yields are often commercially advantageous where land is scarce, labor is cheap, or farmers have additional funds.

The sweet potato serves different roles within farmers' cropping systems. Within a crop rotation, it is sometimes used as a "fallow" crop, to improve the quality of heavy soils for following crops, or as the preferred crop in the dry season or under other problematic conditions. It can be sequentially harvested to provide food security over time. As a polycrop, sweet potato is utilized for agricultural diversification so that the farmer can harvest a variety of crops over time for food, feed, or sale. Its comparatively stable yields and multiple uses as green manure, livestock feed, and for erosion control also contribute to its cultivation.

2.2 Varietal selection

Farmers grow thousands of different varieties of sweet potato in Asia and throughout ther world. Subsistence producers may plant 20 or more varieties (Waddell 1972). Even producers who sell only 2 or 3 major varieties often plant 6 or more for home consumption. It is essential that researchers gain insight into the criteria that farmers use to choose specific varieties or types of sweet potato for cultivation, consumption and sale. Such information gives researchers direction in selecting promising varieties for introduction with target groups in different agroecological zones.

Whether subsistence or commercial producers, farmers are concerned with the phenotypic characteristics of sweet potato varieties as well as with their yield. Farmers often note that sweet potato varieties are differentially susceptible to weevil infestation or diseases such as scab. Such problems affect the edibility and market price of the roots.

Unlike market consumers though, farmers' interests in sweet potato phenotypes include the growth and structure of the total plant. Farmers often choose certain varieties because of their vining or leaf production. Vine growth, length or bushiness is importan since it affects the suppression of weeds, the amount of vine lifting necessary to prevent adventitious rooting, and its usefulness as a means of erosion control. It also is a source of planting stock and livestock feed. Leaf and shoot edibility are often paramount where families consume them.

Sweet potato is frequently polycropped as well as monocropped, under conditions of subsistence and commercial agriculture. Producers choose sweet potato varieties or types for growth, yield and ease of cultivation with companion crops, under shading, to more fully utilize inputs, or to extend the growing period of intercrops into adverse season. Farmers frequently plant multiple sweet potato varieties in the same plot, in mixtures or at edges or centers of rows. Producers contend that polycropping and polyvarietal sweet potato cultivation help "balance" crop yields against environmental contingencies, or provide a diversity of sweet potato and other crops for home cooking and commercial consumption.

Growth durations and storage root formation of sweet potato varieties also influence farmer selections. Patterns of root bulking affect the timing of harvest, price patterns, and opportunity costs of land use. Producers may prefer early harvests for quick cash, higher prices per kilogram, or to quickly plant the next crop in a rotation. Otherwise, they may wait to harvest later in the season for higher yields or for other criteria.

This section has presented a few of the priorities that farmers or producers employ in their selection and utilization of sweet potato. Researchers can develop a more accurate and valid data base to direct future production research and development by asking farmers about these criteria. Situations in one region do not automatically hold for another, since contexts may vary both socio-economically and biophysically.

3. CONSUMERS AND SWEET POTATOES

It is often assumed that consumers in Asia have a national preference for a single color, taste, and texture in fresh sweet potato. On the average, nations do consume more of some types of sweet potatoes than others. See Figure 1 (Takage and Opena 1988) (3). However, the range of colors and cooking qualities of sweet potatoes sold in many Asian markets attests that consumer preferences and demands are also quite variable. Why is there such diversity? How can consumption surveys tap this knowledge to promote the consumption of fresh and processed products?

3.1 Sweet potato consumption

Sweet potato is primarily consumed in fresh, cooked from in most countries in Asia.

From per capita averages and general information, sweet potato can be categorized as a staple, supplementary staple or luxury crop (Collins 1988). However, we know little about the differential role this food plays in the diets of subgroups within any country. Studies on potato (Poats 1983) and sweet potato (Tan et al. 1973; Alkuino 1987) point out that consumption varies according to ethnic group, environment, and economic status, whether consumers live in urban or rural areas, and between producers and non-producers.

Identifying where and when sweet potato is eaten is necessary for an accurate assessment of the role of the sweet potato in the diet. For most producers, sweet potato is a seasonal crop, and its consumption is likely to change according to this seasonal availability. This trend, though, tends to be more pronounced for rural people than for urban areas where markets have higher integration. The status of sweet potato as a food (co-staple, luxury, etc.) influences when it will be consumed; that is, whether is it a source of carbohydrates for early morning work, a mid-day snack, or a "vegetable" complement to an evening meal. Where do people eat sweet potato: at work, at play, at home, or do they but it from sidewalk vendors? The amount of sweet potato consumed at one time may not be reflected in its "title". Sometimes "snacks" can consist of two or three large tubers!

Sweet potato's status as a staple, co-staple, side dish or snack can change from month to month within the year, depending on how much, when and how it is eaten. The food often comprises a major portion of the diet of some members of a household and not of others. For example, producing families often eat large quantities of sweet potato during and for a few months following the harvest season, and then infrequently throughout the rest of the year. As a filler food, sweet potato can comprise a major portion of young children's or field workers' diets, although it may be called a "snack". Consumption preferences are based on a combination of factors, including availability, variety and method of preparation.

3.2 Varieties and methods of sweet potato preparation

Sweet potatoes come in all varieties of colors, shapes, textures, sizes and tastes. Market consumers may not differentiate varieties, but categorize sweet potatoes into types, while some producers are quite specific in their choice of a variety for daily or special consumption. Surveys might well investigate consumer preferences for these varieties in their edible - cooked and raw - forms. Preferences and utilization of varieties or types shifts among economic or ethnic groups, adults and children, or in home-prepared versus commercial products. Consumers generally select particular sweet potato varieties or types according to how they intend to prepare them.

Varieties have different flavors, textures and color or fragance intensity depending on how they are prepared. For instance, baking often increases sweetness, while boiling may preserve a moisten taste and bring out the intensity of color. Frying yields a drier texture, while raw sweet potato is light in color and crispy. Sweet potato can be prepared as a starchy staple, vegetable, eaten raw in salads, fried into slices or chips, and made into cakes, noodles, or confections.

Specific types or sizes of sweet potato may be used to prepare certain dishes. Staple types tend have a drier texture and are generally boiled or baked. A moist type of sweet potato (often a "luxury" type) is not usually fried since it soaks up and "wastes" oil, but may be used in cakes or puddings for its sweetness or color. Very dry types are sometimes boiled rather than baked or fried to improve texture. Smaller roots may be prepared in one way (such as boiled snacks), while larges ones are used in others (such as for fried chips). Sweet potatoes may substitute in some dishes for cooked potatoes, raw carrots, or flour. Obviously, costs of preparation, including additional ingredients, salability and fuel costs are consumer and vendor considerations. However, present uses are all potential avenues to expand sweet potato's commercial marketability to other groups or areas.

Particularly in tropical and sub-tropical countries of Asia, the long-term commercial and subsistence storage of sweet potato is uncommon. Lack of adequate storage facilities affects the availability of different varieties over time, and seasonal consumption peaks frequently occur. Deterioration in sweet potato quality due to damage in shipping and weevil infestation are primary concerns. Some local populations have developed methods for storage of 3 months or more, and these should be investigated.

Consumer preferences direct the production and marketing of fresh sweet potato and sweet potato products. Target groups vary both within and outside of the household. To assess consumption patterns and preferences, the season, time of day, member of the family and form of prepared food should be examined. This data can be used as a guide to establish preliminary criteria for probable consumer acceptability.

4. SWEET POTATO SURVEYS

Initial research should provide a broad perspective on regional or local situations in which sweet potato is used. Baseline, preliminary, and pre-surveys (also called ex ante surveys), including field surveys, can be used to delineate different areas, target populations, and constraints or potentials in varieties, cultivation techniques or products.

It is suggested that semi-structured or "open-ended" group discussions can best achieve the objectives of baseline or preliminary surveys as well as more directed topic discussions. Group discussions give client participants a forum in which to talk about their views on sweet potato and its utility within their social context. If farmers or consumers reply from the position of qualified experts rather than that of passive (and powerless) respondents, the relevance and reliability of acquired information is likely to improve. Since many farmers participate, researchers can collect a range of opinions and pursue new areas of mutual interest quickly and relatively easily.

The group methodology allows researchers to quickly gain familiarity with sweet potato as a commodity within the farm context and from a varietal perspective (4). Research hypotheses can be more rapidly formulated and even informally "tested" with participants, while possibilities for new technologies or techniques can easily discussed. This helps insure that future research addresses substantive issues. By simultaneously differentiating potential target populations and weighing the relative applicability of particular innovations to them, group research methods may improve the cost effectiveness of research programs or technology transfer. If needed, formal surveys or intensive interviews and observations can be based on this initial data (5).

Group discussions initially enable researchers to define consumer and producer practices and interests. Users' and clients' priorities are often different than those considered relevant by scientists or policy makers. However, clients make the final decision about whether they will accept or reject a variety, agricultural technique, or food product. The reliable assessment of producer and consumer environments, practices, preferences and logic in sweet potato use will therefore point out probable "market demands" and chances for the adoption of products or technologies.

5. CONCLUSIONS

Sweet potato projects must address the concerns of their clients; that is, those targetted farmers, merchants and consumers who produce, market and buy specific types of sweet potato. This may require the reorientation of producer and consumer surveys to identify the reasoning, practice and demands of their client constituent, and in relation to the varietal choices which make it possible.

National programs adapt varieties and technologies to specific situations within their countries. Additional planning for changes in production or consumption should insure that client demand is large enough to support the new input, technique, or product. Training and product availability also help insure utilization. In short, the success of new techniques or products depends on adoption by the client as well as national aims and objectives (West and Earle 1987:16).

Group farmer discussions are a rapid means to pinpoint relevant areas for research, and to investigate more specific issues. Formal surveys or additional informal or semi-structured field visits and interviews can then be used to extend the research.

5. FOOTNOTES

(1) Although the word "landraces" is the scientifically accurate term, the word "variety" will be used here by convention. In this paper, the word "variety" is synonymous with the word "cultivar" and refers to the locally defined name for a phenotypically differentiated type of a crop, although there may be no biochemical evidence for such distinction (see Boster 1983:59).

(2) The perspective presented in here owes much to concepts and approaches developed through commercial market and technology diffusion research. See Rogers (1983) or Young and MacCormac (1987) for background material.

(3) The large proportion of scientists from this survey who list certain sweet potato characteristics as "not important" is surprising. Conventional production for subsistence or commercial sale generally follows clients' preferences (that is, preferences of the producer and consumer). It is unusual that national choice is apparently completely nondiscriminating.

(4) This assumes that group discussions are correctly conducted; that is, that all participants have a chance to speak; their responses reflect the logic of their practices and preferences as well as general facts; and that researchers are non-judgmental, can work with respondents' ideas, and regard respondents as qualified and experienced informants. For more information on methods of group discussion, see Watson and Basuki (n.d.).

(5) The high quality of a formal survey is based on strong background preparation, including accurate secondary data, informal or semi-structured surveys, and pre-testing. Without such preparation, most formal surveys are neither useful or accurate.

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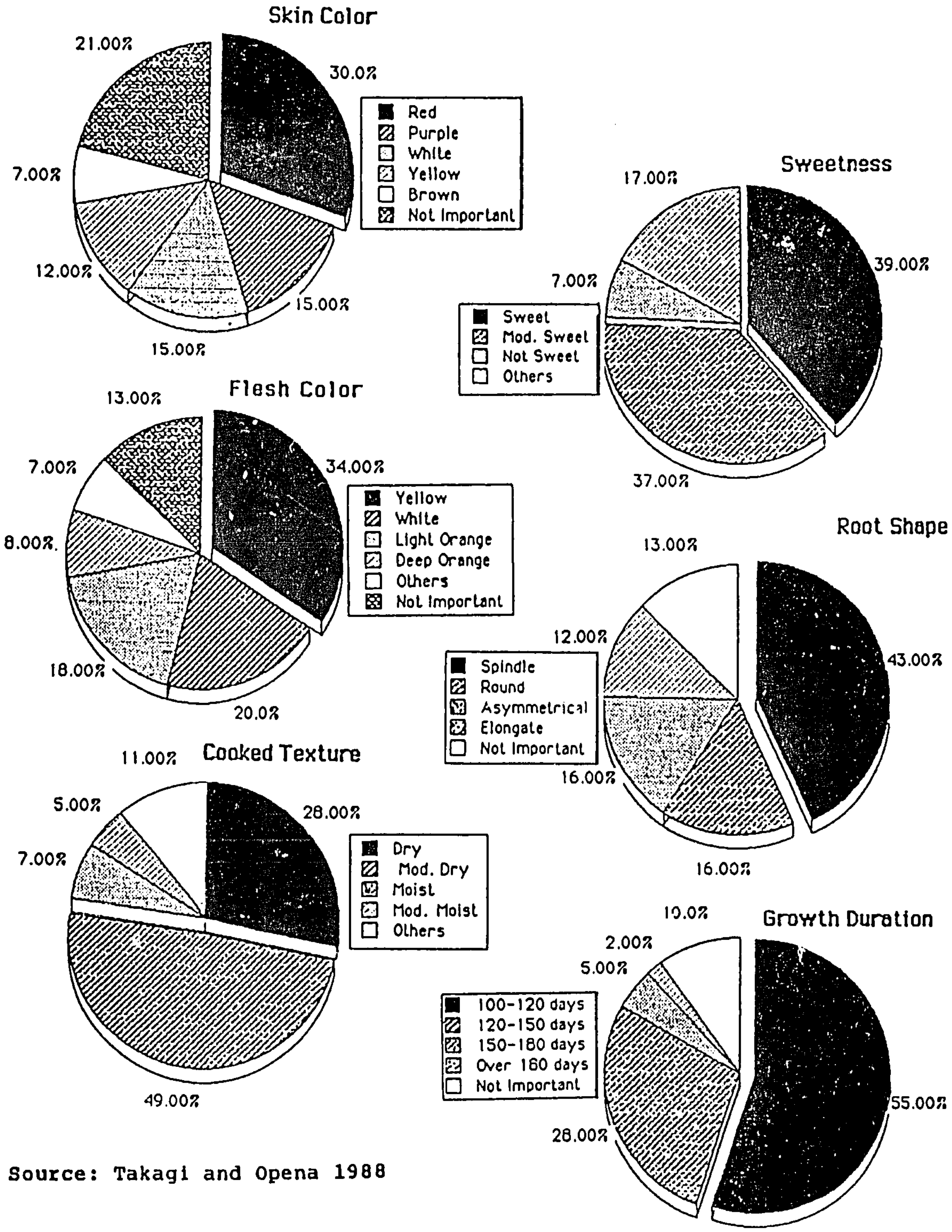
Table 1. 1985 Reported production of sweet potato in Asia

Country	Production (000 tons)	t/ha.	kg./ person	S.P. % of Root & tuber production*	Primary Use
Bangladesh	683	11	7	37	food
Brunei	0	5	1	n.a.	food
Burma	25	5	1	10	food
China	90,000	18	92	65	food
India	1,523	8	2	8	food
Indonesia	1,876	9	14	12	food
Japan	1,527	23	12	29	food/proc
Kampuchea	30	10	4	23	food
Korea D.P.R.	470	15	23	20	food
Korea Rep.	787	24	22	58	proc./food
Laos	40	11	19	24	food
Malaysia	50	17	3	12	feed
Pakistan	22	16	4	4	food
Philippines	1,005	5	15	32	food
Sri Lanka	140	9	9	15	food
Taiwan	465	16	22	83	feed
Thailand	355	9	7	2	food
Vietnam	2,000	5	32	38	food
All nations	101,003	$\bar{x}$ = 12	$\bar{x}$ =16	$\bar{x}$ = 28	food
Excl. China	11,003	$\bar{x}$ = 12	$\bar{x}$ =12	$\bar{x}$ = 25	food

* Does not include production of unspecified root crops data rounded to the nearest 1,000 t.

Source: Horton 1988

Fig. 1 AVRDC survey of sweet potato scientist (n=43) in Asia and the Pacific regions: National preferences for sweet potato.



Source: Takagi and Opena 1988

CIP's PROGRAM FOR HUMAN RESOURCES DEVELOPMENT THROUGH TRAINING

Manuel Piña, Jr.[1]

1. INTRODUCTION

Since CIP's inception, more than 15 years ago, it was recognized that improving potato production in the developing world depended not only on CIP's ability to generate new technology, but, more importantly, on the abilities of researchers, extensionists, and educators in national potato programs to make use of newly-generated technologies. The following ideas, which are now equally applicable to sweet potato improvement, form the basis for CIP's program for human resource development through training:

- National programs have the ultimate responsibility to reach farmers.
- Information and expertise on potato and sweet potato production is needed in many countries.
- National programs must be capable of using new or improved technologies--germplasm and production techniques.
- The flow of technology should operate in both directions, with the potential user participating in the selection of appropriate technologies.

2. HUMAN RESOURCE DEVELOPMENT

Training is a topic often used synonymous with human resource development (HRD). It is a topic that is often mentioned in meetings of this type. But, how we define or interpret HRD will determine to a large extent what problems we identify, what actions we take to respond to those problems, and how we determine what successes have been achieved.

Some recent writers on the subject claim that HRD focuses on increasing the talents and abilities of people in a system. The term implies that individual persons within organizations are resources, not problems. Other resource inputs in any serious developmental activity are: financial, physical (materials, equipment, and facilities), and knowledge.

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The writers assert that training is included in HRD, but that HRD is much broader than training alone, including education and development. They say that training focuses on learning experiences to improve the performance of a person's present job skills. Examples of training in this sense is training on rapid multiplication techniques for use in seed production and tissue culture methods for propagation and clean up.

Education broadens the abilities of persons to perform a specific job or group of jobs that the parent organization will need some time in the near future. Examples are: advanced degree studies where scientists study topics of national priority and also gain exposure to other related fields and computer applications to manage research taught as a part of short courses.

Development strengthens capacity to respond to growth that organizations must make as external conditions change and to circumstances expected to be encountered in the future. Examples of development are: teaching to write research project proposals and scientific reports in English.

When persons participate in HRD activities --training, education, and development-- that are well planned, carried out, sequenced, and coordinated, they not only become more effective in contributing to achieving the goals of the organization but also develop a strong relationship themselves and the parent organization. In this way, organizations tend to keep their goals clear and develop individuals who will contribute to achieving the goals over longer periods of time.

3. CIP's HRD PROGRAM PHILOSOPHY AND OBJECTIVES

CIP's Training Program is based on the philosophy that research and extension efforts conceived and executed in collaboration with national programs will be more appropriate for the conditions of the country and have a longer-lasting beneficial effect than those conceived and executed independently by CIP.

The program is based on the conviction that national programs are in the best position to examine the growing conditions of their crops, analyze government agricultural policies, assess research and training needs, and undertake the transfer of technology to farmers.

CIP, in its relationship with national programs, plays a catalytic role by addressing individual country priorities for research and training. As such, CIP's HRD activities are directed toward improving the abilities of national programs to:

- Identify research priorities and needs.

- Conduct research on priority problems.

- Use existent technology that has been identified as relevant to the country's needs.

- Evaluate research results from other sources under home-country production conditions.

- Participate in transferring appropriate technologies within their countries and surrounding countries.

- Train others to identify existent technology and research needs, to conduct research and evaluate results, and to participate in the transfer process.

To date, based on this philosophy and objectives almost 6,000 national researchers, extensionists, and educators from over 80 countries have received training through CIP's support.

4. HRD PROGRAM ACTIVITIES

Activities of the Program are determined primarily as a result of assessment and communication between CIP staff in the Regional Research structure, i.e., scientific staff outposted in key sites around the world who interact continually with national leaders of potato and sweet potato programs from countries in their respective surrounding areas.

At the same time, input is also given by Lima-based scientists whose research extends into the regions and who travel extensively. Guidance is given to national program scientists as well as to CIP's regional staff.

Through this process of collaborative planning for research and training, production potentials and constraints, identification of research needs, and assessment of training requirements are continually carried out. As a result, collaborative plans emerge. These plans address national production problems and, more importantly, reflect the contributions that can be made by expertise existent in the national systems. Based on this methodology, CIP's HRD activities are essentially of two types: specialized and production-oriented.

Specialized training - concentrates on areas of research for which CIP is the principal source of information and experience. The objective is to provide researchers with the skills necessary to conduct research. Examples of such training is management of advanced clones in breeding for variety development and use of the nucleic acid spot hybridization (NASH) test to aid in the elimination of the potato spindle tuber viroid.

Specialized training is provided through the following activities which take place at headquarters and in the regions: courses, mid-career and visiting scientist training, postdoctoral training, and scholarships.

Production training - focuses on general principles of potato and sweet potato production and is designed to enable national researchers and extensionists to respond to farm-level production situations. Capable national programs provide direct input by assisting in organizing activities and in instruction, oftentimes CIP staff direct input is minimal. This type of training is conducted only in the regions as international courses for countries of a region or as in-country courses for single countries.

5. FIVE-YEAR PLAN FOR TRAINING

Recognizing the importance of capable human resources to conduct research and training, CIP's regional staff and, as well as other staff traveling to the regions, are continually assessing and discussing training needs with national staff. At the end of each calendar year, in conjunction with CIP's Annual Internal Review, the HRD activities of each region are reviewed by headquarters and regional staff in Lima.

Based on this scientific and managerial review, plans are made for all events to take place in the regions - international and in-country courses and workshops - and all other types of events, e.g., visiting scientists in the regions or at headquarters in Peru. These activities are reflected in a plan for training that covers the next five years.

The plan for each CIP region is reviewed each year and is under constant modification, responding to the guidance given by headquarters scientists who are specialists in certain areas of CIP's research and regional scientists who represent the needs of the countries in their respective regions. Budget allocations are made for the following two years. In this way, regional staff are able to make commitments prior to the end of each year for activities to take place in the following calendar year.

6. COMMUNICATION SUPPORT

CIP's long-term plan calls for "the development of a global communications network for the transfer of technology" involving national scientists, extensionists, and educators in research and training. Communications support is an essential and integral element of CIP's HRD effort. It is felt that improved technology --germplasm and improved production technologies-- must first be converted to information before it can be used by national programs. Therefore, it is necessary to plan, synthesize, produce, and evaluate publications and visual aids, and also to assimilate and interpret feedback.

Materials to support HRD activities include course handouts, technical information bulletins, specialized technology manuals, and slide sets. These are designed in such a way that they may be easily adapted or reproduced and are made available at no charge in limited quantities to national programs. HRD participants often receive a full set of materials to take for use in the home country.

7. INFORMATION SERVICES

A constant flow of the latest research information to national program researchers is essential for the development of a global communications network, and HRD. Since 1985, CIP has been developing an effort to respond to the long-range information needs of potato and sweet potato researchers world-wide. This effort incorporates the services previously offered by the library to CIP staff in Peru and in the regional network and has the following as its objectives:

- Develop an automated database of conventional and nonconventional literature.
- Assist national researchers to gain access to other databases, such as AGRIS and CABI.
- Provide additional services to national researchers, e.g., selected dissemination of information, specialized searches, and bibliographies, and acquisition lists.
- Facilitate exchange of information among national researchers through financial and technical support to national journals.
- Assess national program information needs continually.

Eventually, this project will coordinate a continuous follow up system of training, an effort to not only assess impact but also be a mechanism for providing necessary HRD support to national programs.

8. EFFECTS OF HRD REVIEWS AND STUDIES

In the past few years CIP's HRD program has undergone a number of review and studies. These have had an effect on CIP's training program and are now beginning to be reflected in our five-year plan of work. Some specific examples are:

- Closer attention being given to behavioral objectives for all training activities.
- Longer regional seed production courses, with more time allocated for hands-on practical experiences.
- More hands-on experience in in-country production courses, with the trend toward courses on the call system.
- Promotion of the involvement of national staff as instructors in region-wide specialized activities.
- Inclusion of topics such as communications and on-farm research in region-wide and in-country group activities.
- Promotion of M.S. and Ph. D. theses research to be conducted in the home country or under similar conditions to the home country in another country or at CIP headquarters in Peru.

- Increased attention being given to formative and summative evaluation of group activities.

- Recognition of the need to conduct follow up activities in a more systematic fashion.

9. SUMMARY AND CONCLUSION

The philosophy and objectives of CIP's program for human resource development through training focuses on developing national capacities to perform a large number of skills that respond to present and future needs of potato and sweet potato researchers, extensionists, educators, and agribusiness men and women. These are driven by a recognition that unless these competencies exist in the national systems, the results of our research and results that may be available from other sources may never have an effect in the lives of rural farm families.

WORKSHOP ON SWEET POTATO IMPROVEMENT IN ASIA.
HIGHLIGHTS OF SESSION PRESENTING CIP SWEET POTATO
RESEARCH PROGRAMME

1. INTRODUCTION

These highlights are concerned only with those points arising from the discussion sessions which were pertinent to sweet potato improvement in Asia they are not concerned with individual papers but rather the themes running through all of the discussion sessions which are relevant to the interface between National Programmes and CIP.

2. PRESENT STATE OF KNOWLEDGE

The very specific nature of many of the questions indicated that very little is known in many field. In particular there seemed to be a need to better understand and document current production and post-harvest practices and develop methodologies towards these ends. Also questions were orientation towards "constraints" rather than focussing upon the potential of the crop.

3. CIP's RESEARCH STRATEGY

Throughout all the presentations and the discussion it was emphasized that country needs were the focal point of CIP's strategy and that collaboration was the primary means of reaching objectives. CIP required from the meeting an indication of where National Programmes and where CIP had a comparative advantage to carryout work. The frequent discussion across disciplines emphasized the inter-disciplinary nature of the work to be carried-out. CIP's ability to fulfill this and the need for Agronomy. The Social Sciences and Human Resources Development to be involved in all stages, particularly in the development of methodologies.

4. GERMPLASM COLLECTION AND CHARACTERIZATION

The need to collect and characterize germplasm both improved cultivars and native cultivars was referred to several times: reflecting similar discussions the previous day. Of concern to many participants was the need to maintain collected material (field maintenance vs in-vitro) and methods of making it available to others (clean-up and quarantine).

5. BREEDING

The need for strong breeding programmes to support many other aspects of the crop's improvements pest and disease control or quality was constantly emphasized. There were differing views as to what extent existing cultivars could be used within the region and to what extent reference would have to be made back to CIP's world collection

6. PLANTING MATERIAL

Following on from the previous day's discussion, the need for quality planting material was raised but this did not appear to be of equal concern in all countries.

7. PESTS AND DISEASES

The very specific nature of the questions following these sessions emphasized how little is known; there was even debate as to whether opposed to quality, and as to how certain common viruses were transmitted.

The weevil and viruses would appear to be the main problems. The possibility of there being genetically based resistance to weevil was hotly debated and the need for breeding to be part of an integrated approach was highlighted. The need for CIP to continue to devise methods for identifying and testing for viruses was emphasized.

8. POST HARVEST

It was agreed that there was unlikely to be an increase in fresh consumption in most countries in the near future. Any increase in production would have to be orientated towards processing. Although it was recognized that sweet potato is currently processed in many ways (more than 20 within SAPPRAN alone) little is known about either the technical or socio-economic aspects. It was noted that present practices needed to be documented before new processes were initiated. The ability of Networks to help in the collection of the information and its transfer was mentioned. Networks could help in the transfer of technologies but methodologies for collecting the information were still lacking as were methodologies for identifying clients in other countries.

Storage *per se* appeared to be of little concern at the present time.

9. HUMAN RESOURCES DEVELOPMENT

The need for Human Resources Development at all stages was recognized. It was noted that help in methods of writing scientific articles should be given to National

Scientists in order to make available the considerable amount of research presently being done and to enhance scientists careers.

The need for improved technology transfer mechanisms in some countries and the role that training could fulfill was mentioned.

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