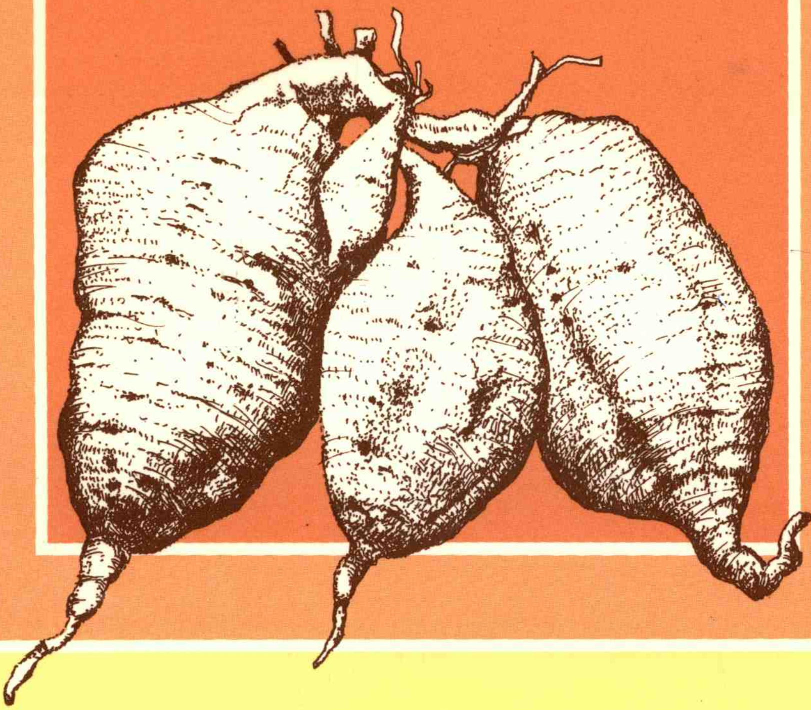


sweet potato research and development for small farmers

edited by:
Kenneth T. Mackay
Manuel K. Palomar
Rolinda T. Sanico

The SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA) is the agriculture center of the Southeast Asian Ministers of Education Organization (SEAMEO), an intergovernment body founded in 1965 to promote cooperation among Southeast Asian nations through activities in education, science, and culture. SEARCA is hosted by the Philippine government on the campus of the University of the Philippines at Los Baños (UPLB) in Los Baños, Laguna, the Philippines, which is situated 65 km southeast of the capital city of Manila. It initially operated on an interim basis from 1 July 1967 to 30 June 1969. It was launched as a permanent center of SEAMEO on 1 July 1969.

The International Development Research Centre (IDRC) is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activities are concentrated in five sectors: agriculture, food, and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters is in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

COMMUNICATIONS DIVISION

3-N-90-3001-03 $3,200.00

300 copies

sweet potato research and development for small farmers

edited by:
Kenneth T. Mackay
Manuel K. Palomar
Rolinda T. Sanico

This publication is the proceedings of the International Sweet Potato Symposium conducted on 20-26 May 1987 at the Visayas State College of Agriculture (ViSCA), Baybay, Leyte, the Philippines. The symposium was cosponsored by the International Development Research Centre (IDRC) of Canada, Philippine Root Crops Research and Training Center (PRCRTC), Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), and SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by SEAMEO-SEARCA, College, Laguna, the Philippines.

September 1989

For information, please write to:

The Director
SEAMEO-SEARCA,
College, Laguna 4031
The Philippines

FOREWORD

Sweet potato is an Asian crop in spite of its new world origin. Over 80 percent of the world's root crop production is now in Asia and Oceania. Sweet potato is an important staple and emergency food in many countries, especially for the poorest -- the resource poor farmers and the urban poor. It is also a vegetable, a snack food and confectionery item in most countries. Throughout Asia, it is an important ingredient in animal diets (particularly for pigs) on many small farms. The lowly sweet potato is starting to increase in status and is finding a role in the diets of the urban elite, and is now being used more for processed products. These are some of the results that are presented in this publication of the proceedings of the Sweet Potato Workshop held at the Visayas State College of Agriculture (ViSCA) at Baybay, Leyte, the Philippines, on 20-24 May 1987.

This workshop, the second International Sweet Potato Meeting held in Asia, is unique. Representatives from all the top sweet potato producing countries were present, particularly China and Vietnam, the top two producers which had been absent in previous meetings. In addition to the scientific program, which covered recent advances in breeding, diseases and pests, chemical composition, storage, processing, and marketing, the program also focused on the problems and research needs of the small farmers who produce most of the sweet potatoes in Asia. In addition, considerable discussion on future networking and collaboration in research and training ensued.

It was fitting that the workshop was held on the beautiful campus of ViSCA, overlooking the Camotes (Filipino for sweet potatoes) Islands in the Camotes Sea. The meeting was hosted and organized by the Philippine Root Crop Research and Training Center (PRCRTC) based at ViSCA. The International Development Research Centre (IDRC) of Canada, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), and the SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA) were cosponsors. The Australian Council for International Agricultural Research (ACIAR), Asian Vegetable Research and Development Center (AVRDC), International Potato Center (CIP), and Universiti Pertanian Malaysia (UPM) funded their participants.

This meeting represents the beginning of greater collaboration among Asian researchers on this important Asian crop for the future benefit of farmers and consumers.

K.T. Mackay
Program Officer
International Development Research Centre
Regional Office for Southeast and East Asia

CONTENTS

WORKSHOP OBJECTIVES

- To document indigenous technologies used by small farmers and recent results of sweet potato research and development in different countries.
- To provide a forum for exchange of information, experiences and ideas among researchers to sharpen the focus of future research thrusts.
- To identify appropriate areas for future collaborative activities and explore the possibility of establishing a network for sweet potato research in Asia, the Pacific region, and selected international centers.

INVITED PAPERS

SWEET POTATO EVOLUTION

Itaru Shiotani*

INTRODUCTION

In China, there is an ancient technological literature entitled "Tien-Kung Kai-wu." The title connotes nature and humans working together to make good use of natural resources. The same may be said of the domestication and improvement of crops because any cultigen, local farm cultivar, or modern variety are products of the co-evolution of national selection and the selection of better crops by humans.

This presentation consists of three parts. The first part deals with two features of evolutionary significance in sweet potato and its wild ancestral plants. The second part focuses on an analytic breeding plan that uses a gene in diploid. The third part discusses a breeding system that is consistent with conservation of genetic resources.

Two Features of Evolutionary Significance in Sweet Potato and Its Ancestral Plants

Among more than l00 species of the genus *Ipomoea,* a group of wild plants ranging from diploid to hexaploid, called *I. trifida* complex (Kobayoshi, l984), is thought to be ancestral plants of sweet potato for two reasons: l) the diploid and polyploid forms can be hybridized with sweet potato (2n=6x=90); and 2) the polyploid forms of *I. trifida* and the hexaploid sweet potato are being produced by duplication of the genome in the diploid form of *I. trifida.* Consequently, the tetraploid and hexaploid of *I. trifida* and sweet potato must be of autopolyploid origin (Nishiyama, l97l, l982; Shiotani and Kawase, l970, l980; Shiotani, l987). These plants of *I. trifida* are distributed in a pan-Caribbean region covering Mexico, Guatemala, Colombia, Ecuador, Venezuela, and the West Indies.

With data on seed fertility (KAES, l962, l967, l980b, l98lb, l982b, l984, 1985) and starch content (KAES, 196l, 1962, 1980a, 198la, 1982a), the wild plants of the different ploidy level in *I. trifida* and sweet potato were compared (Table l). In *I. trifida,* a trend from profuse flowering to nonflowering is seen as ploidy becomes higher. Moreover, the averages or highest percentages of seed fertility in intercrosses decrease with the higher level of

*Professor, Plant Breeding Laboratory, Faculty of Agriculture, Mie University, Tsu 5l4, Japan.

Table 1. Flowering habit and seed fertility, and storage roots and starch content of *Ipomoea trifida* and sweet potato (*I. batatas*).

Species ploidy	2n	Flowering habit	No. of crosses	Seed fertility (%)	Storage root characteristic	No. of strains	Starch content (%)
I. trifida (2x)	30	Profuse	52	62.5(18.0-100)	Slender	12	13.0(11.1-15.4)
			244	61.4(0.0-100)	Thick-veining	39	12.8(9.0-16.2)
					Thickening	68	13.1(3.6-20.8)
I. trifida (4x)	60	Sparse	121	37.4(0.0-90.0)	Slender	13	11.2(2.4-17.3)*
		None	33	32.4(4.5-72.0)	Thickening		
I. trifida (6x)	90	Sparse	11	40.0(7.3-57.3)	Slender	5	14.4(13.3-16.1)*
		None	6	20.9(1.1-55.4)	Thickening	6	16.8(13.5-19.6)*
					Semi-tuberous		
I. batatas (6x)	90	Sparse	30	20.3(4.6-44.9)	Thickening	27	24.9(19.3-27.9)
		None	16	24.5(3.2-39.0)	Semi-tuberous	30	24.8(21.2-29.2)
			16	21.4(9.5-33.3)	Tuberous	33	25.6(21.2-28.4)
			18	37.0(21.6-54.8)			

*Values in pot trials.

ploidy. Sweet potato exhibits seed fertility as low as that of hexaploids of *I. trifida*. In principle, the sterility of these hexaploids can be attributed to the nature of autopolyploidy.

Except in extreme dryland, wild plants of *I. trifida* grow perennial with storage roots in their natural habitat. These storage roots show various degrees of thickness (slender to semi-tuberous) when the plants are cultivated. As shown in Table I, the starch content of the wild plants is generally lower than that of the cultivated sweet potato. The slender and thickening roots of diploids showed an average of 13 percent in starch content. The starch contents of II percent in tetraploid and I4 to I7 percent in hexaploid were taken from the results of pot-grown trials. On each ploidy level, the percent starch content varied widely among the clones examined. This may suggest a considerable natural variation in the accumulation of storage starch.

These experimental data suggest an evolutionary pathway of the cultivated sweet potato. First, the polyploidization resulting in low fertility and occasionally in nonflowering may prevent individual plants to freely interbreed with other relatives. It is an incomplete or complete isolation that acts in reproductive phase. Second, among the isolated individuals, certain individuals which can produce clonal individuals through the development of adventitious storage roots would have a selective advantage in natural selection.

As Darwin said: "Nature gives successive variations, man adds them up in certain directions useful to him." In this way, sweet potato could have been selected for its capacity to accumulate starch in the roots.

Recent studies in sweet potato have shed light on genetic mechanisms that condition the flowering habit and the various traits of storage roots. Sakamoto (I974) reported partial dominance of flowering habit under a long day, but the degree of flowering of F_1 plants from crosses between nonflowering and flowering lines under a long day varied in a quantitative manner. In a review by Martin and Jones (I986), estimates of heritability for various agronomic traits were summarized. Fairly high broadsense heritabilities for root weight and dry matter content (crude starch content) illustrated that selection on the basis of clonal performance is effective without progeny test. However, low or intermediate narrowsense heritabilities for root weight suggest that root weight is governed largely by nonadditive gene effects.

The genetic system of inbred lines of S_1 and S_2 had marked decreasing effects on seed fertility, but the degree of inbreeding depression differed among the inbreds rerpesenting similar inbreeding coefficients (Yunoue and Hirosaki, I975).

These findings have contributed valuable information for further "domestication" of the sweet potato.

An Analytic Breeding Plan Using a Gene in Diploid

The number of genotypes formed with a given number of genes increases as the level of autoploidy becomes higher. For an allelic pair at one locus, there are three genotypes: AA, Aa, and aa in diploid; five genotypes A^4, A^3a, A^2a^2, Aa^3, and a^4 autotetraploid and seven possible genotypes are formed in autohexaploid. The general formula for the total number of possible genotypes N was given by Haldane (1948), as follows:

$$N = (gHm)^n = [(g + m - 1)! \div m!\,(g-1)!]^n$$

where g is the number of alleles per locus, n is the number of loci, and m is the level of autopolyploidy.

Results of these calculations are presented in Table 2 with respect to 2, 4, and 6 alleles per locus at 1, 2, and 3 loci in diploid, autotetraploid, and autohexaploid. For example, in a given assortment of 4 alleles at 2 loci, the number of genotypes is 100 in diploid, 1,225 in autotetraploid, and 7,056 in autohexaploid.

Breeding sweet potato is an effort to select the ideal genotype out of segregated genotypes for a given number of genes involved. The above comparison suggests that a reasonably large size of the segregated population is required for the pedigree selection.

Another problem is the difficulty of identifying and locating a gene or genes on the hexaploid level. Therefore, reconstruction of the hexaploid by using diploids that have a known gene or genes may provide some genetic sources for breeding. This reconstruction can take place only when tetraploid hybrids between sweet potato and diploid are fertile enough to reproduce their progeny. Indeed, the produced tetraploid hybrids were demonstrated to be fertile.

A plan illustrated in Figure 1 involves five steps of resynthesizing the hexaploid with the diploid lines having a recessive gene resistant to a pathogen.

Step 1. To avoid a deleterious effect of inbreeding, two sets of parents are used. Each set consists of a sweet potato variety and two diploid lines. The diploids are homozygous for the resgene but different in their genetic background.

Step 2. Sterile triploid hybrids that have one or two resgenes are then manipulated to double their chromosomes. For chromosome doubling, the colchicine treatment of seedlings is successful at present. If chromosome doubling of shoots from clones can be achieved, the selection for higher resistant clones is possible at this step.

Step 3. The cross between two colchicine hexaploids of different lineage is made to establish the resynthetic hexaploids. The number of resgenes may vary from 0 to 6 in the resynthetic hexaploids.

Table 2. The number of possible genotypes formed with a given number of genes in diploid, autotetraploid, and autohexaploid.

No. of alleles per locus	Diploid No. of loci			Autotetraploid No. of loci			Autohexaploid No. of loci		
	1	2	3	1	2	3	1	2	3
2	3	9	27	5	25	125	7	49	343
4	10	100	1,000	35	1,225	42,875	84	7,056	592,704
6	21	441	9,261	126	15,876	2×10^6	462	213.444	98×10^6

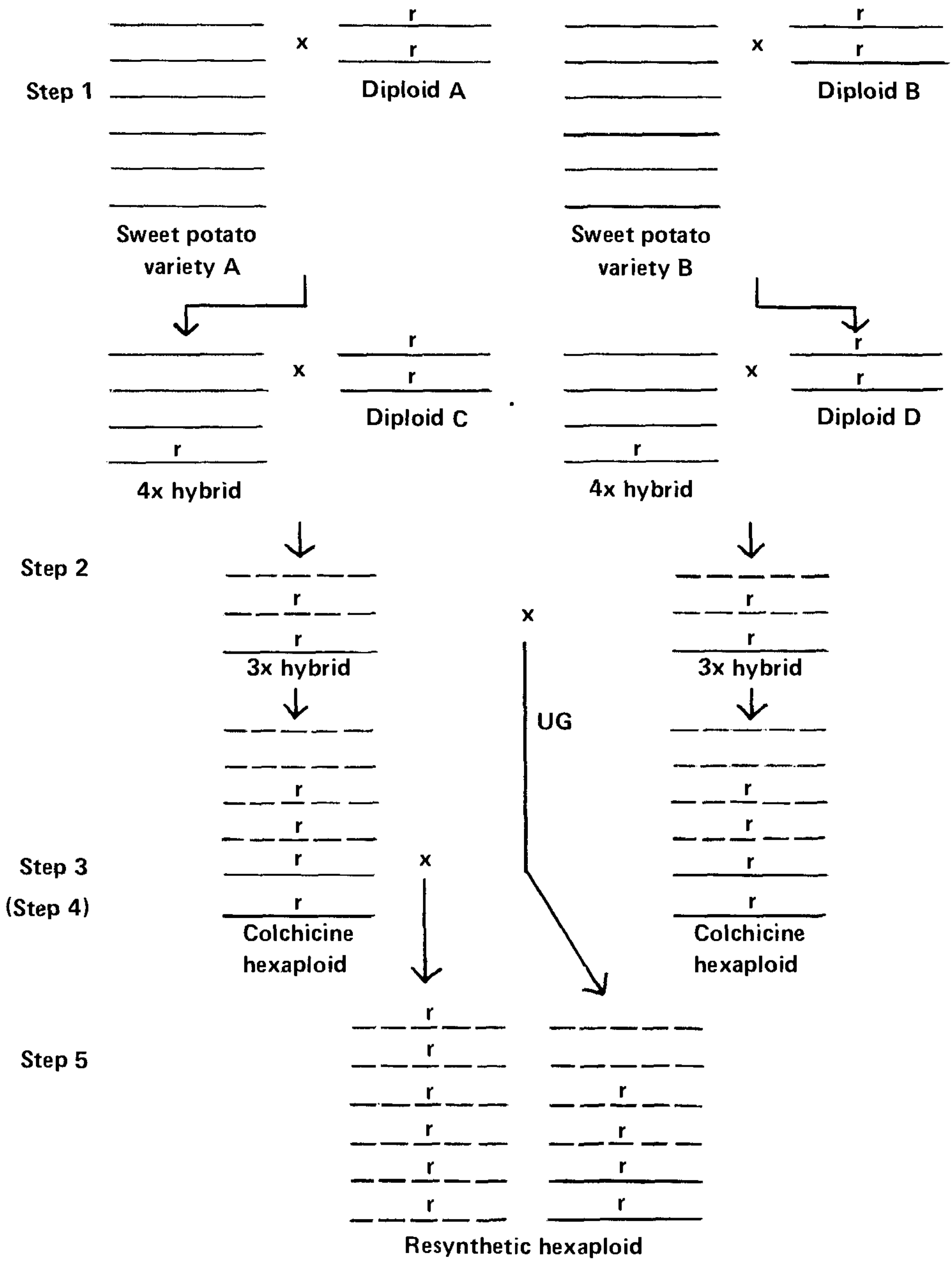


Figure 1. An analytic breeding plan to resynthesize the hexaploids having the resistant genes of diploids. "r", resistant gene; UG, unreduced gametes; dashed line, the chromosome altered by crossing-over.

Step 4. Alternative resynthesis may be possible from the crosses between the two triploid hybrids when both of them form unreduced gametes. The resulting hexaploids may have the resgenes from 2 to 4.

Step 5. After the pathogen test and yield trial, the selected resynthetic hexaploids are used as a genetic source for conventional breeding.

All steps, except step 4, were experimentally demonstrated in an attempt of resynthesis by using some diploids of the thickening root type.

A Proposal for the Breeding System That is Consistent With Conservation of Genetic Resources

The Center of Agricultural Experiment Station of Japan has received a sweet potato collection from Dr. Yen at the Crop Research Division, Department of Scientific and Industrial Research, New Zealand. The collection of 6l7 clones over a pan-Pacific region contained the largest number of cultivars (l02) from northern Luzon in the Philippines. Takemata and Sakai (l975), who conducted field trials from l970 to l973, found that among the l02 cultivars, 46 were non- or poor tubering, 4l were medium tubering, and l5 were good tubering.

The 29 cultivars, which were used in the yield trial in l972, are listed in Table 3 with their yield (root weight/a), dry matter percentage, and their resistance to black rot (BR, *Ceratocystis fimbriata*) and to rootknot nematode (RKN, *Meloidogyne incognita* var. *acrita*).

These cultivars are generally lower in yield than the standard variety (Tamayutaka). However, cultivar nos. l2l, l35, and l77 attracted breeders' attention for such traits as high yield potential (no. l2l), resistance to RKN (nos. l2l and l35), and high starch content (no. l77). Nos. 121 and 135 have since been used for breeding of resistant, high starch lines.

What can we deduce from the cultivars that had no measurable storage roots? These local cultivars should be those that have shown appreciable degrees of tubering in their native habitat. Two factors seem to be of importance, namely: changes in latitude and genetic tolerance limits of the cultivars for thickening growth of roots. The new location for these cultivars is at about 35°N, but their native habitat is originally at a range of l4°-l8°N in latitude. Moreover, the thickening of late-maturing cultivars is greatly inhibited by lowering temperature in autumn at the high latitude.

Ono et al. (l972) pointed out a marked regional difference in yield of certain varieties in l5-year yield trials in Kyushu, Japan. They ascribed the cause of regional differences to the interaction of genotype and soil factors such as nitrogen content and water-holding capacity.

For a root crop, a clonal variety may be an ecotype. Therefore, the local cultivars are ecotypes selected by natural factors such as climate,

Table 3. Local sweet potato cultivars in northern Luzon of the Philippines (Takemata and Sakai, 1975).

Coll. no.	Vernacular name	Area*	Root weight (kg/ha)	Dry matter (%)	Resistance** to	
					Black rot	Root knot nematode
54	Dumaquin	1	75	28.1	R	R
62	Unknown	1	101	28.1	M	HS
67	Dinalman/pukin	2	117	24.6	M	R
70	Pukin	3	159	24.4	R	M
73	Budqa	3	268	25.9	S	HR
74	Qinhud	3	277	27.8	M	R
79	Unknown	3	61	23.1	S	S
85	Kawitan	3	156	26.5	HR	M
93	Tuttolid	3	239	25.9	M	R
99	Tuqqag	3	173	25.6	M	S
116	Hoɬhoɬyo hiɬyan	4	77	25.8	M	R
119	Kawitan qad	4	180	26.2	R	M
121	Yawa	4	228	25.8	M	HR
122	Lakwaw	4	151	25.9	M	S
130	Hiɬyon	5	200	26.7	M	R
133	Qimpayan	5	98	27.0	HR	HR
135	Qontig	5	194	26.3	M	HR
136	Qulguldin	5	298	26.0	R	S
141	Hobul	5	82	30.8	R	HS
142	Bayani	5	206	20.9	M	R

Table 3 (continued).

143	Pugal	5	167	27.1	M	M
144	Qibagyo	6	120	32.5	M	HS
147	Taŋŋaka	6	159	26.8	R	HS
149	Yakutkut	6	196	25.9	M	M
158	Kinagayqan	7	220	26.3	M	M
173	Immubi	8	210	33.9	M	M
174	Baisiŋ	8	253	34.5	M	S
177	Illagan	8	203	32.7	M	S
179	Ubi	8	248	33.8	M	M
Check:	Tamayutaka		345	30.0		

*Area 1, Mountain Prov., Bainina-Poitaan.
Area 2, Ifugao Prov., Bublei-Ligang.
Area 3, Ifugao Prov., Liwang-Mayaoyao.
Area 4, Ifugao Prov., Lugu.
Area 5, Ifugao Prov., Piwon-Lagawi
Area 6, Ifugao Prov., Kiangan.
Area 7, Ifugao Prov., Sadaga
Area 8, Ilocos Norte Prov.

**HR, highly resistant; R, resistant; M, moderately resistant; S, susceptible; HS, highly susceptible.

topography, soil fertility, and soil structure in their native habitat. Furthermore, local cultivars are valuable genetic stock when breeders wish to produce outyielding modern varieties because a prominent variety for a proper area is (as demonstrated in some crops) exclusively produced from the hybrids whose parent or parents are the long adapted, indigenous cultivars. In short, the genetic diversity in native cultigens provides a basis for the establishment of new varieties.

Genetic diversity is rapidly reduced when the activity of local agriculture is on the ebb. There may be many social causes of recent genetic erosion. One cause is said to be the modern breeding program aiming at a widely adaptable supervariety.

The following is a summary of a proposal for a breeding system that is consistent with gene conservation in local regions.

> Varieties that are different in growth type, response to nitrogen, maturity time, tolerance to environment stress, and resistance to pathogens and pests should be chosen as indicators of the ecological factors. The yield trials of these indicators could be conducted for 5 to 10 years in the local regions.
>
> The regions could be classified into a few ecological areas with a battery of yield tests of the indicator varieties.
>
> Traits of an indicator ought to be design criteria for breeding lines that would have better fitness in an ecological area.
>
> However, the selection and evaluation at the breeding center will not always guarantee the production of breeding lines highly adaptable to the remote local regions. Then, the final selection for promising lines is left in the hands of the local growers or farmers.

The above proposal is only a desk plan. It, however, aims to have an outcome of hundreds of leading varieties if there are 100 ecologically different areas. Ten years is more than enough wherein ample genetic resources are lost; but the same time expanse is rather short for the production of at least one outstanding variety.

REFERENCES

Haldane, J.B.S. 1948. The number of genotypes which can be formed with a given number of genes. Jour. Genet. 49:117-119.

KAES (Kyushu Agricultural Experiment Station) 1961. Crossing Experiments in Sweet Potato. Ann. Report. p. 84.

KAES. 1962. Crossing Experiments in Sweet Potato. Ann. Report. p. 64.

KAES. 1967. Crossing Experiments in Sweet Potato. Ann. Report. p. 106.

KAES. I980a. Ann. Rep. Sweet Potato Breeding. p. I64.

KAES. I980b. Crossing Experiments in Sweet Potato. Ann. Report. p. I82.

KAES. I98Ia. Annual Report. Sweet Potato Breeding. p. I53.

KAES, I98Ib. Crossing Experiments in Sweet Potato. Ann. Report. p. I82.

KAES, I982a. Annual Report. Sweet Potato Breeding. p. I73.

KAES, I982b. Crossing Experiments in Sweet Potato. Ann. Report. p. 72.

KAES. I984. Crossing Experiments in Sweet Potato. Ann. Report. p. 78.

KAES. I985. Crossing Experiments in Sweet Potato. Ann. Report. p. 86.

Kobayashi, M. 1984. The *Ipomoea trifida* complex closely related to sweet potato. Proc. 6th Int. Sym. Trop. Root Crop, Lima, Peru. pp. 2I-26.

Martin, F.W. and A. Jones. I986. Breeding sweet potatoes. Pl. Breed. Review. 4:3I3-345.

Nishiyama, I. I97I. Evolution and domestication of the sweet potato. Bot. Mg. Tokyo. 84:377-387.

Nishiyama, I. I982. Sweet potato. Proc. Ist Int. Sym. (R.T. Villareal and T.D. Griggs, eds.). AVRDC, Tainan, Taiwan, China. pp. 263-274.

Ono, T., S. Marumine and O. Yamakawa. I972. Regional yield response of the sweet potato varieties in Kyushu district. Ann. Rep. Kyushu Agr. Exp. Sta. pp. I9-2I.

Sakamoto, S. I974. Studies on the flowering of sweet potato and related species. 2. Inheritance of flowering habits. Jap. J. Breed. 24 (suppl. 2):2I0-2II

Shiotani, I. I987. Genomic structure and the gene flow in sweet potato and related species. Proc. Plan. Conf. "Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources." CIP, Lima, Peru. (*in press*).

Shiotani, I. and T. Kawase. I970. Genomes of sweet potato, *Ipomoea batatas* (L.) Lamk. Jap. J. Breed. 20 (suppl. I):83- 84.

Shiotani, I. and T. Kawase. I980. Origin and differentiation of the sweet potato. 2. Genome constitution and domestication. Jap. J. Breed. 30 (suppl. 2):306-309.

Takemata, T. and K. Sakai. I975. Agronomic characters of an introduced sweet potato collection from New Zealand. J. Cent. Agr. Exp. Sta. 22:2II-239.

Yunoue, T. and S. Hirosaki. I975. Effects of the selection of fertility of in-bred parent lines in sweet potato breeding. Bull. Kyushu Agr. Exp. Sta. I8 (I):I-42.

RECENT TRENDS IN WORLD SWEET POTATO PRODUCTION AND USE

Douglas E. Horton*

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is grown in more than 100 countries. Among the world's root crops, it is second only to white potato (*Solanum tuberosum*) in importance (Horton, 1987). Nevertheless, until recently, few resources have been allocated to agricultural research and development programs involving sweet potato. In a recent review of priorities and future strategies for the Consultative Group on International Agricultural Research, the Group's Technical Advisory Committee noted that sweet potato was a neglected crop in the CG System. "Efforts should be increased significantly to a level where critical mass is assured" (TAC, 1985).

If additional resources were available for sweet potato research and development (R&D), how should they be used? Should they be used for breeding, agronomy, entomology, or extension? Should R&D efforts focus on raising yields, improving consumer quality, or diversifying end uses. To answer these basic questions of resource allocation, it is essential to know where, how, and by whom sweet potato is grown and used. The major constraints to its further production and use also need to be identified.

Published literature on sweet potato production and use is quite few, and statistics on production patterns and trends are not very reliable. This paper outlines the broad patterns and trends in world sweet potato production and use that can be discerned from available statistics. It then discusses some of the major factors that are likely to influence future trends. At the end, a plea is made for researchers in each country to participate in a survey of constraints to sweet potato production and use.

MATERIALS AND METHODS

This paper is based on unpublished data provided to the International Potato Center (CIP) by the Basic Data Unit of the Food and Agriculture Organization (FAO) of the United Nations. After the author presented a similar paper on root crop production trends at the 1981 symposium of the

*Head, Social Science Department, International Potato Center (CIP), Aptdo. 5959, Lima, Peru.

International Society for Tropical Root Crops, the eminent root crop specialist D.G. Coursey commented: "We all know how worthless these numbers are, but it is a contribution of sorts to put them all together in one place." We all know many shortcomings of the FAO data. However, they can provide useful background information for planning sweet potato R&D if judiciously used.

Every year, FAO estimates the area, yield, production, foreign trade, and domestic utilization of every crop grown or used in every country of the world. Official country statistics are used whenever these are available. In other cases, rough estimates -- usually "guestimates" -- are made.

The "Food Balance Sheet Equation" provides the framework for FAO's statistical compilations.

Food Balance Sheet Equation

Production + Imports − Exports − Change in Stocks = Total Domestic Availability = Seed + Feed + Manufacturing + Waste + Food

The estimation process begins with area, yield, and production, to which imports are added, and exports and inventory accumulations are subtracted. In the case of cereal grains and traditional export crops, easily documented international trade flows provide statisticians with a basis for checking their production estimates. However, this is not possible for root crops, which are seldom traded in international markets. Since many root crops are grown as intercrops in remote areas of small, irregular fields, farm surveys and censuses often overlook them. Hence, official statistics often grossly underestimate root crop production.

Estimation of the uses of root crops is perhaps even more difficult than measuring production. It is extremely difficult to estimate the percentage or root crops that is fed to livestock, processed, and wasted. For example, numerous studies (Christiansen, 1967; Werge, 1979; Yamamoto, 1987) have documented the importance of Andean potato processing. Yet Peru's official statistics indicate that no potatoes whatsoever are processed. The situation is likely to be similar with sweet potatoes.

Each year, FAO publishes a *Production Yearbook* with estimates of each major crop's harvested area, yield, and production. Every five years or so, FAO publishes estimates of crop utilization in its *Food Balance Sheets*. Together, these are the most comprehensive published sources of national, regional, and world crop production and utilization statistics. Unfortunately, however, these do not provide a valid base for time series analysis. This is because FAO continuously revises and updates its estimates of crop production and use. In many cases, the data revisions produce sharp discontinuities in the published time series. For example, in

1983, FAO revised its estimate of sweet potato production in China *downward* by 30 million tons and its estimate for potato *upward* by a similar amount, causing sharp breaks in the published statistical series for both crops.

FAO's Basic Data Unit, which compiles and analyzes the statistics on which the *Production Yearbooks* and *Food Balance Sheets* are based, maintains a computerized data bank with consistently revised estimates back to 1961. Each year, CIP obtains FAO's most up-to-date estimates of root crop production and use for the entire period. This paper is based on an analysis of the 1961-1985 data set for sweet potato.

Given the weakness of data in many developing countries, this paper outlines general regional patterns and trends, and does not analyze specific estimates for individual countries. Moreover, given the particular weakness of utilization data, the discussion focuses on production patterns and trends.

RESULTS AND DISCUSSION

The results can be grouped under four headings: global distribution of root crops, major producing countries, production trends, and prospects for the future.

Global Distribution

Roughly 80 percent of the world's sweet potato is grown in Asia and just under 15 percent in Africa. Only about 5 percent is grown in the rest of the world (Table 1). Europe grows virtually no sweet potato and North American production is small. This pattern contrasts sharply with that of potato, much of which is grown in Europe and North America. Because the northern latitude industrial countries produce few sweet potato and have done little sweet potato research, the base of research knowledge for this crop is thinner than it was for potato when CIP began work in the early 1970s.

Developing countries grow nearly all of the world's sweet potato. China alone accounts for about 80 percent. China has also much higher sweet potato yields and production per head than any other world region. Yields in China are double those of other regions and production per head is several times higher.

Major Producing Countries

With about 90 million tons of sweet potato, China is by far the world's largest producer (Fig. 1). Indonesia, the second largest, produces only 2.5

million tons.

Given the large size and importance of China, it is useful to note the distribution of sweet potato production within the country. Each star in the accompanying map (Fig. 2) is equivalent to 500,000 mu. The original Chinese source reports in units of 10,000 mu. Since 15 mu are equal to 1 ha, each star represents approximately 33,000 ha. These conversions illustrate just one problem of interpreting root crop statistics in China and other countries. Chinese statistical yearbooks classify root crops as "grains" and record root crop production in grain-equivalent units. Sweet potato and other root crops grown in vegetable gardens -- a very significant volume -- are excluded from the official estimates.

While China is the largest sweet potato producer, some other countries have higher levels of per capita production (Fig. 3). According to FAO, the first five countries in this respect are Solomon Islands, Tonga, Rwanda, Papua New Guinea, and Uganda. In most of these countries, sweet potato plays an essential dietary role as a staple food.

Table 1. World sweet potato production, area, yield, and production per capita, 1983/85 average.

	Production (x103 t)	Yield (t/ha)	Harvested area (x 10^3 ha)	Production per capita (kg)
World	114,185	14	7,998	24
Asia	104,603	16	6,413	38
(China)	(93,550)	(18)	(5,067)	(91)
Africa	6,100	6	1,094	11
North & Central America	1,442	7	213	4
South America	1,371	9	153	5
Oceania	560	5	116	23
Europe	108	11	10	0
All developing countries	111,979	14	7,867	32
All developed countries	2,206	17	131	2

Source: CIP Root Crop Data Bank. Derived from FAO Basic Data Unit (unpublished). This source also applies to Figures 1-7.

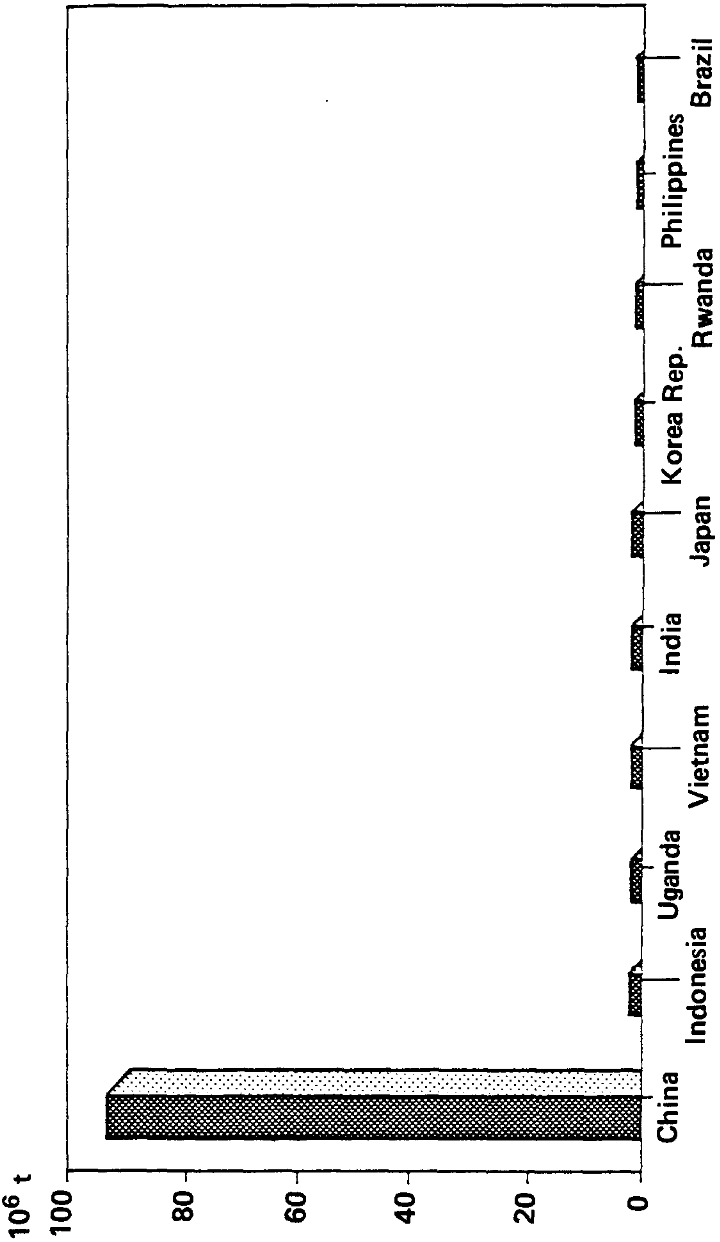


Figure 1. Ten largest sweet potato producing countries.

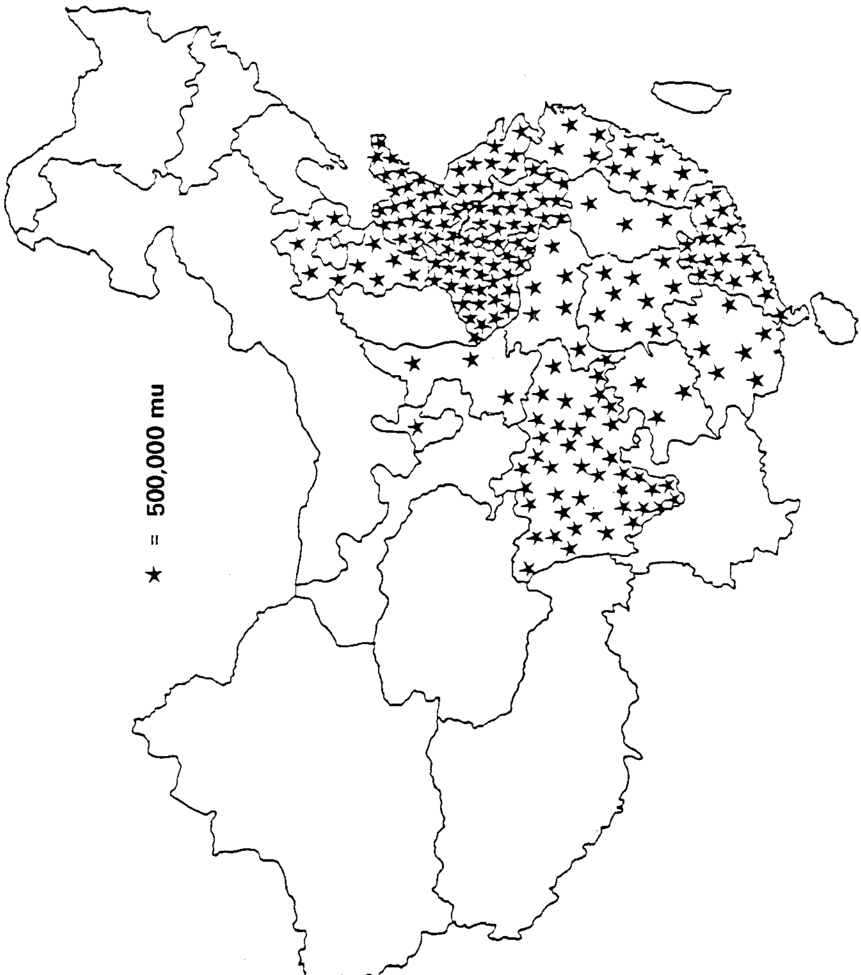


Figure 2. China's sweet potato growing areas.

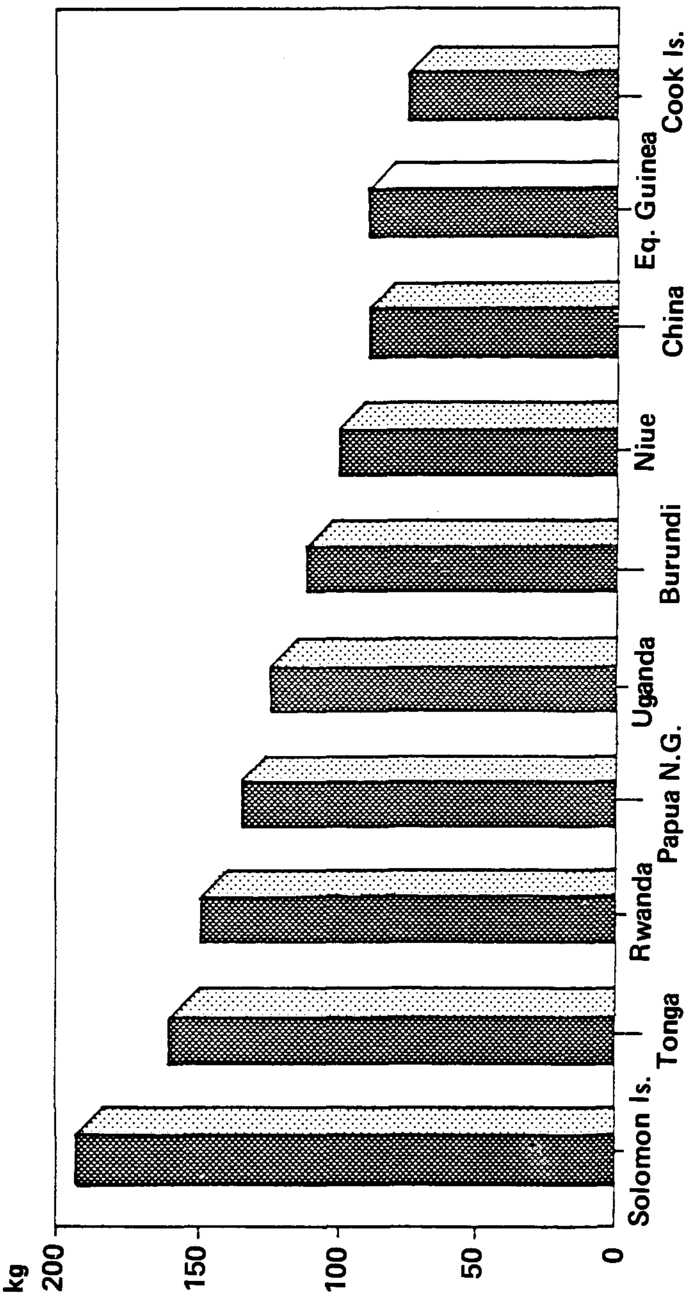


Figure 3. Sweet potato production per capita.

Production Trends

World sweet potato production increased from 1960 to about 1975 and since then it has somewhat declined (Fig. 4). Given the large magnitude of China's sweet potato production, the world trend practically mirrors the trend for all developing countries, which in turn mirrors the trend in China.

Japan and the USA are the only industrial nations that grow significant amounts of sweet potato. Production has fallen dramatically in Japan (Fig. 5). It is generally believed that this was due to an inverse relationship between income and sweet potato consumption levels. As household incomes rose, the Japanese, who consider sweet potato as an inferior food, reduced their consumption of this root crop. However, this should be considered a research hypothesis rather than a fact, since the effects of production costs, marketing problems, and other factors have never been carefully examined. In the USA, sweet potato production has also fallen but relatively less compared with Japan. Here too, there has been little empirical research on the determinants of declining sweet potato production and consumption.

In Latin America, sweet potato production rose in the 1960s, fell in the 1970s, and thereafter stabilized. In China and the rest of the Far East, production followed a similar but less pronounced trend. Only in Africa has production tended to increase throughout the entire period since 1960 (Fig. 6).

In summary, available statistics indicate that sweet potato production has fallen rather sharply in the developed countries (mainly in Japan) and increased modestly and rather erratically in the developing countries (mostly in China).

It is interesting to note that the rather lackluster production trend for sweet potatoes in developing countries contrasts sharply with the production trend for potato which has been steeply upward throughout the period (Fig. 7). The reasons for the potato crop's rapid expansion in developing countries have been discussed elsewhere (Horton, 1987).

Prospects for the Future

It is impossible to predict future trends. Experiences with other crops, however, indicate that agricultural research and development programs can influence production trends by solving problems of three kinds: supply, marketing, and demand (Table 2).

When CIP first set its research priorities for potato, the main factors limiting potato production and use in developing countries were the crop's limited supply and its high price. People wanted more potato but low yields, high costs, and restricted environmental adaptation limited production and use. In contrast, some studies (Lin et al., 1985; Martin, 1983) indicate that marketing and demand problems for sweet potato may

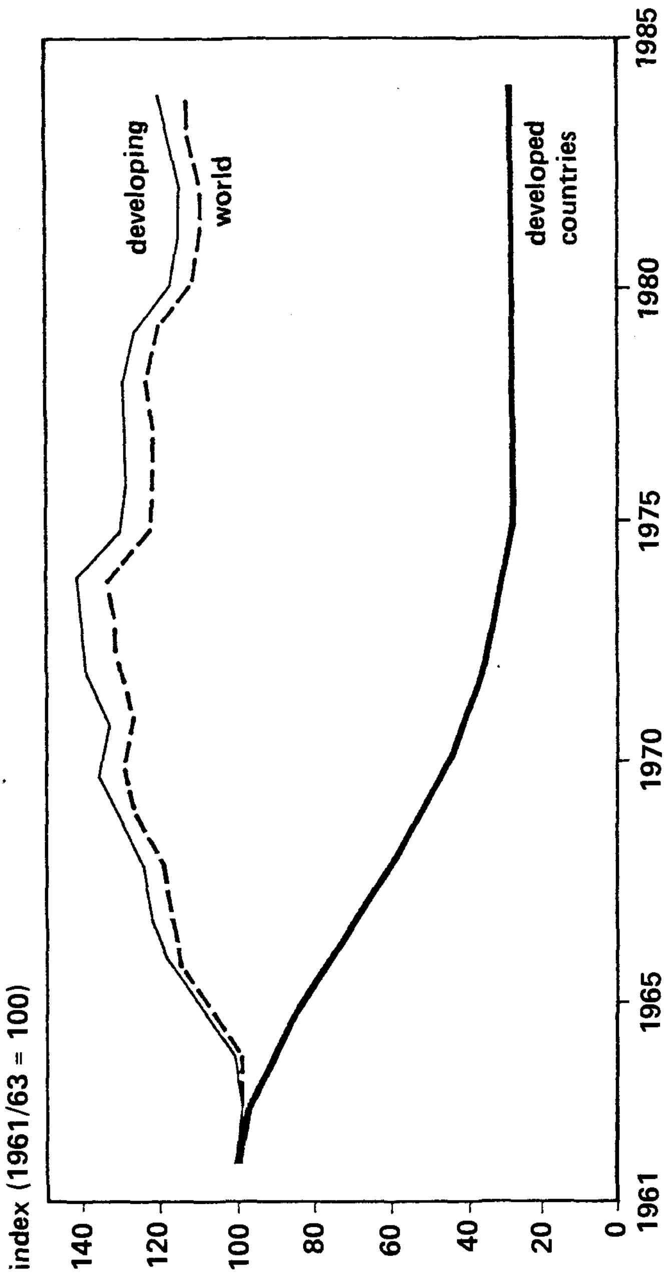


Figure 4. World sweet potato production trends (3-year moving averages).

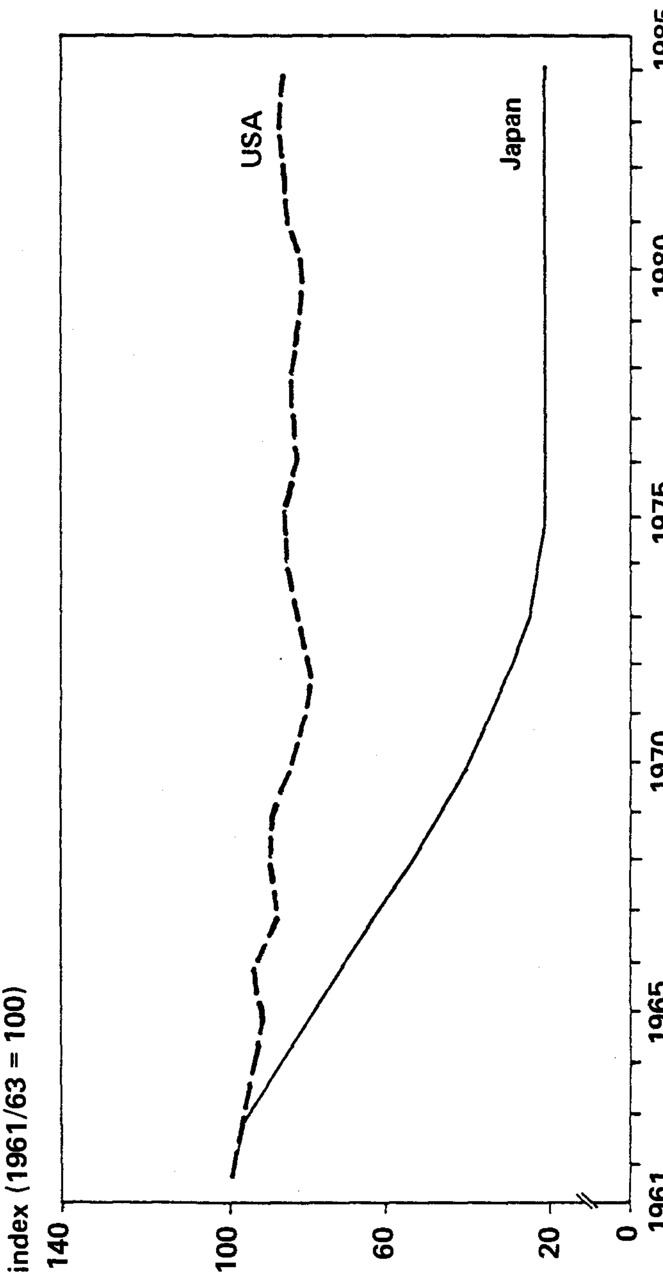


Figure 5. Sweet potato production trends in Japan and USA (3-year moving averages).

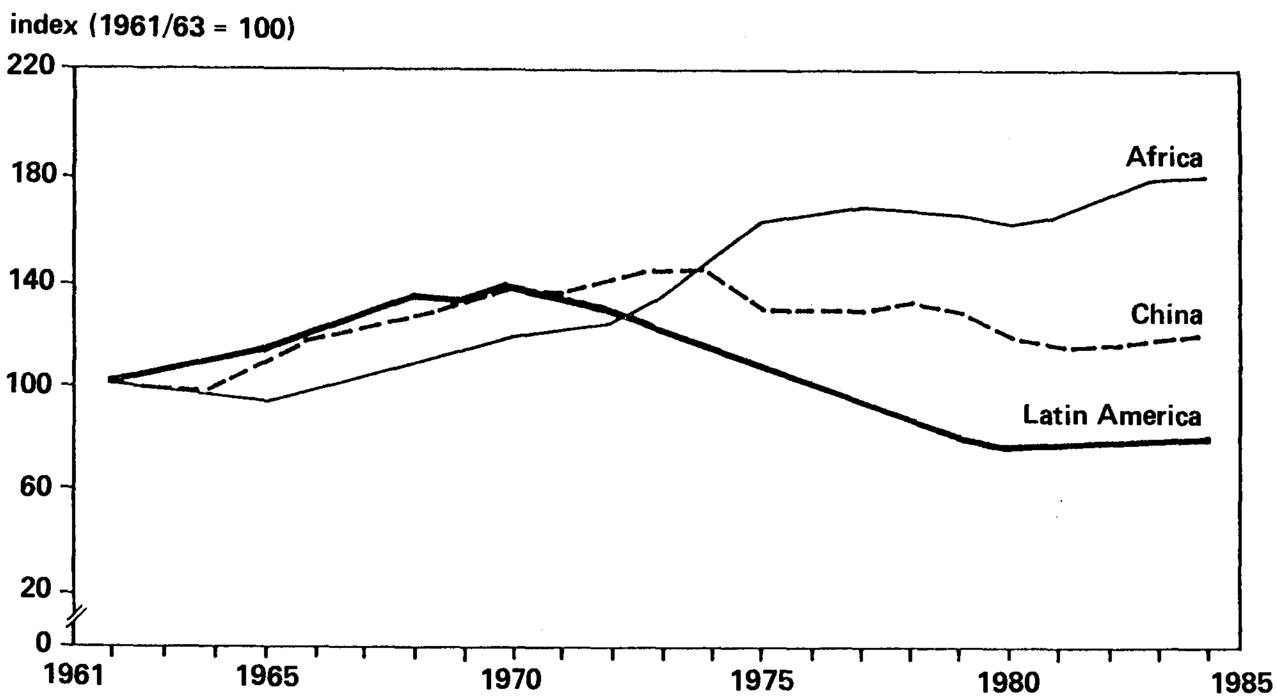


Figure 6. Sweet potato production trends in Latin America, China, and Africa (3-year moving averages).

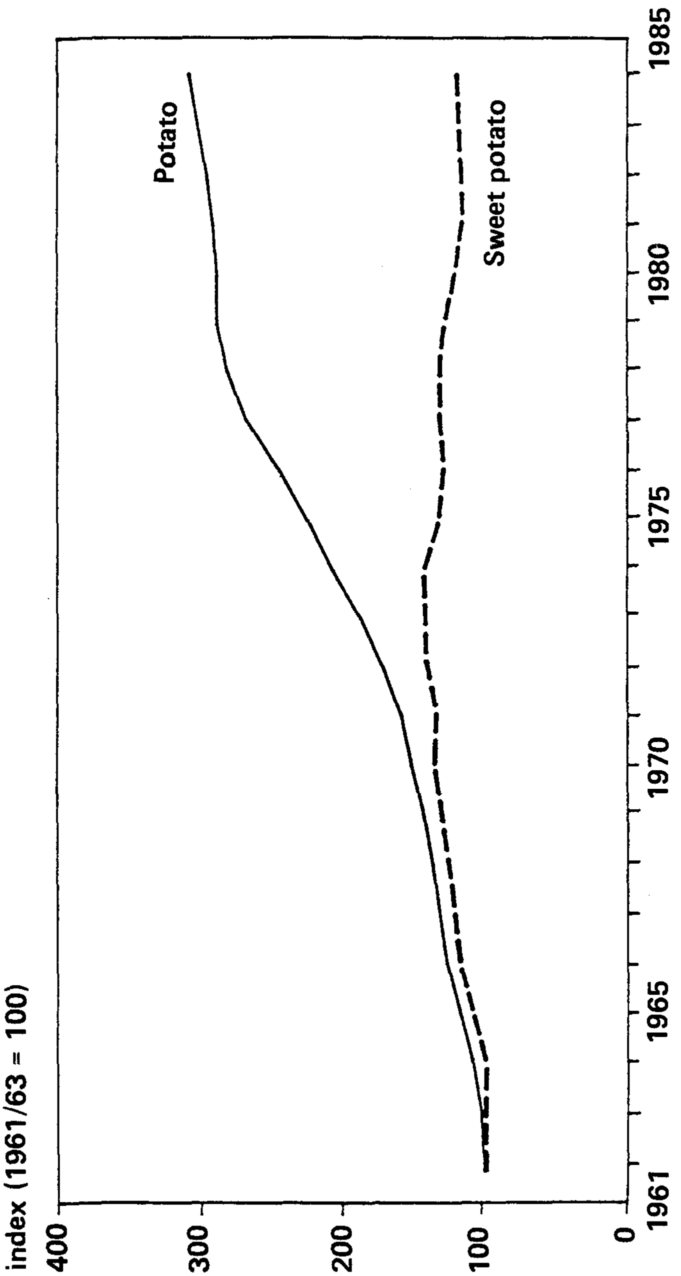


Figure 7. Potato and sweet potato production trends in developing countries (3-year moving averages).

be more important than production constraints per se. Owing to the perishability of sweet potato and the rather primitive transportation and marketing system in many developing countries, marketing and handling problems certainly deserve careful research attention.

Table 2. Potential constraints to sweet potato production and examples of solutions.

Constraint	Solution
Supply	Raise yields
	Lower production costs
	Expand environmental adaptability
	Improve pest and disease management
Marketing	Reduce perishability
	Improve storage and handling
	Improve market information
Demand	Improve quality
	Overcome consumer prejudices
	Diversify uses (feed, industry)

Beyond problems in the marketing system, demand factors may also limit the use of sweet potato. Several authorities have stated that sweet potato consumption is limited by quality factors (Villareal and Griggs, 1982; Collins, 1987). If so, consumer studies in representative areas are needed to identify precisely which aspects of sweet potato should be improved by breeders.

It has also been stated that consumer prejudices limit sweet potato consumption (Tsou and Villareal, 1982). For example, Koreans are said to reject sweet potato because it was a survival food during the Second World War. This logic is not entirely convincing since people who survived on white potato during World War II do not seem to have developed an aversion to it. In short, little is known about why people do or do not like sweet potato. If this root crop is to play an expanded role in meeting the food requirements of developing countries, more need to be known about consumer preferences, prejudices, and how they affect consumption.

A promising avenue for expanding the demand for sweet potato may be to diversify its end uses. In China, most sweet potatoes are processed or fed to livestock (Lu et al., 1987). In Taiwan, a large amount of sweet potato is also used for feeding livestock and in the Republic of Korea, for starch. Expanding such uses in other countries could indirectly increase the food supply, provide additional employment, and expand income sources.

In agricultural R&D, the traditional approach has been to focus attention first on raising yields and production and only later to consider issues of marketing and demand. This is in many ways like "putting the cart before the horse." Increasingly, we are becoming aware of the need to target R&D to meet the needs of specific groups and markets. With the background of national and regional statistics presented in this paper, the next logical step is to assemble more systematically in-country information on sweet potato production zones and systems, marketing, and end uses. Production cost and prices at various points in the marketing chain are essential for gauging the actual and potential competitive position of sweet potato as food, livestock feed, and industrial raw material. Once the requirements of potential end users and the principal constraints to sweet potato production have been determined, decision-makers will have a more solid basis for assigning resources to sweet potato improvement programs.

To improve the information base on these topics, a detailed questionnaire on "Constraints to Sweet Potato Production and Use" has been prepared. It is hoped that representatives from each of the countries present will take the time to fill out these questionnaires and to return them to CIP in Lima. Just as soon as initial tabulations of results are available, these will be made available to all collaborators in the survey.

SUMMARY AND CONCLUSIONS

At a time when sweet potato is beginning to receive greater attention in the international agricultural community, national and regional statistics on patterns and trends in sweet potato production and use can help guide future research and development efforts.

Nearly all sweet potato is produced and consumed in developing countries. Since the crop is not important in most developed countries, there is a relatively small research base to build on. Utilization estimates are poor. It is believed that in most places sweet potato is consumed fresh, but in China most are processed or fed to livestock. Since 1960, sweet potato production in Japan and in the USA has fallen. Production has been rather erratic in most developing areas, except in Africa where it has increased rather steadily.

Since there has been little socioeconomic research on sweet potato production and use, little is known about the determinants of these past trends. Future R&D efforts need to address problems of production, marketing, and demand. More information is needed to determine the relative importance of these three problem areas and the specific problems that need to be addressed within each area. Preliminary information suggests that issues on marketing and demand should be high on the research agenda to determine the types of sweet potato and postharvest technology that are needed for production of food, feed, starch, and other products. To begin assembling the needed information, the participation of sweet potato experts in a questionnaire survey of constraints to sweet potato production and use is essential.

REFERENCES

Christiansen, J.G. 1967. El Cultivo de la Papa en el Peru, Lima. Editorial Juridica.

Collins, W. 1987. Improvement of nutritional and edible qualities of sweet potato for human consumption. *In* Proceedings, XXX Planning Conference: Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

FAO (Food and Agriculture Organization). 1985. Food Balance Sheet average 1979/81. FAO, Rome, Italy.

FAO. 1986. FAO Production Yearbook 1985. FAO, Rome, Italy.

Horton, D. 1987. Potatoes: Production, Marketing, and Programs for Developing Countries. Boulder, Westview.

Lin, S.S. M., C. Peet, D-m. Chen and H-F. Lo. 1985. Sweet potato production and utilization in Asia and the Pacific. *In* Bouwkamp, J.C. (ed.). Sweet Potato Products: A Natural Resource for the Tropics. CRC Press, Florida.

Lu, S.Y., G.L. Shen, and B.F. Song. 1987. The goals of sweet potato breeding in China. *In* Proc. XXX Planning Conference: Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

Martin, F.W. 1983 Goals in breeding the sweet potato for the Caribbean and Latin America. *In* Proc. American Society for Horticultural Science, Tropical Region, Part B, Vol. 27.

TAC (Technical Advisory Committee, Consultative Group on International Agricultural Research). 1985. TAC Review of CGIAR Priorities and Future Strategies (draft). FAO, Rome, Italy.

Tsou, S.C.S. and R.L. Villareal. 1982. Resistance to eating sweet potato. *In* Villareal, R.L. and T.D. Griggs (eds.). Sweet Potato: Proceedings of the First International Symposium. AVRDC, Shanhua, Taiwan.

Villareal, R.L. and T.D. Griggs (eds.). 1982. Sweet Potato: Proc. First International Symposium. AVRDC. Shanhua, Taiwan.

Werge, R. 1979. Potato processing in central highlands of Peru. Ecol. of Food Nutrition. 7:229-234.

Yamamoto, N. 1987. Las Tecnicas Tradicionales del Procesamiento de Papa en Los Andes, Food Systems Research Paper. CIP, Lima, Peru. (*in press*).

SMALL POTATO, SMALL FARMERS,AND NEED FOR COOPERATIVE RESEARCH

Kenneth T. MacKay*

INTRODUCTION

Sweet potato is one of five most important crops in terms of production, economic value, and contribution to calories and proteins. Although it originated in the Americas, sweet potato is now an Asian crop. Asian and Oceanic countries account for 92 percent of total world production; China alone accounts for 82 percent of the total (Table 1). Five other countries, -- Vietnam, Indonesia, India, the Philippines, and Papua New Guinea -- have sweet potato production areas of more than 100,000 ha. There are wide variations in yield per hectare (i.e., from a low of 3 mt in Thailand to a high of 25 mt in the Republic of Korea). The yield has increased considerably in China from 10 to more than 20 t/ha primarily because of changes in cultural techniques (e.g., use of high ridges and wide rows, resulting in increase in plant density). Discrepancies can also be noticed between figures of the Food and Agriculture Organization (FAO, 1986) and the figures presented in Table 1 since it is considerably difficult to collect accurate data on a subsistence and neglected crop like sweet potato.

The area planted to sweet potato has decreased in the past 10 years while production has increased slightly. However, it varies from country to country (Fig. 1). In China, the production area increased after 1949 to a peak of more than 9 million ha during the 1960s and 1970s and has decreased since then to less than 7 million ha. In Vietnam and Kampuchea, there have been recent large increases in area planted. This is probably associated with economic and political disruptions of other agricultural activities. Figures for Sri Lanka (Jayawardena and De Silva, 1987) likewise show a large increase in production from 1973 to 1976 which is associated with acute food shortages. Production has decreased since then as rice production and wheat imports increased. There are also suggestions from Papua New Guinea that population pressure in the highlands and migration from the lowlands resulting in labor shortages have resulted in increased production of sweet potatoes (Kanua and Rangai,

*Program Officer (Crop and Animal Production Systems), Agriculture, Food and Nutrition Sciences Division, International Development Research Centre, Regional Office for

1987). In the Philippines, production appears to have increased in the past three years because of short-term food needs following typhoons, increased crop diversification in sugar lands, and increased specialty marketing of new varieties.

Table 1. Average sweet potato production in different parts of Asia, 1983-85.

Country	Area (x 10^3 ha)	Yield (mt/ha)	Production (x 10^3 mt)
China (Av 82-83)	5,098 (6,900)	18.4	94,033
Vietnam (1980-83 Av)	390 (561)	4.8 (5.6)	1,867 (3,142)
Indonesia (Irian Jaya)	275 (50)	8.0	2,200
India	212	7.4	1,565
The Philippines	191	4.6	873
Papua New Guinea	102	4.6	464
Japan	65	22.0	1,435
Bangladesh	66 (82)	10.8 (13.7)	714 (1,200)
Republic of Korea	39	24.7	965
Korea DRR	31	14.2	440
Thailand	40	3.2	129
Sri Lanka (1980)	15 (6)	8.6 (10.3)	129 (65)
Oceania (– PNG)	14	6.9	96
Malaysia	3	17.0	51
Laos	4	9.4	38
Kampuchea (AV 80-82)	3 (14.8)	9.4 (3.8)	28 (56)
Burma	5	4.8	24
Total world (1983-85)	8,026	14.2	114,321

Source: FAO, 1986. Figures in parenthesis represent data presented in this meeting.

In much of Asia, sweet potato is an emergency crop, and usually associated with hard times -- wars, typhoons, other natural disasters, and economic disruptions. Sweet potato is a crop of the smallest and poorest farmers (Jayawardena and De Silva, 1987; Rashid, 1987). Women are also very heavily involved in its production, processing, and marketing, par-

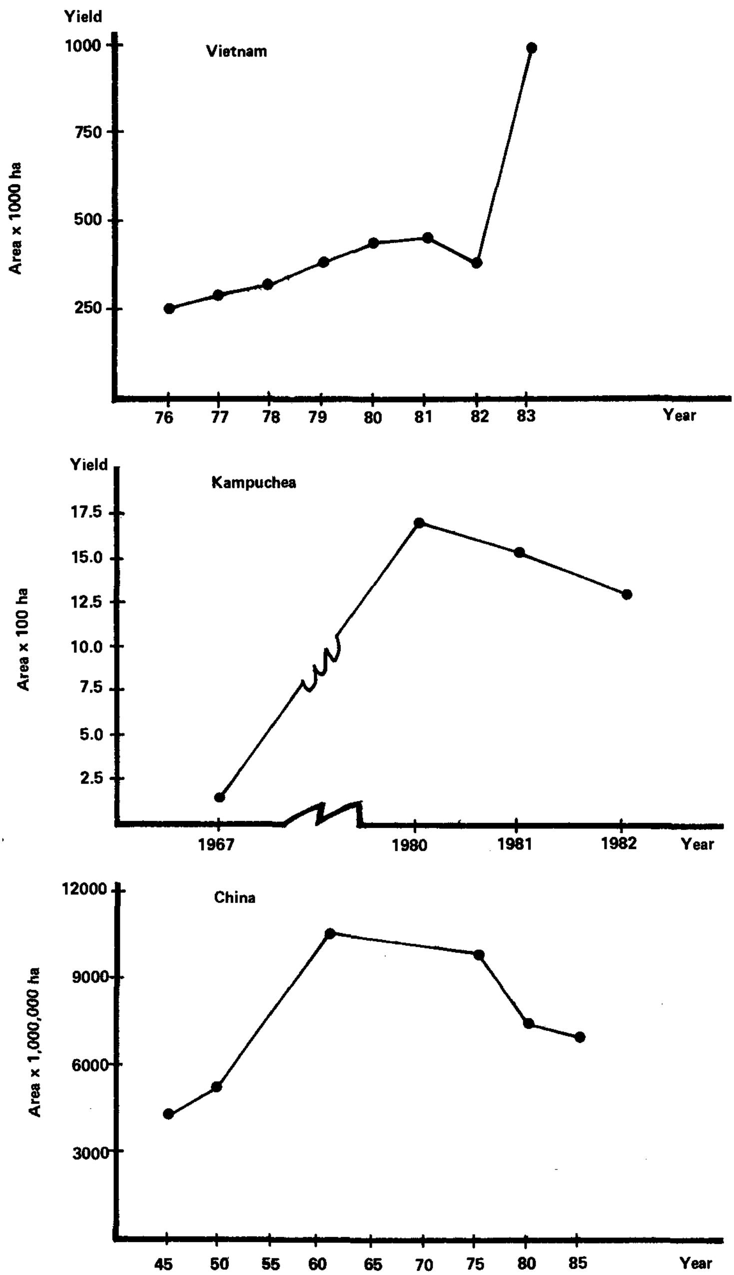


Figure 1. Changes in area of sweet potato production in Vietnam, Kampuchea, and China. (Data were taken from papers and documents presented in the workshop.)

ticularly in Papua New Guinea and the Philippines. Table 2 gives preliminary data from a study carried out in the Philippines which shows the considerable involvement of women from planting to marketing.

Sweet potato is an ideal crop for small farmers. It is highly adaptable and can be grown from 15° south to 45° north and from sea level up to 2,800 m. It can also adapt to a wide range of moisture and fertility conditions and can give adequate yields with very little fertilizer inputs. Yield varies from country to country (Table 1). In Bangladesh, the average yield with no fertilizer is 13.7 t/ha (Rashid, 1987) while Kanua and Rangai (1987) reported yields of up to 21 t/ha from the highlands of PNG using only farmers' techniques of mulching, composting, and ash fertilizer. Sweet potato is grown in different farming systems (i.e., from lowland paddy after rice to upland slope). It can be interplanted with a wide variety of other crops (e.g., coconut, maize, cassava, sugarcane, legumes such as peanut and soybean, and even opium). It also has unlimited seasonality so it can be easily grown throughout the year.

Sweet potato has various uses. It is grown by many farmers as a subsistence food. It is particularly important in the Visayas region of the Philippines and in Papua New Guinea (both PNG and Irian Jaya) as a staple food; in Bangladesh as a dry season food when rice runs out; and in China and Vietnam where it is an important staple after rice, maize, or wheat. It is also an important vegetable crop -- the most important vegetable in the Philippines. Their roots are often used in curries while the fresh tips are used as a green. In Thailand and South Asia, however, the leaves are not consumed. Sweet potato is also an important confectionary food in Thailand, Malaysia, and the Philippines. Sweet potato has the potential for processing. However, there is limited commercial processing of sweet potato in Asia with the exception of Taiwan and Japan.

The crop is an important animal feed. In Taiwan, 73 percent of sweet potato production is used for animal feed (Yeh, 1982). The vines are an important pig food in China and PNG. Small farmers use the stems and tubers to feed pigs and ruminants. Trials using dry chips as feed ingredients have been carried out in the Philippines and Taiwan, but they are not yet widely used because of the dominance of low-cost imported maize in most prepared animal feeds.

Sweet potato is considered a traditional crop in Asia and Oceania. While there is a controversy over the time and method of introduction of sweet potato in the region (Yen, 1982), the crop has been grown in most Asian countries for 200 to 450 years. Yet, it is considered a native crop and there are also considerable indigenous techniques for its production. In addition, there are religious beliefs associated with sweet potato production in some countries. There is also a large germplasm availability, particularly in PNG and the Philippines, which are considered to be secondary centers of variability.

Table 2. Percent involvement of household members in sweet potato production and marketing.

Household member	Obtaining planting material	Land preparation	Weeding and Soil cultivation	Pest control	Chemical fertilizer application	Harvesting	Processing	Marketing
Husband	66	78	62	3	34	79		28
Wife	48	48	45	3	26	72	24	75
Children	59	48	45	3	17	62		10

Source: Escalada and Binongo, 1987.

Table 3. Farmers' assessment of sweet potato varieties.

Variety	Taste*	Storage in soil**	Maturity period (month)	Yield class	Vining (month)	Duration harvest (month)	Tuber diameter (cm)	Pests/ weevil***
Kadulaw	S/D	Good, Poor	3-5	1, 2	1-3	7-8, 12	6-10	Res
Karingkit	S/D	Good	4-7	1	2	12	10	Res
VSP-1	S/W	Good, Poor	2-3	2, 3	0	1	5-6	Sus
VSP-2	S/W	Good, Poor	2-3	2-4	0	1, 2	4-8	Sus

*S = Sweet, D = Dry, W = Wet
**Good/Poor = Easily Rotting
***Res = Resistant, Sus = Susceptible

In spite of the large differences in production techniques, cropping systems and utilization, some generalizations can be made:

- Sweet potato is produced by rural households on farms of less than 2 ha with considerable involvement of women. A portion of the crop is eaten, probably stored in ground, and often used during food scarcity. The surplus is sold for cash, usually for consumption by urban poor or landless laborers. The tops, surplus, and damaged tubers are fed to animals.
- Sweet potato production involves no purchases of inputs apart from seedlings (often produced on farm), family labor, and land. Land is usually poor and marginal.
- Farmers grow a mixture of cultivars, as many as 10 per farm, often with different micro habitats and different tastes and uses.
- Sweet potato is usually grown as an intercrop.
- The major problems are sweet potato weevils, rats, and pigs.
- Little or no research or extension assistance is available.

RESEARCH NEEDS

The following are some unique features of the research needed for a subsistence low-input crop for small farmers like sweet potato.

Diversity

There is a need to collect and preserve existing germplasm, particularly in Irian Jaya, PNG, and the Philippines. In addition, the practice of many farmers to maintain considerable diversity by planting a number of different cultivars on their farms so that new varieties or cultivars are able to fit in the system must be appreciated by breeders. This is not easy as Kanua and Rangai (1987) pointed out that "limited evidence suggests that the traditional system of mixed variety plantings has complicated the acclimatization process of newly bred or recommended sweet potato cultivars which are usually selected in monoculture plantings."

Farmers often determine variety preference by taste, texture, or color and not necessarily by yield. This raises a number of problems for both the farmer and the researcher. First, it implies practical difficulties for future adoption of improved cultivars into their mixed variety planting system by farmers. Second, varieties selected for yielding ability in government research stations may not be acceptable to the farmers' taste. Furthermore, it complicates future research in that variety screenings have to be carried out in mixed variety plots as opposed to the traditional monovariety plantings.

Overall, to overcome these constraints, future genetic research must select for specific local needs such as improved protein quantity and quality, taste and color preference combined with yield. However, this is not easy to achieve, particularly for a very highly variable crop like sweet potato.

Low Inputs

It is tempting to look at farmers' yields side by side with research station yields which may be 600 percent greater and suggest that farmers should strive for them. However, most resource-poor farmers do not have cash and supply of inputs or credit, nor are there market systems in place to sell excess potatoes. In the short run, increases will have to come from simple low-input technology and breeding advances. Jayawardena and De Silva (1987) pointed out that current practices in Sri Lanka have a very low cost of production and subsequently a high return for land and labor. They suggested that "the main research objective should be to increase the farmers' income level and not the tuber yield per unit area. In this respect, more research on cost-reducing technologies must be carried out with the idea of reducing the need for weeding, chemical inputs, and intensive cultural methods."

Intercropping

If farmers traditionally grow sweet potato in intercrop, then new cultivars and technology must be tested under these conditions.

Weevil Control

In addition to breeding for resistance, it will be important to study the various cultural techniques that farmers already use to control weevil.

Storage

It will be important to follow the experience of International Potato Center (CIP) in learning from farmers (Rhoades and Booth, 1982; Rhoades et al., 1985). What are the problems? Are they storage of marketable potatoes or seed? Should storage be in ground or in storage structures? What are the labor requirements for single harvest and storage and those in ground storage and multiple harvests?

Learn from Farmers

Sweet potato farmers (both men and women) have centuries of experience in growing, selecting, and managing sweet potato. They and their ancestors were the ones who selected and bred most of the cultivars they used. It is, therefore, important to learn more from the farmers, their constraints, and their traditional techniques. This can be done by formal and informal surveys, and on-farm and informal experiments. It is perhaps instructive to follow the experience of the introduction of the new sweet potato varieties from ViSCA in this region in order to determine lessons that may have wider application. A recent evaluation of the ViSCA sweet potato research (Escalada and Lopez, l986) indicated that the VSP lines had been widely distributed, that yield potential was appreciated by both small and large farmers, and that farm size was not a critical factor in adoption. The short maturity of the new varieties was most appreciated in typhoon-affected areas. The new varieties contributed to land intensification while the production increase generated local processing for snacks and delicacy items and lowered the price to consumers. In addition, the officially released varieties were not necessarily the farmers' choice and there was a need for the release of regionally adapted varieties. Most important, the farmers fit the varieties and the new technology to their conditions. Lightfoot (l986) reported an informal on-farm experiment comparing farmers' varieties with the new VSP lines. Data have been summarized for the two most popular farmers' varieties and these were compared to VSP-l and 2 (Table 3). It is apparent that the new lines are more moist, have lower yields, poor vining (less weed competitors), and are more susceptible to weevils when grown under farmers' conditions. It is important that these comparisons are made in order to feed information back to the breeders to improve subsequent lines. This has been done to some extent at ViSCA and subsequent releases are drier and offer better weevil resistance.

RESEARCH COOPERATION IN ASIA

This topic will be discussed in further detail during this workshop. However, the following areas may be important:

- Information - meetings, newsletters, and literature searches.
- Germplasm - collection, storage, and exchange of disease-free materials not only of *Ipomoea batatas* but also wild relatives.

  There is also a need for feedback of the testing of materials to determine its usefulness over wide ranges of environment.
- Joint research projects on weevil resistance and control, and possibly scab and nematodes.
- Regional training.
- International agricultural centers.

The CIP, Asian Vegetable Research and Development Center, and International Institute for Tropical Agriculture have considerable expertise in information, germplasm, improved varieties, and techniques for virus screening and indexing, which is very useful to the region.

REFERENCES

Escalada, M.M. and S.G. Binongo. 1987. Women in root crop technology. *In* Filipino Women in Rice Farming Systems. University of the Philippines at Los Baños, Laguna, the Philippines. pp. 121-131.

Escalada, M.M. and E.L. Lopez. 1986. Evaluation of root crop production and processing project with emphasis on sweet potato. SEARCA, Los Baños, Laguna, the Philippines. 47 p.

FAO (Food and Agriculture Organization). 1986. FAO Production Yearbook. 1985 Vol.39. Statistical Series No. 70, FAO, Rome.

Jayawardena, S.D.G. and K.P.U. de Silva. 1987. Indigenous and recent advances in sweet potato production, processing, utilization and marketing in Sri Lanka. *In* Proc. Sweet Potatoes for Small Farmers: an Asian Perspective. ViSCA, Leyte, the Philippines. 20-24 May 1987.

Kanua, M.B. and S.S. Rangai. 1987. Indigenous technologies and recent advances in sweet potato production, processing, utilization and marketing in Papua New Guinea. *In* Proc. Sweet Potatoes for Small Farmers: an Asian Perspective. ViSCA, Leyte, the Philippines. 20-24 May 1987.

Lightfoot, C. 1986. Indigenous research and on-farm trials. J. Ag. Admin. (*in press*).

Rashid, M.M. 1987. Indigenous technologies and recent advances in sweet potato production, processing, utilization and marketing in Bangladesh. *In* Proc. Sweet Potatoes for Small Farmers: an Asian Perspective. ViSCA, Leyte, the Philippines. 20-24 May 1987.

Rhoades, R.E. and R.H. Booth. 1982. Farmer-back-to- farmer: A model for generating acceptable agricultural technology. Agricultural Administration. 11:127-137.

Rhoades, R.E., R.H. Booth and E. Schmidt. 1985. An illustration of CIP's approach to the generation and transfer of postharvest technologies, Part 1. *In* Developing an appropriate technology for small farmers in Third World Countries. CIP, Lima, Peru. 29 p.

Xue, Q.H. and G.L. Shen. 1987. Sweet potato production and breeding in China. *In* Proc. Sweet potatoes for small farmers: an Asian Perspective. ViSCA, Leyte, the Philippines. 20-24 May 1987.

Yeh, T.P. 1982. Utilization of sweet potatoes for animal feed and industrial uses: Potential and problems in sweet potato. *In* Proc. First International Symposium. AVRDC, Tainan, Taiwan.

Yen, D.E. 1982. Sweet potato in historical perspective. *In* Proc. First International Symposium. AVRDC, Tainan, Taiwan.

SCREENING OF SWEET POTATO CULTIVARS BY SUBSISTENCE FARMERS: IMPLICATIONS FOR BREEDING

C. Lightfoot, R. de Pedro, Jr., and F. Saladaga*

INTRODUCTION

It seems a little sad that agriculturists in 1987 were still far off their rhetoric on development of technologies for resource poor or subsistence farmers. A traveler in the uplands of Eastern Visayas (Central Philippines) sees mostly, if not only, subsistence farmers employing age-old technologies producing the same low yields. The Green Revolution varieties and techniques bypassed these people, but this is well known now. Indeed, it has been known for the past 10 to 15 years. Moreover, a lot of talk about all the things research was going to do about this and time generating appropriate technology have gone, like water under the bridge.

At present, it is necessary for us to reexamine the theses that technologies are not neutral to farm size or class and, more specifically for this paper, that varieties bred for commercial growers are not necessarily also useful to subsistence farmers.

It is also necessary for us to remember that subsistence farmers do their own experiments, their own screening. Back in 1957 in the Philippines, Conklin (as quoted by Johnson 1972) reported that cultigens of all sorts, especially new or unfamiliar varieties, were grown experimentally in small homeyard gardens as simple objects of great horticultural interest.

The potential of such indigenous research is cogently argued by Paul Richards (1985) in his book "Indigenous Agricultural Revolution." But, while notions of indigenous knowledge and indigenous research are now accepted, little work, with few notable exceptions like that of Rhoades (1984), has been done on combining them with conventional research. Researchers certainly document now the farmers' planting methods but how they affect modern experimental programs is not known. One way an effect can be realized is by asking new questions. Ashby's work on farmer knowledge of phosphate did this "because new questions were raised

*Agronomist, International Agriculture Programs, Cornell University, Ithaca, New York, USA, and Instructor and Associate Professor, Visayas State College of Agriculture, Baybay, Leyte, the Philippines, respectively.

about the chemical reactions of rock phosphate with organic fertilizers and in mixtures with conventional phosphate sources" (Ashby, 1984). The possibility of using indigenous research in on-farm experiments is argued by Lightfoot in a study that borrows from data presented here (Lightfoot, 1987). Even if asking new questions was the only utility of indigenous knowledge, turning basic research agenda toward subsistence farmers would go a long way to meeting the rhetoric mentioned earlier.

Rhetoric, on the one hand, says we must help small farmers when, on the other hand, we tailor a sweet potato for commercial growers. Of course, the assumption that it will be adopted by subsistence farmers is implicit. And sure, it is grown by some in some places; it has a niche on subsistence farms. But the questions we must ask ourselves are: Are these enough? Can we do more for these people? What kind of sweet potato would better satisfy subsistence needs?

Even at a cursory glance, assuming that a single variety could span both commercial and subsistence needs is somewhat heroic. It is shown in this paper, by monitoring indigenous research in the farmers' screening of sweet potato cultivars, what exactly subsistence farmers are looking for in their cultivars. Moreover, this paper shows that these farmers' needs cannot be mixed with commercial objectives. A mechanism for combining indigenous and conventional research is then proposed.

METHODS

Methods employed were divided into three activities. First was identifying indigenous research. Second was determining the screening criteria and the descriptive characters that farmers were using. The third and final activity was the actual establishment and monitoring of the farmers' experiment.

Identifying Indigenous Research

While this study is being reported as the farmers' screening of sweet potato varieties, it did not start as a conventional on-farm variety trial. Our initial purpose was to elicit farmers' experiments. This was done through the use of participant observation techniques on a few farms. The first "experiment" we identified was a comparison of sweet potato cultivars. Experimentation, however, was not the farmers' sole object. They were also maintaining lines as well as producing tubers.

Determining of Farmers Screening Characters and Criteria

From identification of a few experiments, it was necessary to see how widespread experimentation was, what characters farmers used to distinguish different cultivars, and what criteria they used to screen them.

The extent of this farmer experiment was determined by random visits to sweet potato plots and interviewing cultivators. Farmer cooperators from other trials were also interviewed. These farmers distinguished between cultivars by leaf shape and color and by tuber skin and flesh colors. They screened by taste and cooking quality, maturity period, yield, tuber diameter, ability to store in the soil without rotting, ability to resist weevil attack, ability to harvest over a long period of time, and ability to rapidly produce vines over the ground.

Establishing and Monitoring a Farmer's Experiment

While the farmers were being questioned about these experiments, 12 of them received a selection of VSP-1, VSP-2, and BNAS-51 cuttings. Table 1 indicates which farmers got which combination of these varieties. Cuttings were distributed as part of a nationwide relief effort of the Ministry of Agriculture. This group of 12 farmers formed the research group as they were all screening from five to eight varieties, including the improved ones.

In this indigenous screening, all the researchers did after gathering some farm typological data was to ask how varieties were characterized. They also recorded the farmers' values for each assessment criterion. This informal survey did not use a structured questionnaire but rather lines of inquiry. The monitoring resembled more the Rapid Rural Appraisal techniques of Chambers and Hildebrand than any conventional on-farm variety trial (Carruthers and Chambers, 1981; Hildebrand, 1981). Three lines of inquiry were drawn up: farm typology, characteristics for distinguishing varieties, and criteria for assessment. In more detail, farm characteristics considered farm size, land tenure status, main sources of income, and the proportions of time spent in upland and lowland fields. As mentioned, sweet potato characteristics for distinguishing varieties included leaf shape, leaf color, tuber skin color, and tuber flesh color. The farmer's criteria for screening varieties included yield, taste, storage, maturity period, vine growth, tuber diameter, and resistance to weevils.

Farm Typology

By calling farmers' subsistence, we mean that their primary economic activity is farming upland fields mainly, but not exclusively, for home consumption. Many such families sell crops and animals to obtain cash and naturally they barter produce for in-kind payments such as food and labor.

Using this loose definition puts our sample of experimenting farmers within a subsistence class. All our samples worked upland plots and just under half had no lowland plots at all. Furthermore, these farmers (with one exception) spent the bulk of their time (77%) in the uplands. At least half of them, however, spent a small proportion (about 20%) of their time in the lowlands. Farming was their main source of income. However, for some 25 percent, cash was also earned through hired labor, collecting "tuba" (wine made from coconut sap), or doing carpentry work.

Even though classed as one subsistence group, the range in amount and access to resources such as land is wide. A total of 33 percent cultivate 0.5-1.0 ha of lowland and 17 percent cultivate 4-7 ha of upland. However, farmers will typically work none or half hectare of lowland and one hectare of upland. Access to both lowland and upland parcels is restricted since about 70 percent of the farmers are tenants. Again, the degree of access varies greatly. Even though many are tenants, about 25 farmers own their upland fields.

Varietal Characteristics

Sixteen varieties were grown but most farmers grew only six of them (Table 1). Farmers hardly differed in the way they characterized varieties but variations in evaluation were numerous. The uniformity of responses for characteristics permits the use of data even though it is only from one observation. This will not be the case for screening criteria.

Table 1. Matrix of varieties grown by farmers.

	Farmer												
Variety	1	2	3	4	5	6	7	8	9	10	11	12	Total
VSP-2	X	X	X	X	X	X	X	X	X	X	X	X	12
Kadulaw	X	X	X	X	X	X	X	X	X	X	X	X	12
Karingkit					X	X	X	X	X	X	X	X	8
Kasima	X		X		X		X	X		X			6
Inanahaw				X			X	X	X		X		5
VSP-1		X		X			X	X	X				5
Kaulpot			X					X	X		X		4
Binasaynon				X	X						X	X	4
Kangisi	X					X						X	3
Kamamon						X						X	2
Kaapog	X								X			X	3
Kasapad			X			X							2
BNAS-51	X									X			2
Kabusag		X											1
Bano		X											1
Inalegria		X											1
Total	6	6	5	5	5	6	6	7	7	5	6	7	

Four leaf shapes were recognized: ovate or heart-shaped, triangular or arrow head-shaped, lobed, and digitate or hand- shaped. Leaf colors were red, green, or their combination. Red, orange, yellow, and white were the identified colors of tuber skin and flesh. Using these characters, each variety was found to be unique. The characteristics for each variety are given in Table 2.

Table 2. Characteristics of sweet potato varieties grown by farmers.

Variety	Leaf		Tuber	
	Shape	Color	Skin color	Color
Kaapog	Triangular	Red	White	White
Kangisi	Lobed	Red & green	Red	White
Kasima	Ovate	Red (D)	Red	Yellow (D)
Kadulaw	Lobed	Red & green	White-orange	White-orange
Kabusag	Triangular	Green	White	White
VSP-1	Ovate	Green	Yellow-orange	Yellow-orange
VSP-2	Digitate	Red	Orange	Orange
Inalegria	Ovate	Red	Red	Yellow (L)
Inanahaw	Ovate	Red	White	Yellow
Kaulpot	Lobed	Green	Red	Yellow (L)
Kasapad	Ovate	Green	Yellow (L)	Yellow (L)
Binasaynon	Triangular	Red (D)	Red	White
Karingkit	Lobed	Green	White	Yellow
Bano	Ovate	Green	White	Yellow
Kamamon	Lobed	Red (L)	Orange	Orange

Nearly half the varieties have ovate leaves; the rest are lobed or triangular, with the exception of VSP-2's digitate leaf (Fig. 1). Leaf colors among ovate leaf types were either red or green with the exception of BNAS-51 which was both. Among the reds, Kasima was dark and Inalegria could be distinguished from the Inanahaw by its red tuber skin color. Similarly, the greens can be distinguished by tuber skin color (i.e., VSP-1, Kasapad, and Bano have yellow-orange, light yellow, and white colors, respectively). For triangular leafed cultivars, Binasaynon has dark red leaves, Kaapog has red leaves, and Kabusag has green leaves. Leaf color among lobed shapes is either green or a combination of red and green with the exception of the light red Kamamon. Tuber skin colors of orange-white and red distinguish the red/green leafed Kangisi and Kadulaw while red and white tuber skins distinguish the red leafed Kaulpot and Karingkit.

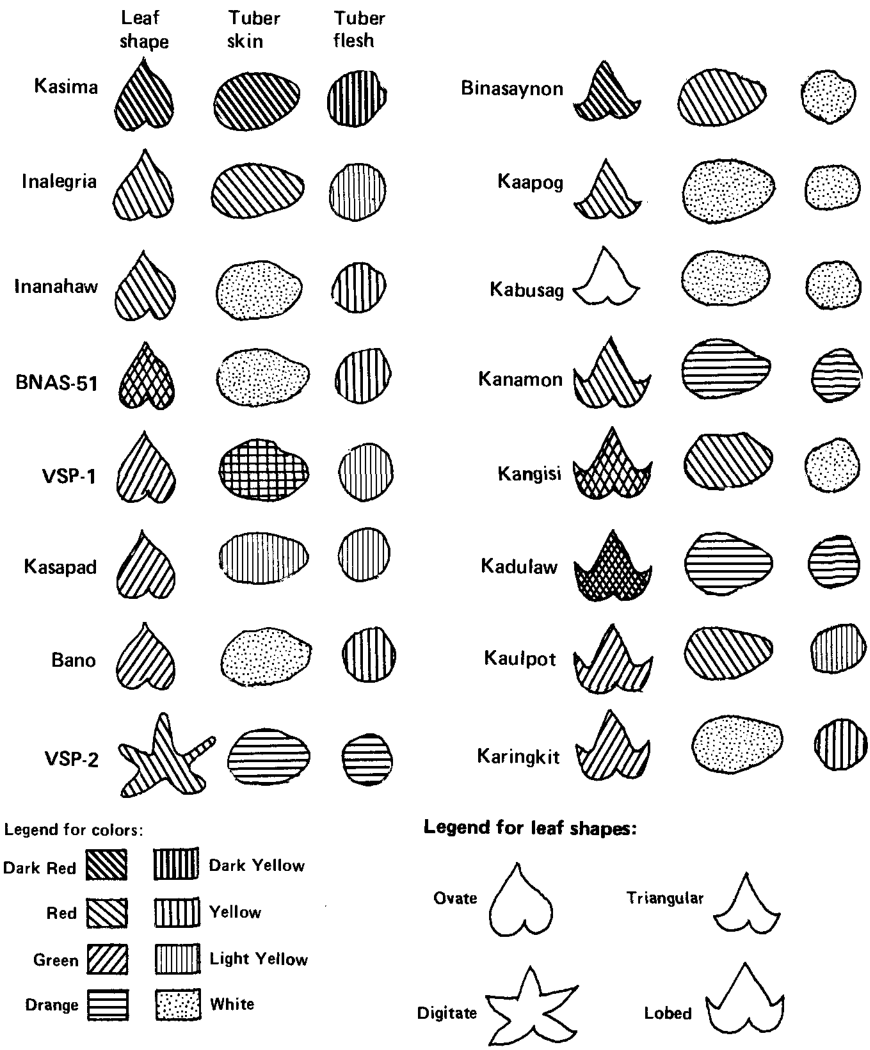


Figure 1. Farmers' descriptive characteristics of sweet potato varieties.

Varietal Screening

Farmers were found to screen varieties by taste, storability, maturity period, yield, tuber size, pest and disease tolerance, vining, and duration of harvest. Since farmers preferred sweet dry eating and cooking qualities of sweet potato, improved varieties VSP-1 and VSP-2 were not as 'tasty' as most indigenous cultivars to them. Table 3 shows local cultivars that are not sweet (e.g., Kaapog and Bano) and some that are not dry but wet (e.g., Binasaynon and Kangisi).

Because in some occasions responses varied, the remaining criteria were examined in the varieties where five or more responses could be obtained. These varieties were Kadulaw, Karingkit, Kasima, Inanahaw, VSP-1, and VSP-2. Figure 2 shows the frequency of positive responses for storability in the soil and resistance to weevils of these varieties. Farmers more frequently rated indigenous cultivars as better than improved varieties in both characters. Among the indigenous cultivars, Kasima was consistently rated by farmers as poorer in storability and pest resistance.

The maturity periods, harvest duration, and vining time between commercial and indigenous cultivars were compared. Commercial varieties have relatively short maturity periods. This advantage is offset by a short harvest duration, a particularly important criterion as subsistence strategies call for several sequential harvests. The vines of all cultivars, except VSP-2, cover the ground in 2 to 2 1/2 months; the bushy cultivar does not vine at all.

This trend of local superiority even holds when we compare tuber size and yield, but differences are often less. Figure 3 shows VSP tuber diameter to be 3-4 cm smaller than the best local, but only 1 cm smaller than Inanahaw and Kasima. Similarly, VSP-1 and VSP-2 exhibit a low yield class of 3 while local cultivars are higher at 2 and 1. This reversal from most research plot findings is partly explained by confounding from plant population and harvesting. Under dense stands and single harvests, VSP's yield well while under farm conditions of wide spacing and multiple harvests, they look weaker.

Thus, we find that farmers' top staple and marketed varieties -- Karingkit and Kadulaw -- have sweet dry taste, high yield class of large 10-cm diameter tubers, and rapid vining to cover the soil in 1-2 months. In addition, they can be harvested for up to l year because they store well in the soil and are not easily attacked by weevil. Long maturity period is their main disadvantage. Conversely, the improved VSPs have considerable disadvantages in their short harvest period, sweet wet taste which only has snack value, poor resistance to rotting and weevil, and, for VSP-2, the inability of its vines to cover the soil. Not only then are indigenous screening criteria very different from commercial breeding objectives; improved varieties are comparatively poorer than most local cultivars when assessed against subsistence needs under farm conditions.

Table 3. Farmers' evaluation of sweet potato varieties.

Variety	Taste	Storage in soil	Maturity period (month)	Yield class	Vine growth (month)	Harvest duration (month)	Tuber size (cm)	Pest
Kaapog	NS/D	Good	4-6 7	2-3	2-3	7-8	4-8 8	R S
Kangisi	S/D W	Poor	3-5	2	1-3	2, 7 8	4-8	R S
Kasima	S, NS D, W	Poor Good	3, 4	1-3	1-3	4-8	6-10	R S
BNAS-51	S	Good	4-5	2	0	7-8	6	S
Kadulaw	S/D	Good Poor	3-5	1, 2	1-3	7-8	6-10 12	R
Kabusag	S/D	Poor	7	2	1	12	6	R
VSP-1	S/W	Good	2-3	2, 3	0	1	5-6	S
VSP-2	S/W	Good	2-3	2-4	0	1, 2	4-8	S
Inalegria	S	Poor	2	3	2	2	3-4	S
Inanahaw	NS/D	Good	4-6	2	2	12	6-8	R
Kaulpot	S/D	Good	2-3	2	1	7-8	5-6	S
Kasapad	S, NS D	Good Poor	3-4	3, 2	1, 2	2	4-6	S

Table 3 (continued).

Binasaynon	S/W	Poor	3-5	2, 3	1	5, 8	6-8	S
Karingkit	S/D	Good	4-7	1	2	12	10	R
Bano	NS/D	Good	4-5	2	1	8	6	R
Kamamon	S/D	Good	3-5	2	2	2, 8	5-6	R
		Good						S

Taste: S = Sweet, (N) Not, D = Dry, W = Wet
Storage: Good/Poor = Easily rotting
Vine growth: Time to cover ground
Tuber Size: Diameter
Pests: R = Resistant, S = Susceptible to weevils

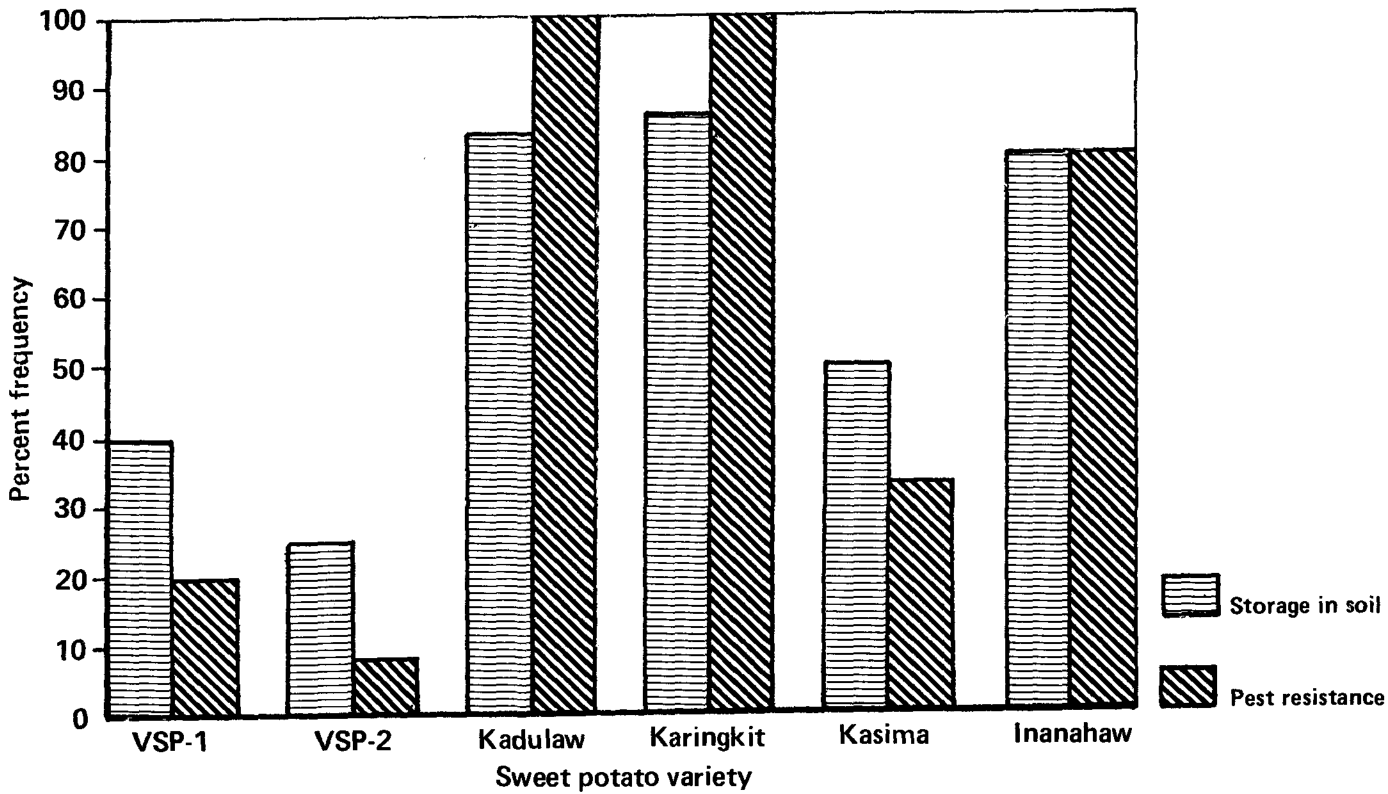


Figure 2. Comparison of frequencies of positive responses of farmers regarding selected sweet potato varieties' ability to be stored and to withstand pests.

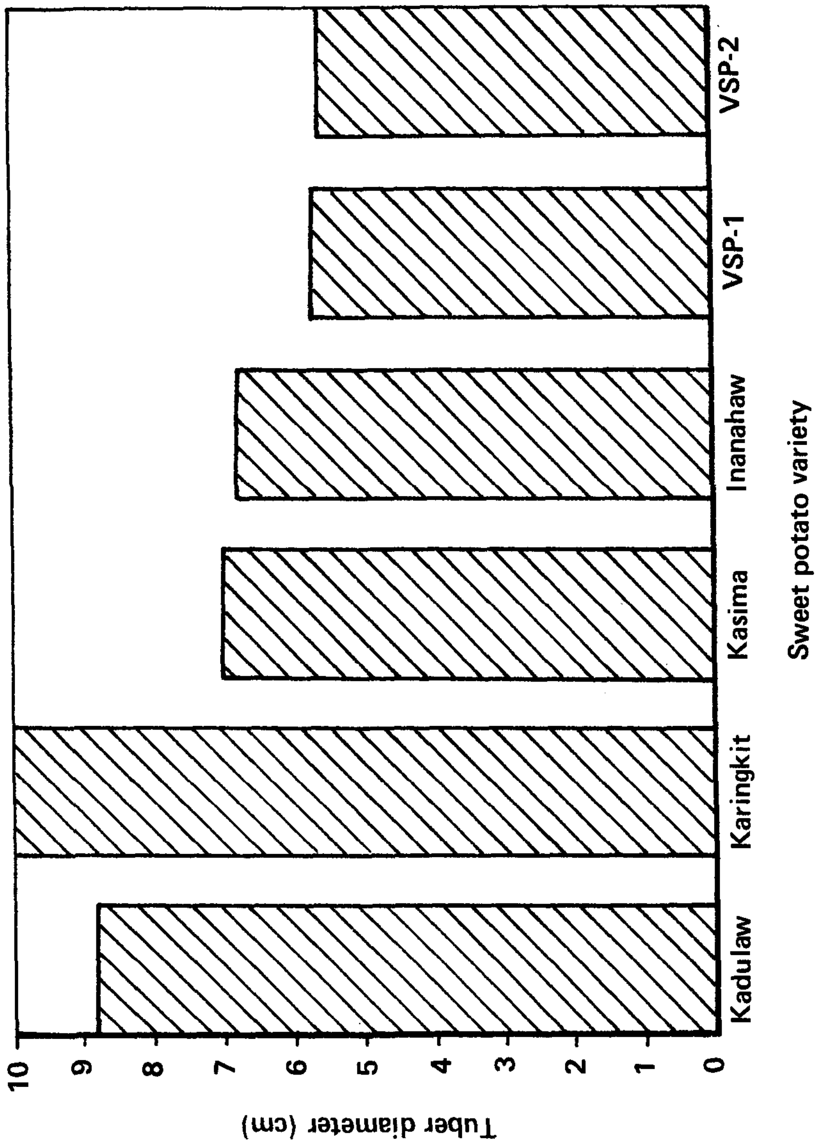


Figure 3. Comparison of tuber diameters of selected sweet potato varieties.

DISCUSSION

It is clear that subsistence farmers have been engaged in screening sweet potato cultivars for a set of objectives suitable to their farming strategies. Moreover, commercial breeding objectives for high yield, short maturity, single harvest, and bush types are inappropriate to subsistence farming systems. Subsistence farmers seek rapid vining to suppress weeds and reduce soil erosion. They also seek prolonged sequential harvesting with good production off the vine, prolonged underground storage without rotting, and weevil resistance after harvest. Nevertheless, in times of calamity they are prepared to compromise on most criteria for short maturity.

Obviously, the predominant cultivars farmers now cultivate are products of many years of indigenous screening. But farmers operate under some handicaps. The heterogenous nature of their farming environment appears to be the most important limitation in their attempt to establish which cultivars are better suited to their requirements. It is only through the repeated planting over many seasons and years (a kind of replication over time) that certain cultivars emerge as the farmer's choice. Farmers are further handicapped by their crossing techniques and gene pool.

These observations mean that mechanisms that exploit farmer's strengths in setting relevant screening criteria and assessing lines, and replacing their weaknesses with a breeder's strength in germplasm collections and sophisticated crossing and replication over space and time would inevitably produce varieties suited to subsistence farmers. Such a mechanism could exist if the long period of indigenous screening can be shortened by the interacting effects of farmer assessments with researcher breeding. After a few years of this, we may perhaps be more comfortable with our rhetoric of helping subsistence farmers.

REFERENCES

Acaba, M., D. Apura, J. Cabiling, R. De Pedro and C. Lightfoot. 1986. A study of farmer's evaluation of camote varieties. FSDP-EV Working Paper No.2. Tacloban City, Leyte, the Philippines.

Ashby, J.A. 1984. Participation of small farmers in technology assessment. IFDC, Alabama, USA.

Carruthers, I. and R. Chambers. 1981. Rapid appraisal for rural development. Agricultural Administration. Vol. 8. pp. 407-422.

Hildebrand, P.E. 1981. Combining disciplines in rapid appraisal: The Sondeo approach. Agricultural Administration. Vol. 8. pp. 423-432.

Johnson, A. W. 1972. Individuality and experimentation in traditional agriculture. Human Ecology. Vol. 2. pp. 149- 159.

Lightfoot, C. 1987. Indigenous research and on-farm trials. Agricultural Administration and Extension. Vol. 24. pp. 79- 89.

Rhoades, R. E. 1984. Breaking new ground: agricultural anthropology. CIP, Lima, Peru.

Richards, P. 1985. Indigenous agricultural revolution: ecology and food production in West Africa. Hutchinson, London, UK.

EVALUATION OF THE BREEDING VALUE OF 5x INTERSPECIFIC HYBRIDS BETWEEN SWEET POTATO CULTIVARS AND 4x IPOMOEA TRIFIDA

M. Iwanaga, J.Y. Yoon, N.S. Talekar, and Y. Umemura*

INTRODUCTION

Wild relatives of many crops have been utilized for plant breeding with varying degrees of success in widening genetic base and introducing a specific trait or traits such as resistance to abiotic and biotic stress, improved nutritional quality, and modified reproductive behavior. Since utilization of wild relatives inevitably involves extra steps in addition to regular variety breeding procedure, one should justify well and plan ahead so that maximum benefit of the wild germplasm can be obtained with minimum extra time and resources. Thus, our knowledge of the value of wild relatives for specific crop and technical difficulties involved in the utilization is essential for modern crop breeding. In this aspect, sweet potato breeders are not in a particularly good position to make plans for utilization of wild relatives in variety breeding program because they are limited in their knowledge of the value and problems of wild relatives.

Nishiyama (1959, 1961) reported the finding of 6x *trifida* (named K123) in Mexico which hybridized easily with sweet potato cultivars and opined that such 6x *trifida* was the ancestor of sweet potato cultivars. Although the taxonomic identity of K123 has been questioned, it was utilized in variety breeding programs in an attempt to transfer nematode resistance. Although some hybrids of sweet potato and K123 had high yield, they were backcrossed to cultivars to improve agronomic traits. From BC_2 progenies, the variety Minamiyutaka was selected and released in 1975. The main attributes of the variety are resistance to root knot nematodes and root legion nematodes, high yield, and high starch content. It has also become the second most important starch variety in Japan, occupying about 5,000 ha in the southern part of that country. It seems that Minamiyutaka has a deep root system, a characteristic probably derived from K123 which allows the variety to have a long growing period until late autumn, resulting in high yield.

---

*Cytogeneticist, International Potato Center (CIP), Lima, Peru; Associate Breeder and Entomologist, Asian Vegetable Research and Development Center (AVRDC), Taiwan; and Head, Sweet Potato Seed Laboratory, Kyushu National Agricultural Experiment Station, Ibusuki, Japan, respectively.

The success in getting an outstanding variety by using just a few accessions is very encouraging. However, more information is urgently needed. For example, breeding value of other ploidy levels of *trifida* (i.e., 2x, 4x) is not known at all even though they are more common in nature and represent wider genetic diversity than 6x *trifida*. Moreover, there are other species (2x and 4x) whose breeding value has never been assessed.

I. trifida was chosen for this study because it is closely related to the cultivated species and is considered an ancestral species of cultivated sweet potato (Kobayashi, 1983). Success of variety release in Japan by using 6x *trifida* also had an important consideration. The decision to use 4x *trifida* accessions instead of 6x *trifida* was based on two reasons. First, a few accessions of 6x *trifida* were already evaluated for breeding value, while no information was available on value of 4x *trifida*. Second, 4x *trifida* may represent wider genetic diversity than 6x *trifida*. The 4x *trifida* is more commonly found in native areas of Central and South America and many accessions have been collected and maintained in Japan while 6x *trifida* is rare in nature and only a few accessions are available in Japan.

MATERIALS AND METHODS

A total of 3,030 hybrid seeds comprising 21 families were produced by crossing seven Japanese cultivars with four accessions of 4x *trifida* which were collected in Mexico and Guatemala. The hybrid seeds, believed to be 5x, were sown on 26 June and 17 July 1985 at AVRDC. Owing to poor germination (29%) and further difficulty of handling viny seedlings, only 757 entries (hybrid clones) of 21 families were evaluated in the field (Table 1).

Agronomic Evaluation

Five cuttings for each clone were transplanted on 6-13 September 1985 and harvested on 3 March 1986. A unit plot consisted of a single row, 1.5 m long, with rows spaced 1 m apart and planted within the row, 30 cm apart, without replication. CN1232-9 was planted as a main check cultivar with 96 replications while two others, TN 66 and CN 1489-43, were used as the checks for nutritional quality. At harvest, the number of roots and storage root weight was recorded. Clones with acceptable yield compared to the check cultivars were evaluated for dry matter using four levels of specific gravity (i.e., 1.01, 1.03, 1.05, and 1.07). Tuber skin and flesh color of these clones were also recorded. Forty-two high-yielding clones were selected for the analysis of nutritional components.

Table 1. Number of entries (clones) from 6x-4x crosses evaluated at AVRDC.

Female	Number of entries (clones) 4x *trifida* accessions from Central America			
	CCP 6-4	CCP 6-23	CCP 9-2	CCP 9-17
Minamiyutaka			24	2
Koganesengan			58	14
Kyushu 78	63		16	49
Kyushu 90	24		18	5
Kyukei 42	112	52	74	50
K 7210-34	45	16	57	40
K 78187-2		15	18	5

Weevil Nursery

The general procedure of resistance evaluation was similar to that being routinely followed at AVRDC, except that a smaller plot size (l.5 m^2 instead of regular 5 m^2) was used without replication. To facilitate analysis at harvest, storage roots with a diameter larger than the thumb (2 cm) were collected from each plot and weighed. This method of grading can be easily applied by field workers. Then each root was carefully examined for weevil infestation. The damaged part was cut and weighed and the number of insects (grubs + pupae + adults) found in the damaged part was counted for each entry. The level of resistance was compared based on the total number of weevils per kilogram of fresh root. TN 57 was planted at the end of each family and used as check for comparison.

RESULTS AND DISCUSSION

Yield

A very wide variation in yield was observed among the hybrids. In the preliminary evaluation, yield of entries varied from 0 to 2.7 kg/plot (Fig. l). The majority of the hybrids, however, produced none or very few roots. Some of the hybrids compared reasonably well with the check cultivar, CN l232-9, which averaged l.l kg/plot yield. Of the entries, l4 percent had yields higher than l.l kg/plot.

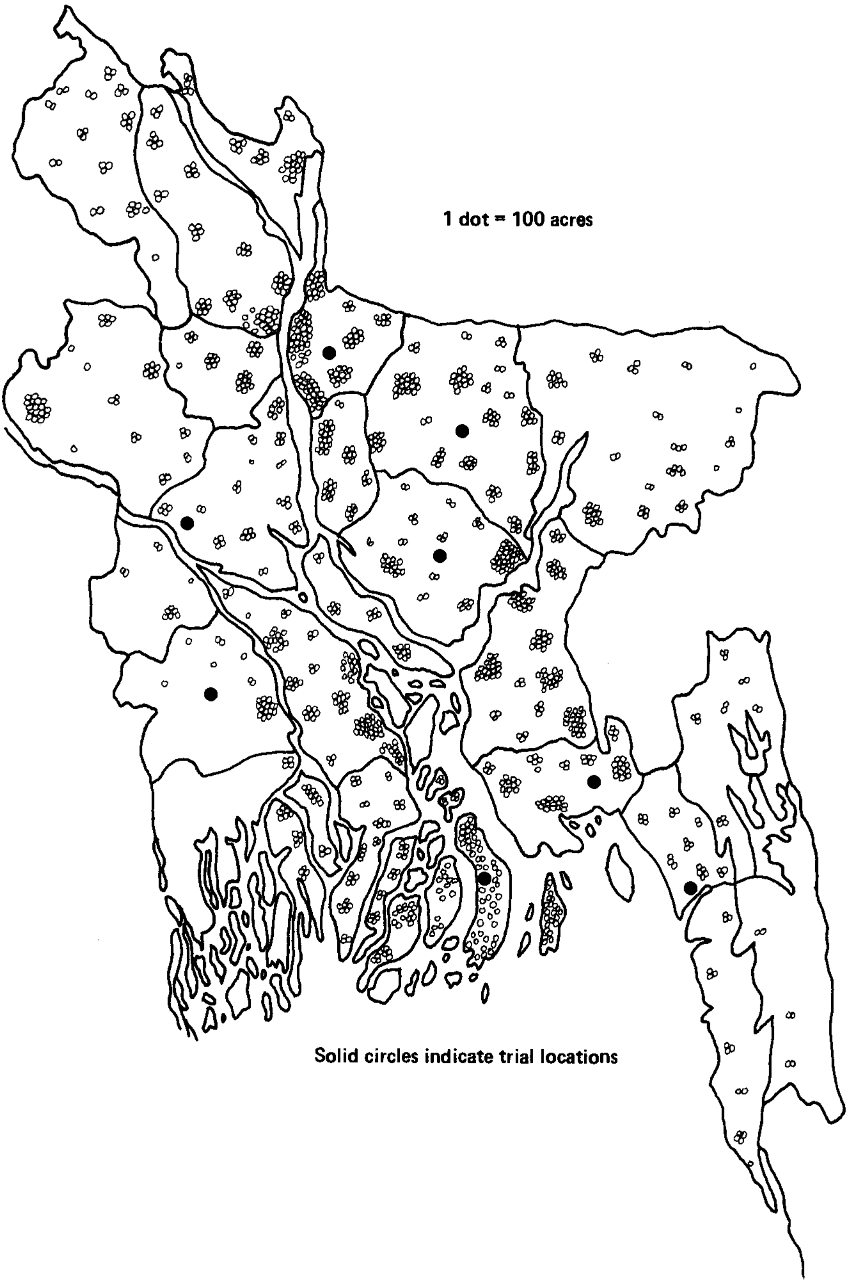


Figure 1. Regional distribution of sweet potato.

The high yield of some entries was very encouraging because it showed that high-yielding clones could be selected and that these entries provided a good chance for proper evaluation of other characters such as dry matter content and resistance to weevil. Comparison of poor yielding hybrids with the check cultivar for those characters would not be justified, since poor yield per se may increase dry matter and protein contents and may reduce undesirable root traits (cracking, over-size) and infestation of weevil owing to less land cracking and less preference of the insect. Thus, evaluation of those high-yielding hybrids for the characters can facilitate assessment of breeding value of the 4x *trifida* germplasm.

The yield of the hybrid progenies appeared to be partially influenced by parental cultivars or lines. Table 2 shows the average yield of the progenies by cross combination. The cross between Minamiyutaka and CCP 9-17 showed high average yield, but only two entries were evaluated. Except this combination, three out of four high-yielding families were from crosses involving CCP 6-4 as male parent. The general combining ability of CCP 6-4 seems to be high. The parental value of K 7210-34 as female plant was also considered better than that of other cultivars. This was because 16 percent of the progenies from K 7210-34 were selected and entered into the second evaluation. This rate among other female plants ranged only from 0 percent to 8 percent. Sakai (1965) also noted the difference in parental value of some Japanese cultivars when crossed with some 6x *trifida* accessions. The use of cultivars that produce high-yielding hybrids when crossed with wild relatives may facilitate evaluation of the hybrids for breeding value.

Table 2. Average yield of entries in preliminary evaluation by cross combination.

Japanese cultivar	Average yield (g/plot) 4x *trifida* accessions from Central America			
	CCP 6-4	CCP 6-23	CCP 9-2	CCP 9-17
Minamiyutaka			229	1350[a]
Koganesengan			407	289
Kyushu 78	313		166	534
Kyushu 90	623		289	200[b]
Kyukei 42	701	484	212	444
K 7210-34	791	384	407	765
K 78187-2	.	433	53	360[b]

[a]Average of two entries

[b]Average of five entries

Undesirable Traits

The use of wild relatives in plant breeding is often limited or discouraged by undesirable traits associated with wild relatives. The present hybrids were checked for any apparent negative traits that might cause difficulty in further breeding work. The range of skin and flesh color was not different from that of cultivated materials. The frequency of undesirable flesh color (pink and purple) was low. The root shape of the hybrids ranged from spindle to round; the prominent shape was spindle similar to that of TN66. Fresh roots of many selected entries were eaten at harvest. None of them had bitter taste. It seems that the *trifida* accessions did not introduce any apparent undesirable trait in the hybrids except that many hybrids did not produce a sizeable level of root yield.

Nutritional Analysis

Roots of 42 hybrids with more than I kg/plot yield were analyzed for dry matter, protein, sugar, starch, and fiber contents. Two checks included in the analysis were VTN66 (wet and dessert type) and CNI489-43 (high starch type).

Dry matter content of the hybrids ranged from 33 percent to 45 percent (Table 3) with a mean of 40 percent. Dry matter content of most hybrids exceeded that of CNI489-43, a cultivar with high dry matter content. About 40 percent of dry matter content has been regarded as the highest value in sweet potato cultivars; dry matter content of the hybrids was extremely high.

The high nutritional value of the present material was not only restricted in dry matter content. High protein content (fresh weight basis) was also found. On dry weight basis, some sweet potato cultivars were reported to have more than I0 percent of protein content and thus, the value found in the hybrids on dry weight basis was not particularly high. The high protein content of these cultivars, however, was always associated with low dry matter content. The present material, on the other hand, had both high dry matter content and protein content (Table 4). For example, WT8I had protein content of more than 3.I percent fresh weight basis which was higher than that of any cultivar reported before. Therefore, the hybrids present very valuable source of germplasm in breeding sweet potato for high dry matter and protein content.

High dry matter content in hybrids between sweet potato and *trifida* was reported earlier by Sakai (I965) and Kokubu (I973). Hexaploid *trifida* accession was used for their studies and dry matter content of their hybrids was as high as that of leading Japanese cultivars for starch use. Present material involved 4x *trifida* and dry matter content of some hybrids was much higher than that of leading starch-use cultivars. However, it should not be generalized that 4x *trifida* has higher breeding value than 6x *trifida*, since the accessions utilized in their present studies were very limited.

Table 3. Nutritional components of 5x hybrids compared with two check cultivars.

Hybrids		DM %	Protein	Sugar	Starch	Fiber
			% DWB			
WT clones	Mean	40	4.2	14	74	3.2
(n = 42)	Range	33-45	2.0-7.5	11-19	64-82	2.4-4.6
TN 66		23	6.5	16	63	3.9
CN 1489-43		37	3.9	9.4	80	2.2

Table 4. Nutritional components of some 5x hybrids and two check cultivars.

Hybrid/Cultivar	DM %	Protein	Sugar	Starch	Fiber
		% DWB			
WT 10	41	7.5	15	71	3.7
WT 81	43	7.3	13	73	3.5
WT 108	42	5.4	13	73	3.6
WT 298	45	3.3	13	78	3.3
WT 843	45	4.1	15	78	2.4
WT 66	23	6.5	16	63	3.9
CN 1489-43	37	3.9	9	80	2.2

Since the 5x hybrids are not of immediate use as cultivar, their high dry matter content needs to be transferred into cultivars by backcross(es). It should be investigated if the high dry matter content can be transferred into cultivars without any significant reduction of this character and if the high dry matter content can be manifested even when the backcrossed progenies may have higher yield than the present hybrids. Female fertility of the 5x hybrids is expected to be high enough for producing backcrossed progenies by 5x-6x crosses (T. Miyazaki, personal communication).

Resistance to Weevil

Check cultivar TN57 was replicated 27 times in this experiment. Ranges of yield and number of weevils in the check were 0.80 to 3.62 kg yield/plot and 0 to I09 weevils/kg, respectively. There was no correlation between yield and level of infestation in the check. Since the small yield of many hybrid entries may have reduced the chance of infestation because of physical escape and nonpreference, the resistance level between the check and the entries was compared using only entries with yields of more than 1 kg.

Twenty-six out of 27 replicates of the check had severe infestation, while only one replicate did not have any infestation, presumably because of the escape by chance. On the other hand, the 86 entries had in general much less infestation. More than half of the entries had less than I weevil/kg. Because of the complicated biology of the insect, the results need to be considered as preliminary. The clear difference found in the study, however, is very encouraging and these materials deserve further study as potential source of resistance to sweet potato weevil, the most serious pest of sweet potato in warm and hot tropics. Further evaluation for resistance using regular size plot (5 m^2) and several replicates should be carried out. If a significant level of resistance is further confirmed in the hybrids, studies to clarify the possible mechanism of resistance would be very interesting.

SUMMARY

With respect to the utilization of wild relatives in breeding, 5x hybrids from crosses between sweet potato varieties and *Ipomoea trifida* (4x) were evaluated in a preliminary test. The hybrids showed good potential for sweet potato weevil resistance, high dry matter content, and high protein content. Although useful as breeding materials, these hybrids cannot be treated as cultivars. A sequence of backcrossing and further selections among derived progenies would be necessary.

ACKNOWLEDGMENTS

The authors wish to thank Dr. S.C.S. Tsou and Mr. K.K. Kan of AVRDC for their excellent support in chemical analysis of present genetic material. General guidance and encouragement provided by Dr. R. Opeña of AVRDC is also greatly appreciated.

REFERENCES

Kobayashi, M. I983. The *Ipomoea trifida* complex closely related sweet potato. Proc. 6th Symp. Inter. Soc. Tropical Root Crops. pp. 56I-568.

Kokubu, T. I973. Thremmatological studies on the relationship between the structure of tuberous root and its starch accumulating function in sweet potato varieties. Bull. Fac. Agric. Kagoshima Univ. 23:I-I26.

Nishiyama, I. 1959. Collecting the sweet potato and its allied species in U.S.A. and Mexico. Japanese J. Breeding. 9: 73-78.

Nishiyama, I. 1961. The origin of the sweet potato. *In* Tenth Pacific Sci. Congr., Univ. Hawaii, Honolulu. pp. 119- 128.

Sakai, K. 1965. Studies on the enlargement of variations and improvement of selection methods in sweet potato breeding. Bull. Kyushu Agric. Expt. Sta. 9:247-397.

BREEDING FOR EARLY-MATURING SWEET POTATO VARIETIES

Ye Yanfu*, Tao Jialan*, Zhu Yunchu*, and Qiu Ruilian**

ABSTRACT

Early-maturing sweet potato breeding (EMSPB) is needed as a production practice in China. The advantages of growing early maturing sweet potato include high benefit from early marketing with a good price, adaptation to multiple cropping system by shortening the growing period of sweet potatoes from 5-6 to 3-4 months, high yielding capacity through early harvesting to avoid infestation of *Helicobasium mompa* and *Ditylenchus destructor,* and proper way of solving food and feed problems, especially in developing countries.

As a sign of maturity, growth and development of sweet potatoes tend to decline or pause after growing for a certain period even under optimal conditions. Based on ripening date, sweet potato can be classified into early- (90-120 days), medium- (120-150 days), and late-maturing (more than 150 days) varieties. The weight of tuberous root 50-60 days after planting can be used as an index to predict maturity performance. Under the temperature condition in Hangzhou, China, the weight of tuberous root of the early-maturing sweet potato planted from May to June ranges from 150-200 g/plant 50-60 days after planting up to 500 g/plant 90-100 days after planting.

When parents in combination belong to early-maturing varieties, the percentage of early-maturing lines in their F_1 seedlings is high. Varieties with early-maturing and high-yielding properties are crossed to incorporate the early-maturing genes with high-yielding properties.

*Professors, Zhejiang Academy of Agricultural Sciences, Hangzhou, Zhejiang 310011, China, and **Vice Professor, Jiangsu Academy of Agricultural Sciences, Nanjing, Jiangsu 210014, China.

INTRODUCTION

Breeding of early-maturing varieties has been one of the principal tasks of breeders but breeding for such in sweet potato (*Ipomoea batatas*), a vegetatively propagated crop, has not been given much attention and few studies have been reported. Experiments conducted at the Zhejiang Academy of Agricultural Sciences (ZAAS) in the early 1970s showed that similar to seed plants, sweet potato could be classified as early-, medium-, and late-maturing types. In 1979-80, ZAAS found that the characters of early tuberization and high-yielding ability of the crop were interrelated and that in F_1 plants of combined parents with early tuberization, there was high frequency in the appearance of high-yielding type.

Breeding for early-maturing sweet potato to replace local cultivars has been conducted in Central and North Taiwan (Wang, 1982). The Asian Vegetable Research and Development Center (AVRDC) considered early maturity as the third goal in breeding edible varieties of sweet potatoes with a growing period of 100-120 days in Asian and Pacific countries (Lin et al., 1982). The International Institute of Tropical Agriculture (IITA) considered it, however, as a principal breeding objective and was breeding varieties with a growing period of 3 months (IITA, 1985). Similar programs have been undertaken in China.

EARLY-MATURING SWEET POTATO VARIETIES BREEDING (EMSPB) -- A REQUISITE OF PRODUCTION PRACTICE

The development of EMSPB in China started in the 1960s as the sweet potato growing acreage in the Chinese mainland topped 9 million ha. In the early 1980s, in areas where sweet potato was used as staple food, it has become a main supplementary or nonstaple food or industrial raw material, and its production has changed from self-supporting to market-oriented farming. Low price encouraged farmers to grow cash crops for more money, resulting in the decrease of sweet potato acreage down to 7 million ha.

There are alternative schemes to enhance the benefit of growing sweet potato based on its utilization for vegetable or nonstaple food. It is necessary to produce early sweet potato to bypass the peak season and make it marketable as early as possible. The price of sweet potato supplied early in August or September is two to four times higher than that in October or November. Thus, there is a demand to breed early-maturing sweet potato.

Secondly, with the agriculture reformation in China, multiple cropping system has been widely adopted. Under the system, farmers acquire more output per unit of land area. They manage to plant more in a year, while the growing period becomes shorter -- from 5-6 to 3-4 months. Farmers procure early-maturing cultivars from research institutions.

In dry plain areas, the cropping system of winter crop--summer sweet potato--autumn vegetable, spring watermelon, autumn sweet potato--winter crop, or spring sweet potato--autumn sweet potato--winter crop gives a total income of RMB ¥1500-3000/ha more than the cropping system of winter crop--summer sweet potato. Likewise, hilly land raising of early-maturing sweet potato following the first rice is likely to give a flesh root yield of 22-23 t/ha in 3 months. Provided that 5 t of flesh root is equivalent to l t of rough rice and coupled with the yield of the first rice, l0 t/ha of rough rice can be produced, which means an increase of 3-4 t/ha of grain over the yield from single-crop late rice. In some areas in Jiangsu Province in China, where only carrot is grown after spring maize, the cultivation of autumn sweet potato with early maturing varieties Ningshu l and Ningshu 2 (85-90 days) produces l8-l9 t of tubers and l4-l5 t vines while the fresh biomass is 2-3 times that of the carrots.

Thirdly, in areas seriously infested with *Helicobasidium mompa* and *Ditylenchus destructor,* early harvesting of sweet potato enables the crop to avoid the season when pathogen is most prevalent. In Wenling County of Zhejiang Province, the early-maturing variety Zheshu 60-2 planted at the end of May and harvested in mid-September yielded 32.4 t/ha, about twice that of the medium-maturing variety Honghong l. However, those harvested as late as mid-November, because of serious incidence of diseases, obtained only 28.2 t/ha, equivalent to a l3 percent decrease in production.

Finally, early-maturing sweet potato produces large quantities of dry matter within a short time and may speedily solve the food problem in developing countries, especially during periods of failure in other crops. Breeders must aim to integrate the early-maturing genes with high-yielding genes and develop some ultra-high yielding sweet potato varieties that produce tubers early as well as grow for a longer time.

CONCEPT AND CRITERIA OF EARLINESS IN SWEET POTATO

Sweet potato generally grows incessantly and gives higher yield without respect to maturing. However, we found in the early l960s signs of maturity such as the following: (l) tops exhibit senescence, (2) slow tuber bulking or even pauses regardless of favorable conditions, and (3) budding and flowering. *These signs are similar to those in potato (Miscel-*

laneous Food Crop Section, ZAAS, 1961). A few varieties exhibited cambium and parenchyma cells in the tuberous roots that do not enlarge or remain in dormant state after growing for a certain time, even under proper environment (JAAD and SAAS, 1984). We consider such phenomenon as the pauses of tuberous root growth as the setting in of its mature period. The growth of top and tuberous roots of the early-maturing variety 52-45 declines or even pauses 90 days after planting, while for the late–maturing variety Chaosheng I, tuber bulking rate increases at the middle and late stages (Fig. Ia, Ib). Sweet potato varieties are thus classified by the time when they reach mature stage: early- (90-120 days), medium- (120-150 days), and late-maturing (over 150 days) varieties. This is fundamentally the same classification of sweet potato being used by Filipino breeders. They also believe that when the tuber reaches the mature stage, its growth will gradually come to a standstill and sprouting in field is likely. Early maturity, therefore, should be one of the breeding goals for sweet potatoes used for starch and alcohol production.

So far, no definite nor widely accepted criteria have been set for earliness in sweet potato. From the observation of a few varieties with natural flowering in Hangzhou, tuber growth gradually slows down to stop after the plant has begun to flower. This appears to be related to maturity, though it is not yet confirmed by experiments (ZAAS, 1981).

Flowering date as a criterion, however, is of no or little practical value since most varieties in China do not flower. In the Philippines, rapid drying up of the sap after cutting the tuber root is taken as a sign of maturity. Early-maturing types exhibit fast tuberization and rapid tuber bulking at an early stage, whereby early maturity means a high-yielding ability within a growing season of 90 to 110 days (Zhang and Yu, 1978). Another criterion set for early-stage evaluation and selection of high-starch varieties involves the number of sieve tube bundles per cm^2 inside the xylem tissue of tuberous root at about 40 days after planting (Lu et al., 1983). Through years of assessment on plants dug up at different stages, we found that it is possible to use the time when tuber growth is at a significant decline and when the tuber weight has reached 80 percent of total tuber weight in the whole growth period as a maturity marker. However, the mature stage can be calculated only after harvesting.

We found that early or late tuberization is closely related to maturity. Varieties with early tuberization expand roots rapidly at the early stage and mature early, while those with late tuberization have rapid expansion of tuber at late stage and mature late. The findings conform with those of Zhang and Xu (1978). Early or late tuberization, however, is influenced by other factors such as temperature, moisture, porosity and fertility of soil, vigor of seedling, planting depth, and survival rate. In general, tuber-bearing comes early where the soil is porous and well–aerated with high temperature and suitable moisture, whereas tuberization comes late

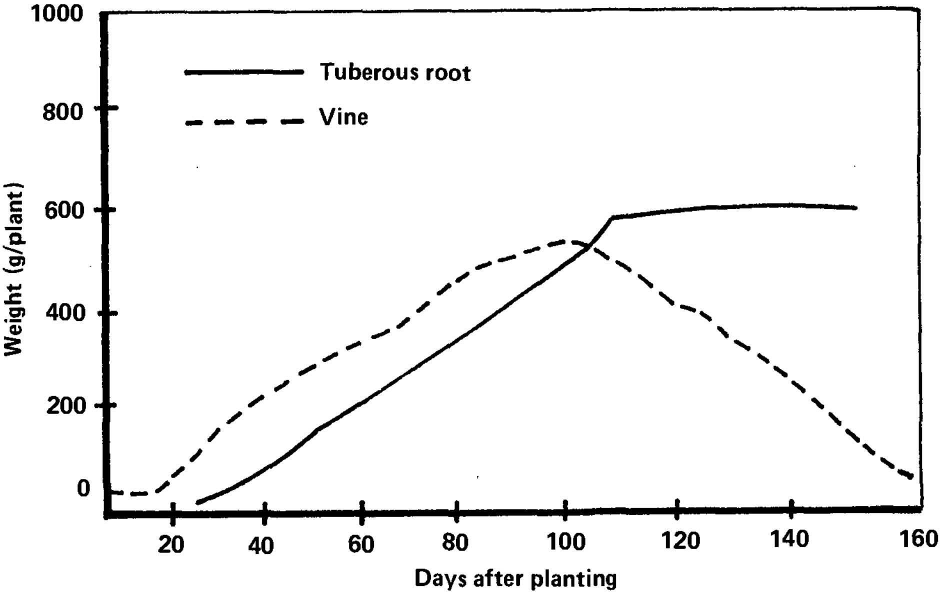


Figure 1a. Changes with time in tuberous root and vein weights of early-maturing variety 52-45.

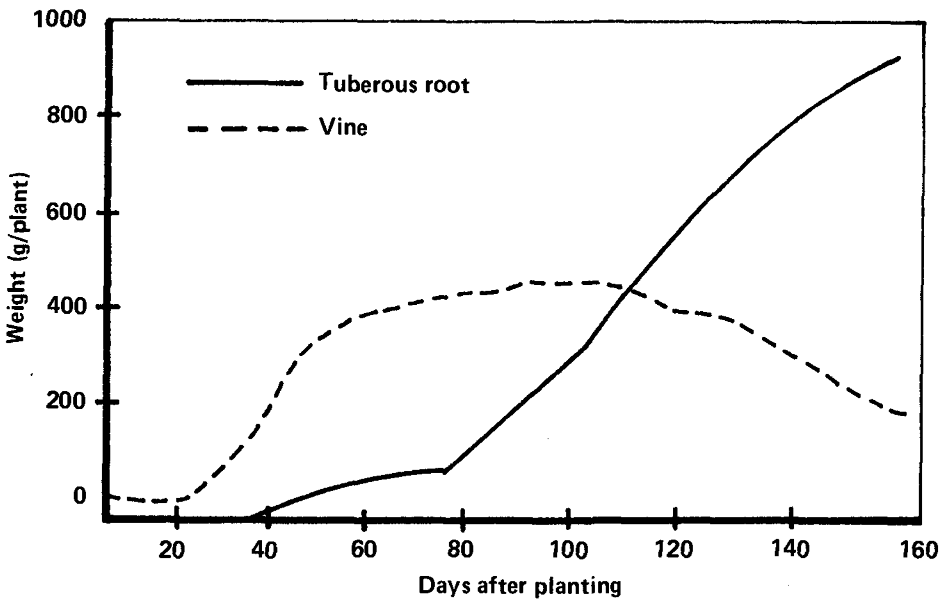


Figure 1b. Changes with time in tuberous root and vine weights of late-maturing variety Chaosheng 1.

where the soil is hardened, compact and poorly-aerated with low temperature, too high moisture or water deficit, or heavily applied with nitrogen. Shallow planting and strong sprouts help in early tuberization but deep planting and weak sprouts result in late tuberization. Vigor of the sprouts after planting affects early or late tuberization. Development of the proper environment for tuber-bearing and for a successful survival of the sprouts need further study. To exclude the influence of the external factors on tuberization, we suggest setting up of the tuber weight in 50-60 days after planting as an index for predicting maturity. In our experiments with seedlings from three combinations in 1981, significant correlations were shown between the tuber weights 50 and 90 days after planting ($r = 0.82^{**}$ to -0.83^{**}). But there was no significant correlation between the tuber weights at 50 and 150 days after planting. Analysis of data in 1982 showed high correlation ($r = 0.755^{**}$) in tuber weights of the cross Ningshu I x Honghong I at 50 and 90 days, but a negative correlation ($r = 0.246$) was found at 50 and 140 days. Therefore, considerable reliability is expected in taking the tuber weight at 50 days after planting and using this as principal index to predict the earliness of the crop. Through years of observation in Hangzhou, we classified as early-maturing varieties those planted in May and June at a density of 4,500 to 5,000 plants/ha with satisfactory survival and tuber yields of 150-200 g/plant at 50-60 days after planting and 500 g/plant at 90-100 days after planting.

SELECTION OF EARLY-MATURING PARENTS AND THE HEREDITARY TREND OF THE EARLY TUBERIZATION PROPERTY

Examples of early-maturing sweet potato varieties in China are Hengjin, Ningyuan-30-rizao, Guangjibaibi-60-rizao, and Fujian-60-rizao (indigenous varieties); 51-93, 52-45, Ningshu I, Ningshu 2, Jishu I, Waishu 3, Ning 12-17, and Zheshu 60-2, 79-60-I (hybrids); and Allgold and Pope (introduced cultivars from abroad). The early-maturing materials in indigenous Chinese varieties are very important genetic resources for the EMSPB. Most of the newly developed early-maturing varieties have consanguinities to early-maturing indigenous varieties. Preliminary observations also suggest that early maturity is a genetic trait resulting mainly from the additive action of genes. It is not difficult to select early-maturing lines with heterosis from progenies that have their parentage in early-maturing cultivars such as 52-45, Ningshu I, Zheshu 60-2, and 79-60-I. Around 21.1 percent to 55.6 percent of the F_1 hybrids with 79-60-I as female parent and 9.6 percent to 40.5 percent of the lines with Zheshu 60-2 as female parent exhibited early maturity, with a tuber yield of 200 g/plant at 70 days after planting. In the F_1 seedlings, with one of the above two varieties as male parent, the proportion of early-maturing lines was 47.1 percent to 80.0 percent and 30.0 percent to 58.3 percent, respectively. Of these two varieties, which are sib lines, 30 percent exhibited higher proportion of early-maturing line in the F_1 seedlings from their reciprocal crosses, reaching 76.9 percent and 56.4 percent (Table I). Zhang and Yu (1978) observed that there was a significant increase in the frequency of early tuberization in F_1 seedlings if one of the parents is early tuber-forming, and that there was maternal heterosis in the heredity of early tuberization property in some seedlings from cross combinations. They also claimed that early tuberization property was related to high-yielding ability and there was high frequency in the apprearance of high-yielding type in F_1 from early tuber-forming parents. We have noticed that relations between early tuberization (represented by the tuber weight 50 days after planting) and high-yielding properties vary with growth durations. Early tuberization property is positively correlated with the yield of flesh roots of the plants with short growth period harvested early while for those with long growth period harvested late, there is insignificant or negative correlation between early tuberization property and flesh tuber yield. On the other hand, some varieties showed signs of maturity at the onset of maturity, but when the varieties were not harvested, they restored the ability to grow at a later stage and obtain high yield of tuber under adequate temperature, moisture, and soil fertility conditions. These observations point to the possibility of incorporating the early-maturing and high-yielding genes into varieties with early tuberization property and to develop those lines that are both early-maturing and high–yielding. Further researches are needed on how to develop lines combining the early-maturing and high-yielding properties.

A QUICK METHOD OF SELECTING EARLY-MATURING SWEET POTATO

Development of a sweet potato variety in the past usually required five years from seedling screening trial to comparative and advanced trials. It would take as long as 7-8 years, on the other hand, to develop a new variety through regional and production trials. Only one seedling of each line used to be planted in the first year without evaluation of yield ability, while individuals that developed string and pencil roots and yielded very poorly were discarded.

Improvements in the procedure have been made by Chinese sweet potato breeders. They usually plant the cuttings from seedlings of each line twice in the first year, one cutting or seedling as spring sweet potato and 5-10 cuttings as summer sweet potato, and screen them by their root yield and dry matter rate, thus increasing evaluation opportunities and plant numbers of each line to get higher accuracy. To speed up the

Table 1. Root yield and percentage of early-maturing lines of seedlings with early-maturing parents.

Combination	Range of root yield (g/plant)	Average root yield (g/plant)	Percentage of early-maturing lines*
60-1 as female parent[a]	25-885	124-214	21.1-55.6
60-2 as female parent[b]	10-650	81-178	9.6-40.5
60-1 as father parent[c]	50-400	165-278	47.1-80.0
60-2 as father parent[d]	25-700	127-226	30.0-58.3
60-1 x 60-2	75-600	262	76.9
60-2 x 60-1	25-450	206	56.4

[a]The father parent in combinations is as follows: Kogane-Sengan, Ningshu 1, Honghong 1, Meijinghong, and Wanchun 1.

[b]Honghong 1, Wanchun 1, Jinxian 4, and Luhong 3 are used as father parents.

[c]Wanchun 1 and Honghong 1 are used as female parents.

[d]1349, Honghong 1, and Luhong 3 are female parents.

*Early-maturing lines refer to those whose root yield is over 200 g/plant 70 days after planting.

breeding process, some breeders forward directly the excellent selections to advanced trials. But the advanced materials for screening are not precise and reliable enough owing to a shorter period of evaluation. The characteristics in the vegetatively propagated crop make it possible to quickly stabilize the desired traits in excellent clones from the F_1 seedlings. But hereditability in the clonal generations differs in various traits, and higher hereditability owing to additive action of genes is found in traits such as dry matter rate, starch content, and resistance to diseases. Traits from heterosis, such as yield of flesh tuber and vine, have low hereditability and decline with the year of planting. So, the key to enhancing efficiency in selection and breeding lies in the evaluation and screening of the F_1 plants and their subsequent clones. To improve selection and evaluation in sweet potato breeding, a few F_1 seedlings are evaluated for numerous times, instead of evaluating many plants in one test, and the method of promoting superior seedlings directly in advanced trials is combined with the evaluation at different locations. To accelerate the progress of breeding, propagation of the clones at their breeding sites, varietal comparison trials, regional and production trials, and propagation of superior materials are carried out simultaneously. Thus, it can be done within one year, instead of 2-3 years as in the traditional way (Fig. 2).

As the F_1 seedlings and their first and second clonal generations are evaluated at different locations in terms of early and late planting, long and short growing season, flat and hilly land as well as various soils, more seedlings of high quality are selected and more lines are chosen than during the evaluation. The lines thus selected have also characteristics that are adaptable to different conditions.

The method of generation advance has been used to speed up progress in breeding rice and wheat. It was difficult for sweet potato to have two clonal generations bred in the north of China within one year, because of quarantine diseases and pests in the south, as well as the difficulty in the long distance transport of bulky tubers that tend to rot. We made selections out of two successive clonal generations within one year directly from fields in Hangzhou in 1982 and 1983. The first clonal generation was planted in May and June and selected after two months. The selected lines were planted in July and August for the second clonal generation. This practice gave satisfactory results. Since 1984, acceleration of generation has been carried on inside plastic-film tents where the growth duration for both generations can be prolonged, making possible earlier planting and late harvesting, and propagation of cultivars that mature in 90 and 120 days.

DEVELOPMENT OF EARLY-MATURING VARIETY ZHESHU 60-2

The early-maturing and high-yielding edible variety Zheshu 60-2, after five years of breeding with comprehensive use of the above-mentioned selection methods, was developed in 1984 and has been widely released for production since 1985. The variety was bred in 1979 from F_1 seedlings of Ningshu I, a species of Pharbitis from Uganda. Its tuber weight was 1,850 g/plant, 130.4 percent higher than that of the neighboring control. In a line evaluation in 1980, it outyielded the control by 57.7 percent after growing for 132 days in flat land plots. In a hilly land test, its increase over the control was only 2.81 percent after growing for 160 days. In 1981, it was further advanced to line comparison trial in which the variety was outstanding in early-maturity and at 30, 60, and 90 days its tuberous roots weighed 9.8, 250.5, and 549 g/plant, respectively, much higher than the other entries (Table 2). Cuttings of Zheshu 60-2 were planted immediately after harvesting for autumn multiplication of seed tubers.

Based on the data gathered during the 1982-84 evaluations, including varietal productivity evaluation, regional trials on the provincial level, production trials under various cropping patterns, and observation on

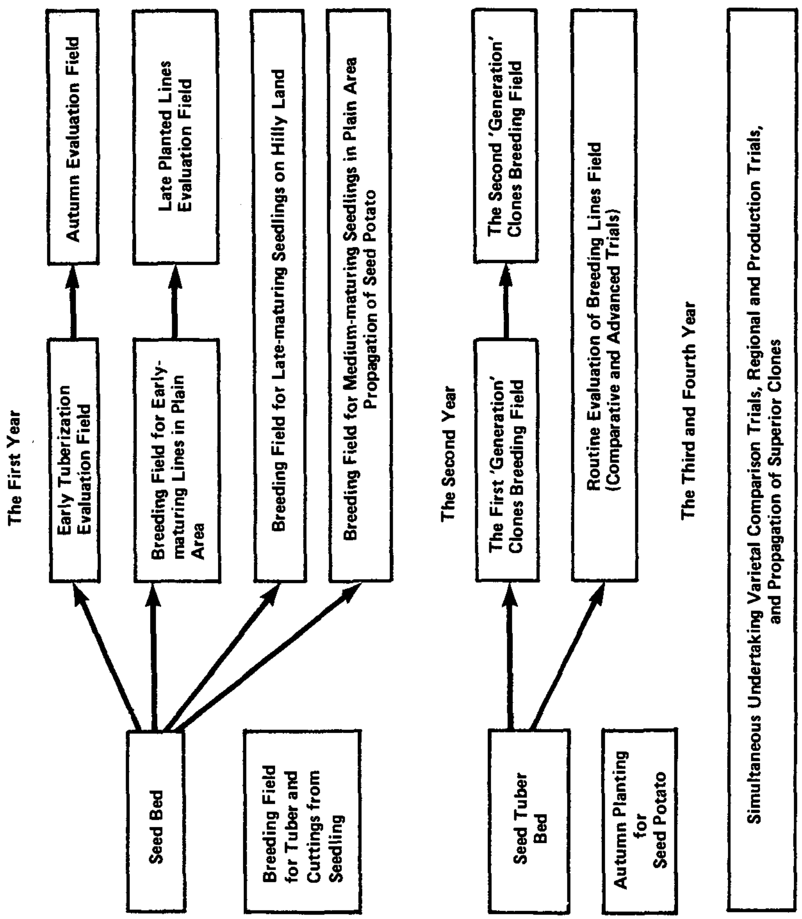


Figure 2. Model of quick breeding of sweet potato.

Table 2. Comparison of tuber-developing behavior of varieties planted on hilly land in Hangzhou.

Variety	Root weight at different periods (g/plant)					Percentage of overall weight				
	30	60	90	120	150	30	60	90	120	150
	(DAP)*					(DAP)				
Zheshu 60-2	9.8	251	549	631	654	1.5	38.3	83.9	96.5	100
134-9	2.9	185	466	689	770	0.4	24.0	60.5	89.5	100
79-24-52	2.5	66	319	639	639	0.4	10.3	49.9	100	100
79-24-15	2.8	93	290	441	530	0.5	17.5	54.7	83.2	100
1342	0.4	128	265	598	519	0.1	24.6	51.1	100	100
79-53-5	2.6	86	306	472	508	0.5	16.9	60.2	92.9	100
106	0.6	28	234	287	475	0.1	5.9	49.3	60.4	100

*Days after planting.

development and growth of roots and tops, the growth and development characteristics of Zheshu 60-2 were summed up as follows (Fig. 3):

- Early tuberization. Tuberous roots have formed 10-15 days after planting, or 5-10 days earlier than medium-late maturing varieties.
- Shortening tuberization period in correspondence to the increase in temperature. Those planted in May developed tuberous roots in 15-20 days and those planted in June and August formed tubers in 10-15 days, whereas those planted from August to mid-September exhibited longer tuberization period with the decline in temperature.
- Whereas vines of medium-late maturing varieties grow ahead of the development of tubers, tuberization and vine growth in Zheshu 60-2 are almost synchronous and tuber bulking is fast at the early stage. The vine and root weights of Zheshu 60-2 and 79-7-3 varieties planted on 29 July 1982 are shown in Table 3.

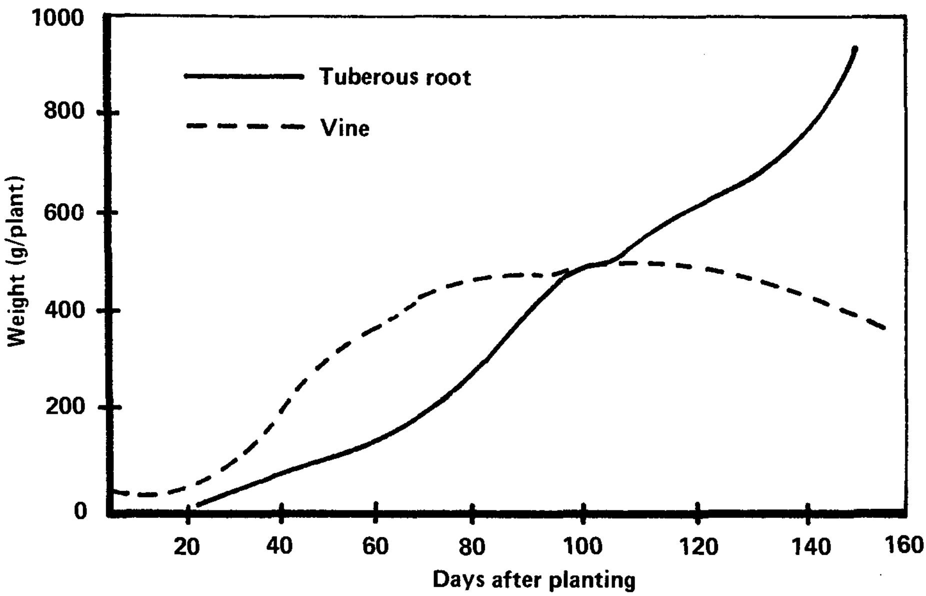


Figure 3. Changes with time in tuberous root and vine weights of Zheshu 60-2, an early-maturing variety.

The three-year regional trials at 51 locations in Zhejiang Province showed that the yield of Zheshu 60-2 increased by 23.2 percent to 35.7 percent over that of Honghong I control after a growing duration of 90 to 120 days at locations with adequate fertility and moisture conditions where the cuttings were planted late or the crop was harvested ahead of time. The yield either increased by only 15.5 percent or even decreased by at most 17.8 percent compared to the control when the variety was planted

Table 3. Vine and root weights of the early- and late-maturing varieties of sweet potato planted on 22 July 1982.

Variety	DAP*	Weight (g/plant)	
		Vine	Root
Zheshu 60-2 (early maturing)	20	222	24.2
	30	417	69
	60	566	60
	70	547	616
79-7-3 (late maturing)	20	191	5.3
	30	408	26
	60	954	349
	70	820	492
	90	436	640

*Days after planting.

as summer sweet potato 150 to 180 days after planting on dry hilly land with inadequate fertility and moisture conditions.

In trials of two croppings a year of Zheshu 60-2, the first crop was planted under film-mulched condition on the first week of May and harvested on the first week of August. The second crop with an additional growth period of 6 months yielded 47.9 t/ha of tubers, 66.8 t/ha of tops, with an output value of RMB ¥6,600/ha, or a net income of RMB ¥5,625/ha. The increase over that of the single-cropping Shengli 100 was 50 percent in tubers, 200 percent in tops, and 100 percent in output value.

An economic analysis of early planting, harvesting, and marketing showed that Zheshu 60-2 as the first crop (105 days) produced a tuber yield of 24.2 t/ha and a vine yield of 19.3 t/ha with an output value of RMB ¥4732/ha and a net ¥3,982/ha. The net income was RMB ¥1,853 more than that of Shengli 100 planted on the same day but harvested later (29 October).

Zheshu 60-2, as autumn sweet potato after watermelon, gave a tuber yield of 27 t/ha after growing for 98 days, no less than the 26.6 t/ha yielded by Shengli 100 that grew 136 days. In another trial in rainfed hilly paddy fields after rice harvest, the root yield of Zheshu 60-2 was 30 t/ha, equivalent to 6 t/ha of rough grain, which exceeded the output of the continuous two rice croppings.

To avoid disease incidence of *Helicobasidium mompa*, cuttings of Zheshu 60-2 planted on the third week of May were harvested early in mid-September after growing for ll4 days. The root yield was low (l9.05) owing to exposure to a drought spell at the early and middle stages. However, the yield was 4l.05 percent higher than that of the late-maturing Honghong I as yield losses at Zheshu 60-2 caused by diseases was diminished.

In trials dealing with enhancement of yearly yield and output value through intercropping on dryland, the yearly total output value was RMB ¥5,884/ha from the cropping system of wheat-soybean-sweet potato-autumn vegetable, in which Zheshu 60-2 after 100 days of growth gave a root yield of 29 t/ha and an output value of RMB ¥3,184. Compared with the cropping system of wheat-soybean-sweet potato in which Zhoushu I was used, there was an increase of 44.4 percent in total yearly output value and 36.4 percent output value of the sweet potato though its root yield decreased by 25.6 percent. The total yearly output accruing from the intercropping of wheat-sweet pepper + sweet potato-Chinese cabbage reached as high as RMB ¥20,47l/ha.

These results made it obvious that Zheshu 60-2 is a new early-maturing and high-yielding sweet potato variety. It is widely received and its planting area in Zhejiang Province was expanded to l,000 ha in l986.

RESEARCHABLE AREAS

It is well recognized that differences in early or late tuberization among sweet potato varieties exist. However, there are controversial issues about indicators or differences in maturities for sweet potato, which is a fundamental conceptional question to be solved in EMSPB. In this paper, we have only presented the question. Our viewpoint on early maturity of sweet potato needs elaboration and study of the source-link relation of early–maturing sweet potatoes, as well as the relationships between the crop and environment based on evaluation of growth and development characteristics and other data on the different breeding materials. Besides, we should verify the correlations among the morphological and physiological traits and early maturity as well as undertake researches on the inheritance and genetic correlation of early-maturing properties. At present, little attention is being paid to the study of selection of parents in breeding crosses for early-maturing varieties. The relationship between early-maturing and high-yielding varieties should be the priority of future research programs.

REFERENCES

Bartolini, P.V. 1983. Cultural management of sweet potato (personal communication).

Cacho, E.C. and B.G. Sagun. 1983. Sweet potato culture in the Philippines (personal communication).

IITA (International Institute of Tropical Agriculture). 1985. Sweet potato varieties become popular. ITTA Research Briefs, Vol. 6 3:8.

JAAS (Jiangsu Academy of Agricultural Sciences) and SAAS (Shandong Academy of Agricultural Sciences). 1984. Sweet potato cultivation in China. Shanghai Science and Technology Press. pp. 15-20, 46, 198-213.

Lin, S. S. M., C.P. Creighton Chen Dermin and Lo Hsiaofeng. 1982. A survey on sweet potato production and utilization. *In* Breeding Goals for Sweet Potato in Asia and the Pacific. AVRDC, Tainan, Taiwan, R.O.C.

Lu Shuyaun, Li Wiji, Feng Qihuan, Zheng Xiangru and Wu Chungguang. 1983. The correlation between the numbers of the sieve tube bundles of the xylem tissue per unit area and starch content at harvest time in sweet potato (*Ipomoea batatas* Lam.). Acta Agriculturae Universitatis Pekinensis. 9:1-6.

Obraztsov, A.S. 1983. On some biological aspects of breeding for earliness. USSR Agricultural Biology. 10:3- 11.

Tao Jianlan, Ye Yanfu, Zhu Yuanchu, Li Baiquan and Gong Qiming. 1986. Studies on improvement of efficiency of high-starch sweet potato breeding. Zhejiang Agriculture Science. 1:18-22.

Wang, H. 1982. The breeding of sweet potatoes for human consumption. Proceedings of the First International Symposium, AVRDC. Hong Wen Printing Works. pp. 297-311.

Ye Yanfu. 1984. Prediction and analysis on perspective of production and utilization for sweet potato. *In* Processing and Utilization of Sweet Potato. Zhejiang Information Institute. pp. 1-5.

Ye Yanfu, Tao Jialan and Zeng Chengxi. 1964. A survey on local cultivars of sweet potato in the Basin of Feiyuan River and directions of sweet potato breeding in South Zhejiang. Information on Agriculture Science and Technology. 25:1-6.

ZAAS. 1961. Studies on regularity of tuberous roots initiation and development in sweet potato. Miscellaneous Food Crops Section. Zhejiang Agriculture Science. 5:237- 242.

ZAAS. 1980. Sweet potato breeding in Zhejiang Province in recent ten years. *In* Collected Papers on Agricultural Science in Zhejiang Province. Sweet Potato Research Group. Zhejiang Science and Technology Press. pp. 96-102.

Zhang Bitai and Xu Pinlian. 1978. Parents selection and its combination for early-maturing, high-starch and high- yielding sweet potato breeding. Jiangsu Agriculture Science and Technology. 4:22-27.

THE THEORETICAL BASIS AND PRACTICE OF POLYCROSS AS USED IN SWEET POTATO

Florencio A. Saladaga*

INTRODUCTION

When the program for sweet potato improvement was started at ViSCA, Baybay, Leyte, the Philippines, various approaches were used. Of these, the polycross technique predominated because of its success. The polycross breeding technique as used in this sweet potato program has been previously described (Saladaga, l982a, l982b, l983a, l983b).

Several questions have been asked in a number of scientific meetings. Such questions often reflect the confusion on the meaning of the term. The present paper traces the beginnings of its use in plant breeding along with other terms suggested for quite the same meaning. It also takes a look at the most frequent use of the polycross for genetic studies of certain crops, and presents the various ways by which polycross has been applied as a breeding procedure, with emphasis on its use in sweet potato improvement.

The Term Polycross in Plant Breeding

Tysdal et al. (l942), who appears to be the first to use the term polycross in connection with plant breeding, stated:

> "For the purpose of distinction in discussion, the name polycross is suggested for the progeny from seed of a line that was subject to outcrossing with the other selected lines growing in the same nursery. In alfalfa, such polycrossed seed is likely to be 80 to l00 percent hybrid."

Stuber (l980) defined the term polycross as a mating arrangement for interpollinating a group of cultivars or clones using natural hybridization in an isolated crossing block. He stated that the polycross was used frequently for forage grasses, legumes, sweet potato, and sugarcane.

Wellensiek (l952) outlined how the term polycross became part of the language of plant breeding. He stated that Fransden (l940) described a procedure for breeding Timothy (*Phleum* sp.) without giving a special name to the technique. Two years later, Tysdal et al. (l942) developed es-

*Professor, Department of Plant Breeding and Agricultural Botany, Visayas State College of Agriculture, Baybay, Leyte, the Philippines.

sentially the same breeding method for alfalfa (*Medicago* sp.), designating it as "polycross." Wellensiek used the term "mass test crossing" for the general method he devised in 1947 for breeding cross-fertilized plants starting from rye (Secale). However, Fransden and Fransden (1948) preferred the name "polycross" as an international designation (Wellensiek, 1952). Since then, the term polycross has become accepted.

The term, however, has been used in various ways, resulting in confusion. Wellensiek (1952), who investigated the different terms used to refer to what was essentially a method following the same principle, had used the phrase "polycross test." It appears that Wellensiek designated the term polycross to the various activities involved in plant breeding where the polycross principle was involved. This is evident in his introduction where he referred to a "general method" he had built up for the breeding of cross-fertilized plants as "one of the main parts of this method termed mass test crossing." In his discussion, however, Wellensiek stated that the procedure is essentially a testcross (a feature expressed by the name "mass test cross"), after he declared that the recognition of desired genotypes by polycrossing has a sound theoretical basis. He then agreed with Fransden (1940) that the term "polycross" is more attractive in English if it is definitely understood that it is meant as a testcross, and suggested the name "polycross test" instead of the polycross method. Two paragraphs later in the discussion portion of his paper, Wellensiek (1952) again presented another idea that could easily cause confusion to a casual reader as follows:

> "Since the polycross in itself is not less but also not more than a test and is therefore incomplete, the question arises as to what else has to be done to make a complete breeding method. Testing by polycrossing disturbs the original genotypes. This is why we want a method of preserving these genotypes, while the polycross is being applied".

On the other hand, Wellensiek wanted to limit the use of the term polycross to only one step of the breeding method where the essential feature of the polycross test is taken advantage of. On the other hand, he wanted the term polycross to be broad to encompass a complete breeding method.

As previously mentioned, the first recorded statement that used the term polycross in plant breeding was made by Tysdal et al. (1942) in a Research Bulletin entitled "Alfalfa Breeding." The paper consisted of four main topics, namely; (1) objectives of breeding, (2) basic considerations in breeding, (3) improvement methods, and (4) conclusion. Under the topic "Improvement Methods" was the subtopic "Developing lines for recombination." This subtopic had a sole sub-subtopic entitled "The polycross method of testing the combining ability of lines." As described in the paper, the polycross method was a special technique proposed and used for alfalfa as a modification of the breeding procedure used in corn since available data clearly showed that the genetic principles in alfalfa were much the same as in corn. However, modification had to be made because of the following reasons: (l) the tetraploid complex in alfalfa, (2) the reproductive characteristic of the crop (i.e., it is impossible to produce a large amount of hand-pollinated seeds), (3) the difficulty of having sufficient number of isolated blocks to plant each line in conjunction with a commercial variety for the purpose of producing a natural top cross, which at best would only be 80-90 percent crossed, and (4) the advantage of the modified method for alfalfa which is easily propagated vegetatively.

The polycross method was described by Tysdal et al. (l942) as one which involves the growing of the selected lines together in a single nursery, the open-pollinated seed from each line being tested thereafter for productivity, disease resistance, etc. For the purpose of distinction in discussion, Tysdal et al. suggested the name "polycross" for the progeny from seed of a line that was subject to outcrossing with the other selected lines growing in the same nursery. They indicated that such polycrossed seed in alfalfa is likely to be 80 to practically l00 percent hybrid. They also found that this method has the advantage of producing a considerable amount of naturally outcrossed seeds from each line, which is necessary for thorough progeny testing. Self-sterile lines would be included in the polycross nursery as clonal lines (propagated by cuttings) of self-sterile plants. Thus, a polycross nursery may consist largely of clones of self-sterile plants selected from the breeding nursery the previous year by appropriate self-fertility tests together with observations on yielding ability and other desirable characteristics. These plants need not have been previously subjected to in-breeding. Clonal propagation would provide adequate seed from the polycross nursery for thorough testing and would have the additional advantage of affording replication in the polycross nursery to ensure random crossing.

Studies on the Polycross Method and Its Application in Genetic Studies

Genetic information on any crop species is an important resource that can serve as guide for the plant breeder in choosing an appropriate breeding scheme and selection procedure. Studies to generate genetic data from a population representing a crop species frequently utilize any of the known mating designs, depending on the (l) predominant type of pollination (i.e., self- or cross-pollination), (2) type of crossing used (i.e., artificial or natural), (3) type of pollen dissemination (i.e., wind or insect), (4) unique features (i.e., cytoplasmic or genetic sterility), (5) purpose of project (i.e., breeding or genetic), and (6) size of population required (Stuber, 1980). The main purpose of designing the mating in genetic studies is to generate progenies of known relationships so that the phenotypic components of variances could be equated with the covariances of relatives so as to derive the genetic components of variances (Becker, 1967). Stuber (1980) listed the polycross as one of the mating designs used frequently for forage grasses, legumes, sweet potato, and sugarcane. He adopted the definition of Tysdal and Grandall (1948) that the polycross is a mating arrangement (or design) for interpollinating a group of cultivars or clones using natural hybridization. Progenies from each entry thus have a common parent in the polycross design and half-sib families which are frequently used for evaluating general combining abilities are generated.

When the appropriate mating design for the crop species has already been identified, the variance component (VARCOMP) procedure described by Becker (1967) may then be used to derive the various phenotypes and gènetic components of variance. Such data is useful to plant breeders in selecting the breeding strategy given the predominant genetic mechanism controlling the trait to be improved. Because the polycross mating design generates half-sib progenies, the phenotypic variance component due to differences among half sibs is equal to the covariance within half sibs. Based on expectation mean squares, the covariance between half-sibs from a polycross mating design is 1/4 additive genetic variance, assuming no epistasis among additive genes. General combining ability reflects the additive genetic components of variance.

Wellensiek (1952) discussed the genetic basis of the polycross test as a means of recognizing the desirable genotypes. Shaepman (1952) proposed two ways of designing the polycross test. As used in genetic studies, one of the assumptions of the polycross test is that each clone is randomly pollinated by all other clones grown in the same polycross seed production nursery. Several suggestions have been given to ensure randomization in pollination. Hittle (1954) suggested that polycross seeds must be produced from a relatively large number of replications (10 or more) of single randomized plants to minimize differential pollen effects.

Fransden (1969) criticized the effectiveness of the polycross mating design. Olesen and Olesen (1973) believed that Fransden's criticism was probably influenced by the lack of a polycross pattern formula, hence, they proposed the polycross pattern formula. From the formula, they deduced the following properties of the pattern: the pattern is a Latin square, and every clone has any other clone as its nearest neighbor and has just one nearest neighbor in each of the four directions -- north, south, east, and west. Wright (1962) claimed that the systematic polycross design he had constructed had the following property: "The plantlets are so arranged that every clone has any other clone as its immediate neighbor (i.e., in the north, south, east, and west positions) an equal number (four) of times." Later, Wright gave ready-to-use field plans for a systematically designed polycross of any possible size from 6x6 to 46x46 m. Olesen (1976) indicated that the polycross pattern formula Olesen and Olesen introduced in 1973 was balanced with respect to nearest neighbors in the intermediate directions. Using mathematical proof, Olesen (1976) later presented a completely balanced polycross design. He stated that the design is completely balanced in that it has the following properties with respect to nearest neighbors: "In anyone of the four main directions -- north, south, east and west -- every clone has any other clone as a nearest neighbor exactly n times, while no clone has itself as a nearest neighbor. In any of the intermediate directions -- northeast, southeast, southwest, and northwest -- every clone has any other clone as a nearest neighbor exactly n-2 times, and itself as a nearest neighbor exactly n-1 times.

If the polycross mating design has already satisfied the theoretical assumptions, the remaining procedure is to statistically analyze the raw data gathered therein to derive useful genetic information (i.e., the magnitude of genetic variance and the heritability values). The VARCOMP procedure of Becker (1967) has been used in estimating genetic variance and heritability in sweet potato (Koonce, 1979; Saladaga, 1980, 1981a, 1981b, and 1981c; Bernardo, 1983; Villordon and Saladaga, 1983). In applying the variance component, the following assumptions must be considered:

- The population is in random mating.
- The population is not inbred and follows a diploid inheritance.
- The progenies are not inbred and can be considered random members of a noninbred population.
- The population is in linkage equilibrium.

The assumption of diploid inheritance may be a problem since sweet potato is an allohexaploid. However, Jones et al. (1969) stated that in the majority of sweet potatoes, chromosome pairing during meiosis occurs in a regular bivalent manner, and qualitative genetic studies indicate that many character segregations can be explained on the basis of multiple factor disomic models. Thus, quantitative genetic theories formulated for use with diploids may be applicable to the hexaploid sweet potato.

The VARCOMP procedure involves the following steps: (1) conventional analysis of variance (ANOVA) with a column on expectation mean square (Table 1) is fitted to provide a basis for computing the phenotypic variance components; and (2) the phenotypic variance components are genetically interpreted based on the relationship of the progenies which is statistically translated into the covariance of relatives.

Table 1. Analysis of variance with expectation mean squares.

Source of variance	Degree of freedom	Mean square	Expectation mean square
Total	Σ ni − 1		
Between parental groups	g − 1	MSg	$\sigma\epsilon^2 + \sigma g^2$
Within groups	Σ ni − q	MSw	$\sigma\epsilon^2$

Note: Σni = number of all i; g = number of parent groups; σg^2 = component of variance due to differences among parent groups; ϵw^2 = component of variance due to differences within groups or error; and k = coefficient, approximately the average number of progenies per parent group.

With the polycross as the mating design, the statistical model for the ANOVA is:

$Yij = \mu + \alpha i + \varepsilon ij$

where Yij = jth observation within the ith group;

μ = overall mean;

αi = effect of ith group; and

εij = residual error.

The component of variance caused by differences between parental groups, σg^2, was estimated as:

$\sigma g^2 = MSg - MSw \div K$

where MSg and MSw are the mean squares between and within parental groups, respectively.

In the polycross mating design of sweet potato where selfing is almost nil, relationship between progenies within a female parent is mostly half-sib. Therefore, the genetic meaning of the phenotypic variance components is as follows:

σg^2 = covariance of half-sibs

$\sigma g^2 = 1/4\ V_A$ (assuming neglible magnitude of additive epistasis)

where V_A = additive genetic variance component.

Heritability (h^2)in a narrow sense, is therefore calculated as follows:

$h^2 = 4V_A \div \sigma_w^2 + \sigma g^2$

Expected gain or response from selection R can be estimated as:

$R = iV_A h^2 \div Y \times 100$

where i = intensity of selection, with a value of 2.06 assuming selection of the top 5 percent of the population; Y = the observed mean; and V_A and h^2 are as previously defined.

Shiga et al. (l985) used a modified formula for estimating heritability for use in sweet potato under polycross mating design. The modified formula takes into account the incompatibility grouping of the parent varieties. Shiga et al. also used the variance component procedure but preferred to label their estimated heritability as a "broad sense" heritability since it takes into account the incompatibility groupings of the parents used in the polycross.

The formula used by Shiga et al. (l985) in estimating heritability is as follows:

$$H = V_{F1} - V_E \div V_{F1} = V_{FAi} - 1/2\ [V_{Ai} + (\Sigma V_{Bj} + \Sigma V_{Ck}) \div 8\ ] \div V_{FAi}$$

where:

V_{FAi} = phenotypic variance within the first year 2nd planting clones from polycross seeds obtained from the Ai variety used as female parent belonging to the A group of cross-incompatibility.

V_{Ai} = phenotypic variance within parent clone used as female belonging to the A group of cross-incompatibility.

$\Sigma V_{Bj} + \Sigma V_{Ck}$ = Total value of phenotypic variance to the B and C groups of cross-incompatibility.

The foregoing formula for heritability has an advantage when applied to sweet potato since most germplasm collections whose compatibility had been tested show that the cultivar therein could be classified into cross-incompatibility (or cross-compatibility) groupings. If only few parents are used (e.g., l0-l2 parents) and they belong to three or more compatibility grouping, each female parent is mated to only very few (possibly 2-4) male parents and the computed genetic variance would be closer to specific combining ability, hence, the broad-sense heritability. However, if each female parent is mated with a bigger number of male parents (i.e., the real polycross), then the genetic variance would be closer to general combining ability as Stuber (1980) indicated for the polycross progeny test.

The Polycross as an Applied Method of Breeding

As with most breeding methods, the practice of polycross antedated the formal establishment of its theoretical or genetic basis. As noted earlier in this paper, Fransden (l940) described a procedure for breeding Timothy (*Phleum*) without giving a special name to his technique and Tysdal et al. (l942) developed essentially the same method for alfalfa, designating the main topic as polycross. The main reason of Tysdal et al. for adopting the polycross was to produce a large amount of seeds, which is impossible in alfalfa using hand-pollination.

Although Wellensiek (l952) gave the credit to Fransden (l940) as the first researcher to have used polycross as a method of breeding, another work which was used as a field method (Miller, 1939) was actually done much earlier (Miller, 1937). This was later described as a polycross technique.

Jones (1965) was the first to adopt the term polycross to a breeding procedure in sweet potato. His procedure involved selection of 4-20 plants, intermating them, and bulking the seeds in every generation for four generations without selection to establish a randomly interbreeding base population. Thereafter, part of the seeds (about 500 seeds) may be used to maintain the base population in the original manner and the rest of the seeds may be used to form as many subpopulations as desired. Each subpopulation may then be altered through selection.

The procedure described by Jones (1965) was still a proposal and he admitted that, at that time, little was known of the appropriate manner and intensity of selection for maximum genetic advancement, as well as the techniques of introducing new variability (e.g., disease resistance), without having to start an entirely new population. These limitations resulted in lesser success that Jones had achieved in his applied breeding program as compared to his greater success in generating genetic data for sweet potato. Later, however, Jones' opinion on the number of parents that should be included in a polycross nursery changed. Instead of his suggested 4-20 parents, Jones (1983a) recommended a polycross nursery of 30 parents and stipulated that one of the previous entries must be removed whenever a new entry is made.

There is even a more fundamental theoretical limitation to the assumptions of Jones' (1965) proposed breeding procedure when viewed as an applied breeding technique. This concerns his statement that he set up in 1963 a randomly intermating population composed of sweet potato plants of as diverse origin as available, and considered an unbiased sample of all sweet potatoes. It was this population that became the parent of many of the subpopulations he had formed for his use in studying the genetics of various horticultural characters. But he also assumed, as his proposed procedure indicates, that he can make progress in his applied breeding goals. It was a very successful program in terms of generating genetic data but had very limited success as an applied breeding program to produce sweet potato varieties. As Jones (1983b) stated in a later paper:

> "It is assumed that as the above procedures are followed, promising plants will be used in polycross nurseries to develop cultivars. If one is lucky, one of the original selections might be suitable for release as a cultivar. However, I am not usually that lucky."

The most that Jones had achieved in the applied aspect of breeding was to produce a number of promising breeding lines that possess many important horticultural traits but did not have all the right combinations of traits that could satisfy the National Collaborators Group to release them as new varieties. The most important shortcoming then of his method as an applied breeding system was in trying to satisfy the methodology requirements for a genetic study while at the same time hoping to achieve the practical breeding goal of producing a variety.

The applied breeding program on sweet potato acknowledged as most successful in the USA is the program based at Louisiana State University (LSU), Baton Rouge, Louisiana, that was then headed by Dr. Julian Miller (Harmon et al., 1970). Several breeding lines developed in this program were entered in the trials of the National Sweet Potato Collaborators Group, USA. The most impressive success was the development of breeding line number L3-77, which was released by the National Sweet Potato Collaborators Group in 1960. It was named Centennial since its release coincided with the Centennial Anniversary of LSU and because it produces an average of 100 bushels more per acre than any other commercial variety then being grown in the USA (Miller et al., 1960). Its adoption by farmers contributed greatly to the development of the sweet potato industry in that country. Centennial accounted for 69 percent of the total acreage of sweet potato in the USA in 1970 (Migmucci, 1983). Pope (1970) reported that since the first sweet potato breeding program was initiated over 30 years ago by Dr. Julian Miller, more than 40 new cultivars have been developed in the United States, with Centennial being the most widely grown. He further stated that improvements that have been made include attractive skin colors, higher carotene and ascorbic acid contents, and resistance to some insects and diseases.

Hernandez (1979) reported that the sweet potato breeding program at LSU consists of a master polycross nursery and several ad hoc polycross nurseries. The master nursery consists of 50 to 60 highly selected parents from the ad hoc nurseries. These nurseries include: (1) a soil rot nursery with 10-15 selected parents, (2) a root-knot nematode nursery, (3) an insect resistance nursery, and (4) an industrial purpose nursery. The types of ad hoc nurseries would depend on the breeding objectives. The purpose of said nurseries is to increase the gene frequency for the trait under improvement while recombining slowly with other horticultural traits. The better lines obtained from the ad hoc nurseries are the only ones that are advanced to the master polycross nursery.

The other successful sweet potato breeding program in the USA is based at North Carolina State University. In 1965, a breeding line developed from that program was released and named Jewel. It accounted for 2 percent of the acreage of sweet potato in the USA in 1970. The release of this variety and the outbreak of the sweet potato soil rot disease epidemic Louisiana paved the emergence of North Carolina in the late 1970s as the top sweet potato producer in the USA (Migmucci, 1983).

Sweet potato breeding programs in other countries (e.g., Mainland China, Japan, and Taiwan) have been using controlled hand pollinations. Lately, the polycross was being started in Taiwan (AVRDC, 1982). Japanese researchers (S. Sakamoto and I. Shiotani, personal communication) and mainland Chinese and Taiwanese researchers preferred controlled crosses to polycrosses partly because they find handling the many seeds produced in the polycross inconvenient. For others, however, preference was influenced mostly by their familiarity with controlled crosses and their nonfamiliarization with the handling of the numerous progenies produced from polycrosses. Dr. Steve Lin, an AVRDC sweet potato breeder, said he was apprehensive in using the polycross because of the possible nonproduction of seeds since he was not sure if pollinating insects were present at AVRDC, Shanhua, Taiwan. After trying the polycross, however, he reported that polycrossing was much more labor efficient for gathering sweet potato seeds (AVRDC, 1982). Jones (1983b) recommended that breeders follow quantitative genetic principles with the use of mass selection and polycross nurseries adapted to appropriate breeding goals mass selection for long-term goals and polycross nurseries for cultivar development. He noted that where labor is plentiful, hand pollination can be used effectively; but where labor is costly, insect pollination can be used more efficiently.

The Polycross as Used in the Philippines

Since the early 1920s when sweet potato breeding by hybridization was started by Mendiola (1921) in the Philippines until the late 1970s, the hybridization procedure that was usually followed was controlled hand pollination or ordinary open pollination. It was only in the early 1980s that the polycross breeding technique became the predominant method of breeding sweet potato in the Philippines.

A number of problems prevented sweet potato breeders using hand pollination from producing several variabilities every year. Wang (1975) reviewed researches showing that poor fruiting and seed setting are the greatest obstacles in sweet potato improvement programs. He stated that some of the factors contributing to low fruit and seed set are self-sterility in most varieties and cross-incompatibility in a number of varieties. Thus, many workers (Nishiyama, 1961; Sakamoto, 1973; Wang, 1964) have attempted to group their sweet potato germplasm collections into different cross-compatibility groupings -- shorter stamen than style, shorter time of anther dehiscence than receptivity of stigma, sterile pollen and degenerated ovule. Wang (1975) continued that although most sweet potato varieties have four ovules per ovary, it is very seldom that all four seeds mature since only one developing seed is needed to produce fruit set. Moreover, the number of flowers that a pollinator can finish in a day is limited. Even for the most experienced pollinator, a higher than 10 percent success of fruit setting after hand pollination is already a desired goal.

The establishment of the polycross breeding scheme, however, was the best remedy for the foregoing problem. Highly selected parents were grown in polycross breeding nurseries and allowed to interbreed. The resulting thousands of seeds produced were then subjected to slight and later to intense selection pressure for horticultural characters of interest in the seedlings grown from seeds and the subsequent clonally propagated ones. This breeding procedure developed many superior seedlings and the release of outstanding varieties. After some years of successful use of the polycross breeding procedure at LSU, Jones (l965) conceptualized the theoretical basis of the procedure/method. The ensuing series of papers he published clarified a number of quantitative genetic concepts as they apply to sweet potato. Data gathered from studies on the mode of inheritance, heritability, and other quantitative genetic data of sweet potato have been very useful guides in the selection of parents for entry in polycross and the subsequent choice of the intensity of selection pressure on the several progenies.

Breeders are always faced with the situation of having to choose alternative strategies. For instance, with 60,000 to over l00,000 seeds produced from polycross breeding nurseries, the breeder must choose between two alternatives: (l) he could grow all these seeds into seedlings and clonally propagate each until sufficient materials are available for replicated tests before selection should be done, or (2) he could apply either slight or immediately intense selection pressure right in the seedlings grown from sexual seeds. These alternatives exist because the sweet potato, being highly heterozygous and highly cross-pollinated, produces seeds that can be grown into plants distinctly different from each other because of the genetic recombination that had taken place in the sexual reproduction process. Natural vegetative propagation, which is possible in sweet potato, enables the breeder to maintain each of the 60,000-l00,000 recombinants for vegetative multiplication without any segregation until replicated tests are already possible. If a certain level of efficiency in selection could be attained at an early stage, however, the selection should be done right then to reduce the bulk of material to be handled. Such may be the choice that the breeder has to make. A breeder's intuition coupled with his best interpretation of data on the mode of inheritance, heritability values of particular characters in his germplasm materials, and other quantitative genetic data are his resources for making the best choice.

At ViSCA, Baybay, Leyte, the Philippines, about five polycross nurseries have been established every year since the late l980s using the following general procedures:

- Vine tip cuttings (20-30 cm) from 25-50 parents were planted in the field following an RCB design with five or more replications spaced at 4 x 4 m between rows and hills.

- Posts were placed between hills and netted hogwire mesh was nailed to these posts to serve as trellis.
- Growing sweet potato vines were oriented into the trellis with occasional pruning of branches, leaving a set of two branches about 30 cm apart.
- The two branches on a set were trained to opposite directions on the trellis until such time that the whole area allotted to each plant was occupied. This allowed good plant growth and development because of the maximum amount of sunlight, nutrients, and air movement made available to the plants.

At first, the practice in Louisiana of imposing selection or screening on greenhouse-grown 4-5-month old seedlings from sexual seeds was adopted. The procedure was later modified. Thus, seeds are sown on seedboxes in the greenhouse and vine tips are planted in the field (after 2-3 months) following the standard practice, except that the plants are spaced 60 cm between hills. This reduces interplant competition and allows each genotype to express itself. At harvest, roots are dug and piled by hill. Selection is then made based on traits of high heritability values and those of importance to the specific breeding objectives. Subsequent clonal tests progressively use characters having lesser heritability values applied only in replicated traits as selection criteria.

Since female parents are known and the male parents for a particular female could be any of the males in the polycross nursery, some genetic information can be deduced from the differential progeny outcomes of all the parents in their role as females. Heritability values for each trait could be estimated using the VARCOMP procedure of offspring-parent regression analysis. The VARCOMP procedure is based on the fact that the mean performance of the progenies of any female parent in a polycross gives a basis for measuring the general combining ability (GCA) of each female parent. Classical quantitative genetics interprets the genetic component of GCA as composed mostly of additive effects. Hence, heritability values derived from VARCOMP procedure in polycross are very useful guides in deciding whether a trait could be used as a selection criteria for particular stages of the selection and screening process, and in determining the intensity of the selection pressure to be imposed given the desired possible outcomes.

Since sweet potato varieties are named and released as highly heterozygous F_1 progenies, a sweet potato breeder must take advantage of the occurrence of heterosis concomitant with the utilization or accumulation of additive genes by recurrent selection. It has so far been observed that, as predicted from genetic theory, some parents that have relatively low GCAs have offsprings possessing higher heterosis than parents with high GCAs.

REFERENCES

AVRDC (Asian Vegetable Research and Development Center). 1982. Sweet potato breeding. *In* AVRDC. Annual Report 1982. Shanhua, Tainan, Taiwan. pp. 95-125.

Becker, W.A. 1967. Manual of procedures in quantitative genetics (Second ed.). Program in Genetics, Washington State University, Washington, USA. 107 p.

Bernardo, R.N. 1983. Inheritance of some characters for a proposed plant ideotype for sweet potato. BS Thesis. Visayas State College of Agriculture, Baybay, Leyte, the Philippines.

Fransden, H.N. 1940. Some breeding experiments with Timothy. Imp. Agr. Bur. Joint Publ. 3:80-92.

Fransden, H.N. and K.J. Fransden. 1948. Polycross-metodens massekrydsningsmetode ved foraedling of fremnedbefnegtende Planter. Nordisk Jorbrusk-sforskning. 7-8:239-261.

Harmon, S.A., H.L. Hammett, T. P. Hernandez and D.T. Pope. 1970. Progress in the breeding and development of new varieties. *In* Thirty Years of Cooperative Research. Bulletin No. 159. Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana 70803 USA. pp. 8-17.

Hernandez, Teme P. 1979. Genetics improvement of the sweet potato, *Ipomoea batatas,* L. Paper presented at a conference in IITA, Ibadan, Nigeria. 15-19 October 1979.

Hittle, C.N. 1954. A study of the polycross progeny testing technique as used in the breeding of smooth bromogram. Agron. J. 46 (9):521-523.

Jones, A. 1965. A proposed breeding procedure for sweet potato. Crop Sci. 5:192-193.

Jones, A. 1983a. Workshop report of the Group on Breeding Techniques. *In* Martin, F. (ed.). Proc. Amer. Soc. Hort. Sci. Trop. Regions, Vol. 27 (part B). Tropical Agricultural Research Station, Box 70, Mayaguez, Puerto Rico 00709.

Jones, A. 1983b. Techniques for breeding sweet potato. *In* Martin, F. (ed.). Proc. Amer. Soc. Hort. Sci. Trop. Regions, Vol. 27 (part B). Tropical Agricultural Research Station, Box 70, Mayaguez, Puerto Rico 00709. pp. 72-75.

Jones, A., C.E. Steinbauer and D.T. Pope. 1969. Quantitative inheritance of ten root traits in sweet potatoes. J. Amer. Soc. Hort. Sci. 94:271-275.

Koonce, K. 1979. Lectures on statistical concepts in animal and plant breeding. Department of Experimental Statistics, Louisiana State University, Baton Rouge, Louisiana, USA.

Mendiola, M.B. 1921. Two years of sweet potato breeding. Phil. Agric. 10(5):177-184.

Migmucci, J.S. 1983. World and tropical production of sweet potato and prospect for their expansion. *In* Martin, F. (ed.). Proc. Amer. Soc. Hort. Sci. Trop. Regions Vol. 27 (Part B). Tropical Regions Research Station, Box 70, Mayaguez, Puerto Rico 00709. pp. 7-14.

Miller, J.C. 1937. Inducing the sweet potato to bloom and set seed. J. Heredity. 28:347-349.

Miller, J. C. 1939. Further studies and techniques used in sweet potato breeding in Louisiana. J. Heredity. 30:485-492.

Miller, J.C., Travis P. Hernandez, Teme P. Hernandez and W.J. Martin. 1960. Centennial, a new sweet potato variety. LSU Agricultural Experiment Station Circular No. 63, Louisiana State University, Baton Rouge, Louisiana, USA.

Nishiyama, I. 1961. Studies of sweet potato and its related species. I. Comparative investigations on chromosome numbers and main plant characters of *Ipomoea* species in section *batatas* Jap. J. Breeding 11:37-43.

Olesen, K. 1976. A completely balanced polycross design. Euphytica 25(2):485-487.

Olesen, K. and O.J. Olesen. 1973. A polycross pattern formula. Euphytica 22:500-502.

Pope, D. T. 1970. Recent progress and current trends of the sweet potato industry in the United States. *In* Plucknett, D.L. (ed.). Proc. 2nd Intl. Symp. Trop. Root and Tuber Crops. Honolulu, Hawaii. pp. 7-10.

Sakamoto, S. 1973. Relationship between the origin and the cross-incompatibility of sweet potato varieties. Jap. J. Trop. Agric. 17(2):58-61.

Saladaga, F.A. 1980. Genetic variance, heritability, and correlation for genetic characters of the sweet potato, *Ipomoea batatas,* L. PhD Dissertation. Louisiana State University, Baton Rouge, Louisiana, USA.

Saladaga, F.A. 1981a. Heritability and expected gain from selection for yield, weight loss in storage, and sprouting in field bed of sweet potato. Annals of Tropical Research. 3(1):1-7.

Saladaga, F.A. 1981b. Breeding techniques for sweet potato. *In* ViSCA (Visayas State College of Agriculture). A Manual for the Southeast Asian and the Pacific Training Course on Root and Tuber Crops Germplasm Evaluation and Utilization. Baybay, Leyte, the Philippines. pp. 180-190.

Saladaga, F.A. 1981c. Some statistical concepts and procedures applied in sweet potato breeding. *In* ViSCA (Visayas State College of Agriculture). A Manual for the Southeast Asian and the Pacific Training

Course on Root and Tuber Crops Germplasm Evaluation and Utilization. Baybay, Leyte, the Philippines. pp. 207- 219.

Saladaga, F.A. 1982a. The polycross method of breeding at ViSCA, Philippines. Paper presented at the 1982 Annual Meeting of the Crop Sci. Soc. Phil. held at Ecotech Center, Cebu City, the Philippines.

Saladaga, F.A. 1982b. The use of polycross in sweet potato breeding at ViSCA, Philippines. Paper presented at a seminar in the Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan.

Saladaga, F.A. 1983a. Promising sweet potato lines developed at ViSCA through the polycross breeding technique. Paper presented at the Annual Meeting of the Crop Sci. Soc. Phil. held at the International Rice Research Institute, Los Baños, Laguna, the Philippines.

Saladaga, F. A. 1983b. Sweet potato breeding in the Philippines. *In* Proc. Int. Sem. on Root Crops in Southeast Asia (ISRC-SEA), held at ViSCA, Baybay, Leyte, and UPLB, Los Baños, Laguna, the Philippines. pp. 370-378.

Shaepman, H. 1952. Application of the polycross test to grass breeding. Euphytica.I:105-111.

Stuber, C.W. 1980. Mating designs, field nursery layouts, and breeding records. *In* Fehr, W.R. and H.H. Hadley (eds.). Hybridization of Crop Plants. Amer. Soc. Agron. and Crop Sci. Soc. American Publishers, Madison, Wisconsin, USA. pp. 83-104.

Tysdal, H.M. and B.H. Grandall. 1948. The polycross progeny performance as an index of the combining ability of alfalfa clones. J. Amer. Soc. Agron. 40:293-306.

Tysdal, H.M., T.A. Kesselback and H.L. Westover. 1942. Alfalfa breeding. College of Agriculture, University of Nebraska Agricultural Experiment Station Research Bulletin No. 124, Lincoln, Nebraska. pp. 1-46.

Villordon, A. and F.A. Saladaga. 1983. Inheritance of skin and flesh color, size, shape and smooth use of skin of *Ipomoea batatas*, L. Paper presented at the Annual meeting of the Crop Sci. Soc. of the Phil. held at the International Rice Research Institute, Los Baños, Laguna, the Philippines.

Wang, H. 1964. A study of self- and cross-incompatibility and the factors affecting seed setting in sweet potato. J. Agric. Assoc. China (New Series)48:3-12.

Wang, H. 1975. The breeding and cultivation of sweet potatoes. Food and Fertilizer Technology Center Tech. Bull. No. 26. P.O. Box 3387, Taipei City, Taiwan.

Wellensiek, S.J. 1947. Rational methods for breeding cross-fertilizers. Meded. Landbouwhogeschool. 48:227-262.

Wellensiek, S.J. 1952. The theoretical basis of the polycross test. Euphytica.I:15-19.

Wright, C.E. 1962. A systematic polycross design. Res. Exp. Rec. Min. Agric. N.I. (I):7-8.

SWEET POTATO FOR SMALL FARMERS: AN INTERDISCIPLINARY APPROACH

Florencio Saladaga*

INTRODUCTION

Based on the achievements of the goals and objectives that have been set, the research program for sweet potato improvement at ViSCA is considered one of the successful research programs in the Philippines. Started in 198l, the program has already developed several breeding lines of sweet potato, six of which were selected for entry in the national cooperative testing for root crops conducted at various regions in the Philippines. Three of these lines were approved for release and were renamed VSP-1, VSP-2, and VSP-3. These three new varieties showed markedly higher yields of l7.3-20.9 t/ha (average of four to six locations) compared to BNAS-51 (8.6 t/ha), the standard check.

After approval of the release of the new sweet potato varieties by the Philippine Seed Board (PSB), several planting materials were made available to various requesting individual farmers, private corporations, and government agencies. This system of dissemination and other related activities (e.g., training) has been well recognized as shown by several pertinent articles that have been published in newspapers and magazines of regional and national circulation.

Sweet Potato Research in the Philippines Before the l980s

Early government policies placed low priority on research in general and agricultural research in particular. The few agricultural research endeavors were mostly concentrated on important agricultural crops (i.e., rice, sugarcane, corn, and some vegetables). Only sporadic and voluntary research work on the improvement of the sweet potato were done, beginning with the work of Mendiola (l92l) which was short-lived. It was a common experience for a person who works on "camote" (the local name for sweet potato) to be referred to as Dr. Camote, with the implication that he is "mangamote" or of low category. Likewise, a student who flunks in his subject is usually told by his teacher to "go home and plant camote."

*Professor, Department of Plant Breeding and Agricultural Botany, Visayas State College of Agriculture, Baybay, Leyte, the Philippines.

In the early l970s, a small segment of the world scientific community began to give attention to the lowly root crops, which include the sweet potato. Dr. Barry Nestel, then Associate Director of the International Development Research Centre (IDRC) of Canada, was one of the moving spirits behind the resurgence of interest in root crops research. In the Philippines, two researches on root crops were funded by the erstwhile National Science Development Board (now Department of Science and Technology) in the early l970s. One was at the University of the Philippines at Los Baños and the other was at ViSCA (Saladaga, l976).

Although the aforementioned researches on root crops were intended to be interdisciplinary, the fact that the researchers had to deal with more than one crop (i.e., sweet potato, cassava, taro, and yam) accounted for the slow progress. Moreover, emphasis was then placed on training of researchers in the important disciplines of plant breeding, plant production and physiology, and crop protection. Two staff members of UPLB were supported by IDRC for their PhD degrees abroad -- one in plant breeding and the other in crop production and physiology. From ViSCA, three staff members were also supported by IDRC scholarship grants in their PhD studies -- one each in plant breeding, crop science, and plant protection. The idea then was to have them work as a team upon their return. Although the idea did not quite work the way it was conceived, an interdisciplinary team was still formed for sweet potato research.

The Impetus for the Organization of the Sweet Potato Improvement Program at ViSCA

Leyte, one of the five provinces in Eastern Visayas, has been leading the region in root crops hectarage and production in the Philippines. In the late 1940s, Dr. Dominador Clemente, Superintendent of the then Baybay National Agricultural School (BNAS), now ViSCA, made a selection of sweet potato varieties and came up with a breeding line that was released as BNAS-51 in 1951. While it has become one of the farmers' favorite varieties until today, indicating the success of that work, not much was done on sweet potato research at BNAS until the 1970s.

With a small "seed money" from ViSCA, Mr. Sergio Abit of the College's Department of Agronomy started the collection of root crop varieties. The present author took over the collection activity from Mr. Abit who went on study leave. The collection then included five varieties of cassava, 32 varieties of sweet potato, and some varieties of yam, colocasia, and other root crops. Subsequently, a research study entitled "Collection and evaluation of introduced and local varieties of root crops" was approved and funded by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) (Saladaga, l976).

In November 1975, the First Regional System Research Congress for Region VII and Region VIII was organized by PCARRD, National Electrification Administration (NEA), Ministry of Agriculture (MA), and ViSCA to define the research status in the region and formulate policy directions (Saladaga, 1975). A program for the establishment of a National Root Crops Research Center was approved and funded by IDRC and PCARRD in 1976. In 1977, this national center was formally established by a Presidential Decree and given the name "Philippine Root Crop Research and Training Center." Former President Ferdinand Marcos amended the Presidential Decree to include the creation of a Northern Philippine Root Crop Research and Training Center (NPRCRTC). NPRCRTC was established at Mountain State Agricultural College (now Benguet State University) in La Trinidad, Benguet.

The program consisted of projects on infrastructure development, staff development, production, pest resistance, and root crop breeding.

When IDRC consultant Dr. Barry Nestel visited ViSCA in early 1981 to evaluate the ongoing Root Crops Program, a draft proposal on sweet potato improvement was submitted to him. The proposal was the start of the interdisciplinary team approach to research.

The Interdisciplinary Team Approach to Sweet Potato Improvement at ViSCA

The overall goal of the proposed sweet potato improvement program at ViSCA is to produce and release sweet potato varieties that possess most, if not all, of the characteristics desired by Filipino sweet potato farmers and consumers. During the early stages of the program, the research team and other interested persons or agencies in the Philippines could request or decide the release of sweet potato varieties that possessed a few desirable traits (while awaiting for the genotypes that combined more desirable traits) if the need to name and release a variety was called for by the situation. The specific (operational) breeding objectives were to develop sweet potato varieties with (l) high fleshy root yield under normal and marginal farming conditions, (2) high dry matter content of fleshy roots, (3) resistance to sweet potato pests and diseases with emphasis on the sweet potato weevil and sweet potato scab, (4) high protein content, (5) acceptable organoleptic quality and well-shaped roots with smooth skin, and (6) acceptable weight loss in storage.

Since the foregoing goals/objectives could best be attained by an interdepartment, interdisciplinary, and integrated approach, the proposal was conceived by a team composed of an agronomist, a plant breeder, a geneticist, an entomologist, a pathologist, a postharvest physiologist, and a home economist; each was to undertake the various independent but related and integrated research projects, namely: (l) increasing sweet potato plant variability; (2) nonreplicated screening of seedlings grown from seeds and replicated trials of selected genotypes; (3) studies on sweet potato plant resistance to insect pests and diseases; and (4) studies on postharvest characteristics of various sweet potato genotypes.

Each project under the program had an individual set of goals/objectives which could be a justification for any individual project itself. With the coordination of the different projects as conceived in the proposal, not only was each project expected to achieve its individual goals/objectives but also to contribute to an overall output, which was the development and release of recommended and farmer/consumer-accepted sweet potato varieties during various stages in the implementation of the research program.

The different studies under each project and the method of carrying out each study with alternative methods, advantages, and disadvantages or shortcomings were described in the proposal.

In 1983, a proposal for Phase II of the program was submitted and approved, this time including a project on marketing and economic feasibility studies. The team is presently preparing a proposal for Phase III. Thorough analysis is required to decide on whether to expand the program by additional projects with the same financial support; whether the present program has already reached a certain limit of complexity and difficulty in coordination and monitoring; or whether to continue it as it is, and look for a loose coordination with other programs and projects within the Philippines, with other national programs in other countries, and with international centers. These issues will have to be resolved bearing in mind previous experiences and the changing context within which research is proceeding. As Koppel (1981) stated:

> While it is too soon to foresee all the likely outcomes, it is clear, if not always admitted, that relationships between the international and agricultural research centers (IARCs) and the national agricultural research systems (NARSs) are characterized by divergent assumptions about who should and should not be doing what...

He stated that the conclusions of the Consultative Group for International Agricultural Research (CGIAR) review committee and the Bellagio conference on potentials for cooperation among NARS has pointed out the appropriate, the sometimes appropriate, and the inappropriate range of cooperative activities among IARCs and NARSs (Madamba, 1981) .

Impact of the Program on the Sweet Potato Industry

Magpayo (1984) stated that with domestic sale and export potentials, the new sweet potato lines developed by the ViSCA Sweet Potato Improvement Program have brightened the country's economic horizon. Van der Wal (1984), the director of Granaria which is reported to be the largest distributor of feed grains in the European Economic Community (EEC), stated in his business travel report that new sweet potato varieties that look attractive to farmers, profit-wise, have been developed in the Philippines. He estimated that the local market of the Philippines could absorb 300,000 to 400,000 metric tons of dried sweet potato chips per annum and the EEC could absorb the surplus without doubt. He continued that 30 million tons of feed ingredients are imported by the EEC annually. Since annual sweet potato consumption in the EEC is estimated at 2 million tons, Granaria could easily sell 30,000 to 40,000 metric tons of dried sweet potato chips to the EEC with an estimated volume of 115,000 metric tons in 1984.

In April 1985, the Netherlands Embassy in Manila and the Granaria headquarters in the Netherlands commissioned Engr. Harry Van Ruiten to collect data on the production prospects of sweet potato in the Philippines in view of the possible export of sweet potato chips and pellets to Europe through the Netherlands. He reported the bright prospects of sweet potato production are largely motivated by (1) the development of high-yielding varieties in the Philippines, (2) the need to increase sweet potato production to meet local food and feed requirements, (3) the unfortunate collapse of the sugar industry with no short-term recovery prospects, and (4) the pressing need for the Philippines to establish a profitable export market in support of currency balance of payment (Van Ruiten, 1985). He also stated that access to the feed component was important for the dairy and poultry industries of many EEC member countries, thus expressing sincere interest in the procurement of sweet potato chips/pellets on a regular and secure basis. Because of this market demand of the EEC, various programs have been put forward to increase sweet potato production. Espiritu (1986) reported that the Philippines hopes to capture a larger share of the export market for sweet potato within a few years, following government and private efforts to organize and integrate production of the erstwhile backyard crop.

Training activities for technicians have been organized in various provinces of the different regions of the country. Region I (northern Luzon) conducted trainings for over 60 Ministry of Agriculture and Food (MAF) technicians at the Mariano Marcos State University in Batac, Ilocos Norte. The Technology Resource Center in Makati (Metro Manila) also conducted training activities on sweet potato. MAF Region V (Bicol) has so far conducted a series of three trainings in sweet potato for its personnel at the MAF regional office in Pili, Camarines Sur, and produced an attractive pamphlet on sweet potato production. The Rotary Club of Cotabato City conducted training courses for the technicians of various government agencies and private corporations interested in sweet potato.

A greater number of these trainings, however, were conducted at PRCRTC/ViSCA.

The most significant impact of the sweet potato improvement program was in helping alleviate the food problem faced by typhoon victims. MAF distributed truckloads of camote and cassava cuttings to farmers of Santa Rita and Basey, Samar, who were victims of typhoon "Undang." Because of the new sweet potato varieties' earliness in forming tubers, edible roots the size of the fist of a l2-year old child can already be available 2 months after planting. The Philippine Training Center for Rural Development (PTC-RD) organized a Southern Leyte Information Caravan to help the people of typhoon-stricken Southern Leyte. PTC-RD staff distributed planting materials of the new varieties, provided pamphlets, and conducted lectures and demonstrations on the recommended practices in producing sweet potato.

During the eruption of Mayon Volcano in Albay, evacuees numbering about 60,000 had to be housed in various elementary schools, government buildings, and other houses around Mayon Volcano far from the molten lava and volcanic ash. Such large displaced population could not have brought with them enough food. Luckily, the former Governor of Camarines Sur, Juan Trivino, was one of the early cultivators of the new VSP sweet potato varieties. He obtained 8,000 cuttings in the middle of l983, 70,000 cuttings in October l983, and increased this further on his farm. The food needs of the 60,000 evacuees were partly met by the supply of tubers from his farm (Trivino, 1986).

CONCLUDING REMARKS

In the beginning of this paper, it was stated that the research program reported here is one of the successful researches based on the accomplishments of the goals/ objectives that have been set. Not all the objectives have been fulfilled but the statement was made owing to the positive impact that the output of the program had created. Yet, it was realized that the goals/objectives could have been improved further. In a meeting organized by PCARRD for researchers engaged in technology adaptation and technology verification, the author reported that the sweet potato improvement program has already distributed several planting materials to farmers of the various provinces in the Philippines. The distribution of planting materials was not a part of the objectives of the program. However, as Javier (l98l) said, "the ultimate measure of the success of a breeding program is not the number of varieties approved and released by the PSB but rather the hectarage devoted to the released varieties and the incremental benefits arising out of their usage by our farmers."

If we now assess what must be done for the future (i.e., Phase III), the feedback from farmers and users/consumers will have to be given adequate consideration in setting the objectives. Moreover, the following analytical concerns which Koppel (l98l) discussed, among other things, should be considered: (l) identification, analysis, and evaluation of higher order impacts; the effect of effects (i.e., what are the consequences of technology utilization, misapplication, or underutilization? It should uncover unanticipated probable consequences, whether positive or negative); (2) the concern whether the development and dissemination of technology is sustainable, whether technology utilization can proceed without incurring a succession of adjustment problems that ultimately undermine the viability of the technology.

One strategy that is being looked into is the utilization of the appropriate indigenous research of subsistence farmers (i.e., their long tradition of selection of sweet potato varieties). This is an activity that tries to bridge the gap among sweet potato breeders, technology verification researchers, and farmers (Lightfoot et al, l987). Another suggested approach is to loosely link with agencies concerned with highland agriculture so that they could also serve farmers in similar situations.

The suggested approach to take advantage of the farmers' indigenous screening techniques appears to have some merit. Such strategy would come close to the experience in China. As Umali (l98l) reported, the gap between agricultural research and the peasant in China must be one of the narrowest in the world. As with many things in China, the research system evolved from local conditions; it seeks to serve local needs and relies heavily on local techniques, thus effectively bridging the gap between research and its intended beneficiaries by putting proven results into immediate practice; its key unit is a research group on the brigade level; in some communes, even the production team which is the basic people's unit conducts its own experiments (e.g., on varietal selection and cultural practices).

REFERENCES

Espiritu, C. l986. Sweet potato export project to be funded. *In* Bulletin Today, Business Section, Manila, the Philippines. 27 January l986. p. 22.

Javier, E.Q. 1981. Program planning at the level of a small research institute or center. In Agricultural Research Management (Asia). SEARCA Los Baños, Laguna, the Philippines. Vol. 3:l49-l58.

Koppel, B. l98l. Technology assessment and research management in agriculture: A perspective on conceptualization and implementation. *In* Agricultural Research Management (Asia). SEARCA, Los Baños, Laguna, the Philippines. Volume 3: l9-40.

Lightfoot, C. 1987. Screening sweet potato cultivars by subsistence farmers: Implications to plant breeders. Paper presented at the International Seminar-Workshop on Sweet Potato for the Small Farmers - An Asian Perspective. ViSCA, Baybay, Leyte, the Philippines. 20-27 May 1987.

Madamba, J.C. 1981. Potentials for cooperation among national agricultural research systems - a report on the Bellagio conference. *In* Agricultural Research Management (Asia). SEARCA, Los Baños, Laguna, the Philippines. Volume 3: 101-118.

Magpayo, P.E. 1984. Sweet potato: The Philippines' sunshine commodity. *In* Countryside Banking. Central Bank of the Philippines. Vol X:4-32.

Mendiola, N.B. 1921. Two years of sweet potato breeding. Phil. Agric. 10(5):177-184.

Saladaga, F.A. 1975. Status of research and research needs for root crops in Central and Eastern Visayas. *In* Proc. First Reg. Agric. System Res. Cong. for Central and Eastern Visayas. Skyview Hotel, Cebu City, the Philippines. November 1975.

Saladaga, F.A. 1976. Collection and evaluation of root crop varieties. ViSCA Review. ViSCA, Baybay, Leyte, the Philippines. Vol. 1:7-9.

Triviño, J. 1986. The lowly camote potential revisited. *In* Balalong. Naga City, Camarines Sur, the Philippines. 9 and 16 September 1986.

Umali, D.L. 1981. Research elitism. *In* Agricultural Research Management (Asia). SEARCA, Los Baños, Laguna, the Philippines. Vol. 3:139-148.

Van Der Wal, C. 1984. Business travel report for Granaria Amsterdam, the Netherlands. December 1984.

Van Ruiten, H.T.L. 1985. Travel Report. Ref. Phil. HVR-III-No. 19. ASEAN Crops Postharvest Programme. Metro Manila, the Philippines. 8-10 April 1985.

AVRDC SWEET POTATO IMPROVEMENT PROGRAM

R.T. Opeña, H. Takagi, and S.C. S. Tsou*

INTRODUCTION

Sweet potato ranks seventh in total production among the world's food crops (FAO, 1986), and has played a very important role as food source in Asia and Oceania. In the early 1970s, the world's harvested area for sweet potato peaked at 15 million ha with a total yield of over 130 million metric tons (FAO, 1973). At about that time, the Asian Vegetable Research and Development Center was established with sweet potato as one of its principal crops primarily because of its high nutritive value, high energy production, relatively low input requirements (Luh and Moomaw, 1979), and importance in the AVRDC region.

Recent years have seen a significant decrease in the world's sweet potato production area to 8 million ha with 111 million tons output in 1985 (FAO, 1986). Asia, however, still accounted for 92 percent of the total production amounting to 102 million metric tons. There is, indeed, a great potential use for sweet potato as food, feed, and vegetable in Asia and in other tropical regions. These data provide the rationale for AVRDC's continuing research attention on sweet potato.

Albeit, sweet potato is traditionally a tropical crop, most improved varieties have been developed for the temperate regions and are, therefore, not well adapted to Asia's adverse hot, wet environments. Coupled with the low inputs normally given to sweet potato in the developing world, its below par productivity in farmers' fields is not surprising. For instance, average yields ranged from 5 to 13 t/ha in selected tropical countries, whereas in temperate countries such as Korea and Japan, production was as high as 20 t/ha (Villareal, 1982a). Apart from poor productivity, the potential of sweet potato to alleviate vitamin A deficiency in starch-rich diets has not been fully realized because only white- or yellow-fleshed cultivars have often been grown and used as high energy food source.

The AVRDC sweet potato program aims to generate and distribute appropriate technology in the form of improved genetic materials and

*Program Director, Associate Plant Breeder, and Crop Director, Production Systems Program, respectively, Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, R.O.C.

management practices, with particular emphasis on fitting the crop to post-rice cropping systems.

Integration of AVRDC's Sweet Potato Research Components

The productivity of sweet potato in farmers' fields is constrained by complex biophysical and socioeconomic problems (Garcia and Gomez, 1980; Gomez, 1980; Lin et al., 1983; Villareal, 1982a). Research at AVRDC is, therefore, linked on both disciplinary and program levels to develop the integrated technological solutions to the major limitations in sweet potato production in the tropics. Plant breeders, plant physiologists, plant pathologists, entomologists, chemists, and scientists of other relevant disciplines work jointly in achieving the desired goals (Fig. 1). The sweet potato improvement program utilizes the multidisciplinary team approach needed to successfully address the complexity of the crop's problems.

Integrated research is carried out by the Crop Improvement Program (CIP) and Production Systems Program (PSP) to develop improved technology for eventual transfer to national programs. In sweet potato, the target utilization types include the staple/feed, dessert, and vegetable leaf types, especially for small farm and home garden systems.

CIP's research covers the following areas: development of stable yielding, widely adapted clones; improvement of acceptability and nutritional quality of sweet potato for human consumption and animal feed; physiology of yield and flowering; studies on the nature and distribution of the major sweet potato viruses and development of an effective quarantine/virus-indexing method to enable a safe germplasm exchange; incorporation of resistance to sweet potato scab and other major diseases in the tropics; incorporation of resistance to sweet potato vine borer; and exploration of cultivated types and related wild species for resistance to major pests and other desirable characters.

Sweet potato research under PSP aims to develop and assess the crop's production systems as low-cost energy and vitamin A source under tropical conditions. Research activities emphasize development of cultural practices, with particular attention to wet season production to complement crop improvement efforts; integrated management practices for disease and insect pest control; evaluation of sweet potato as animal and human food component; and cropping systems research.

An important corollary activity carried out by the Genetic Resources and Seed Unit, (GRSU) includes collection, cataloguing, maintenance, and distribution of genetic resources. AVRDC has been designated as the major repository of sweet potato collections for the Asian and Pacific regions by the International Board of Plant Genetic Resources (IBPGR).

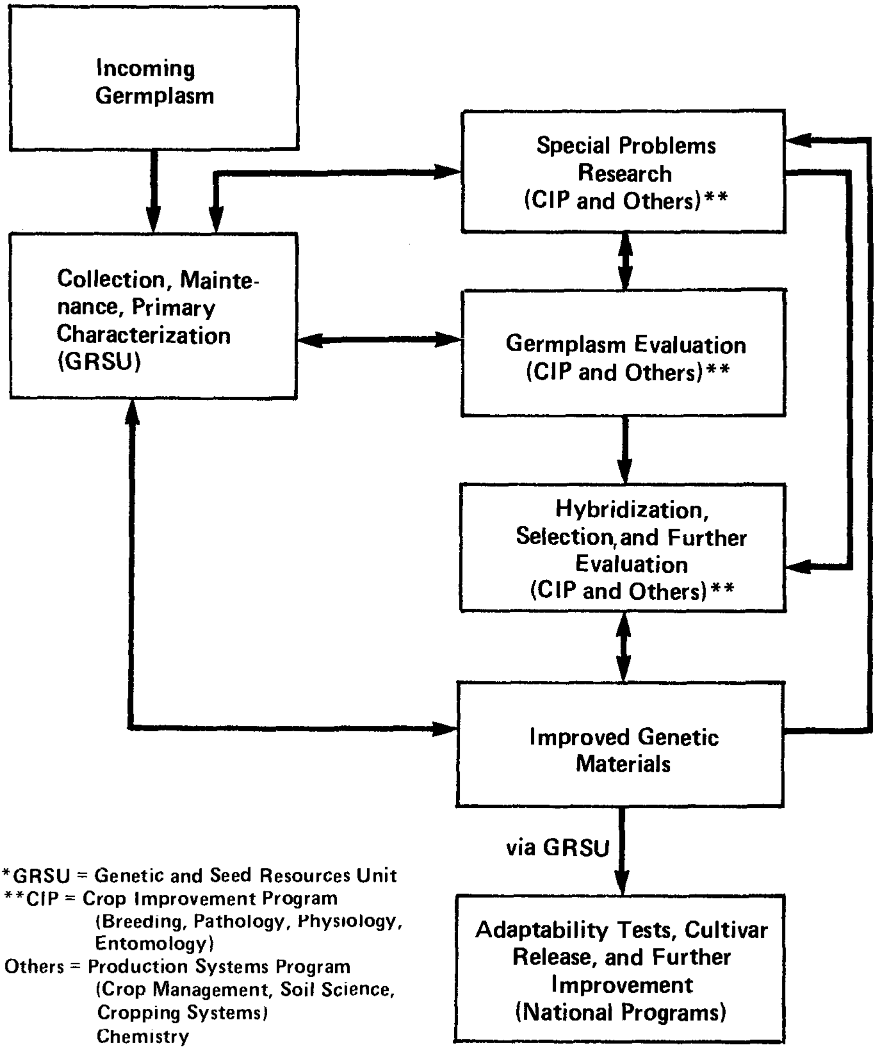


Figure 1. Flow of germplasm and information to various programs and units at AVRDC illustrating the interdisciplinary problem-solving concept (Adopted from Opeña et al., 1986).

PROGRESS AND CURRENT STATUS OF THE AVRDC SWEET POTATO PROGRAM

Accomplishments in the Early Years

Orange-fleshed (high-carotene content), early-maturing, dessert-type clones, which could be grown under low input, post-rice cropping systems have been successfully developed (Villareal, 1982). Clones that meet the criteria for animal feed/industrial uses, and vegetable leaf tips have also been bred and have been distributed to international cooperators. Development of management practices to ease the constraints of biotic and abiotic stresses of the hot, humid tropics has complemented the progress in breeding improved clones (AVRDC, 1982-1987, Villareal, 1982).

The improved selections with better nutritional characteristics and higher yield potential, however, were later found to be unacceptable to consumers, particularly in the Pacific Islands, who were not accustomed to the "wet," highly soluble "mouth feel" taste of the new varieties (AVRDC, 1984). Moreover, production and utilization patterns of sweet potato in Asia and the Pacific appeared to be changing as economic growth and social welfare improved (Lin et al., 1983).

AVRDC scientists, therefore, conducted a general survey of sweet potato production and utilization in Asia and the Pacific in 1983 to redefine the goals of the sweet potato program so that its output could better serve the requirements of AVRDC's target regions.

Biological and environmental factors were listed as the most serious production constraints in the above survey (Lin et al., 1983). Of the respondents, 70 percent reported problems of diseases and pests while 40 percent cited problems of adverse environments. Lack of improved cultivars and postharvest problems such as storage, processing, and marketing were listed as the next most important constraints.

Redefined Targets and Current Status

The 1983 production survey indicated the need for a thorough review of the research priorities in AVRDC's sweet potato improvement program. The current redefined targets include the following major areas: intensified breeding for disease and pest resistance; evaluation of available genetic resources for tolerance to major environmental stresses; enhancement of dry matter content and concomitant improvement of eating quality and nutritional value; improvement of sweet potato as vegetable greens; development of tissue culture and virus-indexing techniques for safe international germplasm transfer; and exploration of other means to control sweet potato weevil (e.g., sex pheromone). The progress that had been achieved in recent years are summarized below.

- Minimization of biological constraints

Sweet potato weevil. Sweet potato weevil is the most destructive pest in tropical and subtropical regions. Since the establishment of AVRDC, its entomologists have screened the entire germplasm collection numbering more than l,000 accessions. Despite these efforts, none showed a stable resistance to weevil. Similarly, in other institutes such as the International Institute for Tropical Agriculture (IITA), no single cultivar with consistent weevil resistance has been bred (Talekar, l986a). Since no useful genetic resource for weevil resistance was evident from our previous work, the development of effective and economical control measures has been accorded high priority for sometime now in the AVRDC program. Pre-plant dipping of cuttings in 0.05-0.l0 percent carbofuran solution or three weekly applications of 2 kg ai/ha carbofuran was found effective though the latter method proved uneconomical because of the large amount of chemical used (AVRDC, l984).

Preliminary evaluation of interspecific hybrids between 6x cultivated sweet potato and its 4x relatives (*Ipomoea trifada*) showed none or low weevil damage (AVRDC, l987; Talekar, l986b). However, confirmation of resistance and further backcrosses to recover the desirable traits of the cultivated species are necessary.

Vine borer. Sweet potato vine borer is a common pest in Asia and the Pacific, and is especially serious in semi-arid areas. In l98l, AVRDC entomologists identified two accessions -- l55 (PI 324889) and l92 (PI 308208) -- with moderate levels of resistance. Because of the difficulty in inducing l92 to flower, l55 is the only current source of resistance available for breeding so far. Selection among its segregating populations is ongoing (AVRDC, l987).

Scab. The importance of the scab disease and the requirement for resistant lines in tropical countries necessitated the initiation of a scab resistance project at AVRDC in l985. The resistance of some cultivars has been confirmed in several screening tests (AVRDC, l986b). Cultivars V2-30, Gl6, and Gll3 have been used as sources of resistance in the AVRDC program. AVRDC pathologists have developed a suitable method for in vitro propagation of the causal organism (*Elsinoe batatas*), the mass screening technique via artificial inoculation, and the disease scoring method. Further improvement of the seedling screening technique and screening of segregating populations is underway (AVRDC, l987).

- Minimization of environmental constraints

The importance of cultivars tolerant to flooding, excess moisture, and drought was evident from the l983 survey. The AVRDC germplasm collection was screened for tolerance to these stresses to identify useful genetic resources (AVRDC, l984).

Flooding. In the screening of 372 accessions under flood condition, only three accessions -- l100 (PI 3l8848), l103 (PI 3l8855), and 1423 (Tainan

17) -- yielded more than 10 t/ha and were considered to possess relative tolerance to flood stress (AVRDC, 1984).

Excess moisture. Under hot, wet conditions of Taiwan, 230 accessions were screened for ability to tolerate excess moisture. Fourteen entries outyielded the local wet season cultivar, Tainung 63. The best four lines -- 1597 (NG7570; PNG), 1444 (Kin-men; Taiwan), 1549 (Piksin; PNG), and 1435 (Nakamurasaki; Japan) -- are especially promising with marketable root yields of nearly 20 t/ha comparable to the performance of AVRDC's elite wet season clones. Interestingly, 11 of the 14 accessions were introductions from the highlands of Papua New Guinea where annual rainfall is close to 2,500 mm (AVRDC, 1984).

Drought. Although AVRDC does not have a truly dry environment, evaluation for drought tolerance is normally achieved by screening materials during the dry season with no irrigation. Twenty-nine accessions were screened in this manner. It was found that none was superior to the local cultivar, 1444 (Kin-men). This cultivar also showed moisture tolerance and was identified, therefore, as having good environmental adaptability (AVRDC, 1984).

- Improvement of nutritional quality

AVRDC chemists have analyzed the chemical composition (dry matter, starch, fiber, sugar, and protein) of about 200 samples a day using the Technicon Infra-Analyzer (AVRDC, 1986a). This rapid analysis enables breeders to screen a large number of genotypes for chemical attributes.

Basic studies on the consistency of traits among seedling and subsequent vegetative generations have been conducted to identify appropriate selection techniques (Yoon et al., 1986). As a result of such studies, rigorous selection is now practiced on stable traits, such as dry matter content and color of root skin and flesh in the early stages of breeding. On the other hand, only moderate selection pressure is applied to traits with high genotype–environmental interactions (e.g., root yield and protein content) until the replicated evaluation stages for the breeding materials have been reached.

ß–Carotene and protein. Initially, AVRDC scientists emphasize the development of dessert type cultivars, with high ß-carotene and protein contents, and adapted to tropical environment. Clones were subsequently developed with over 9 mg ß-carotene/100 g fresh weight and more than 7 percent protein on a dry weight basis (AVRDC, 1982).

Moist texture and low dry matter content are unacceptable to sweet potato consumers in Asia and the Pacific. Ironically, the orange-fleshed clones tend to have a moist texture compared to clones with other flesh colors. Efforts to raise the dry matter of orange-fleshed clones have been continued and orange flesh was combined in selections CN 1108-13 and CN 1028-15 with the preferred dry texture. Dry matter content of these clones is 26 percent during the wet season (AVRDC, 1984). This program is ongoing.

Dry matter content. High dry matter content is required in the yellow- or white-fleshed clones for staple or feed and industrial use. Sweet potato cultivars with high dry matter content have better marketing appeal for feed and starch extraction. While yet unconfirmed, high dry matter might contribute to a longer postharvest storage life of the sweet potato roots.

High correlation between specific gravity and dry matter content allows the use of brine solution for rapid, in-field screening to eliminate clones with low dry matter in the early stage of the selection process (AVRDC, 1986b, 1987).

Attempts to raise the dry matter content and yield of new AVRDC selections have been successful. The average dry matter content of the entries in the preliminary yield trials during the hot, wet season was raised from 26 percent in 1981 to 35 percent in 1986 (Fig. 2).

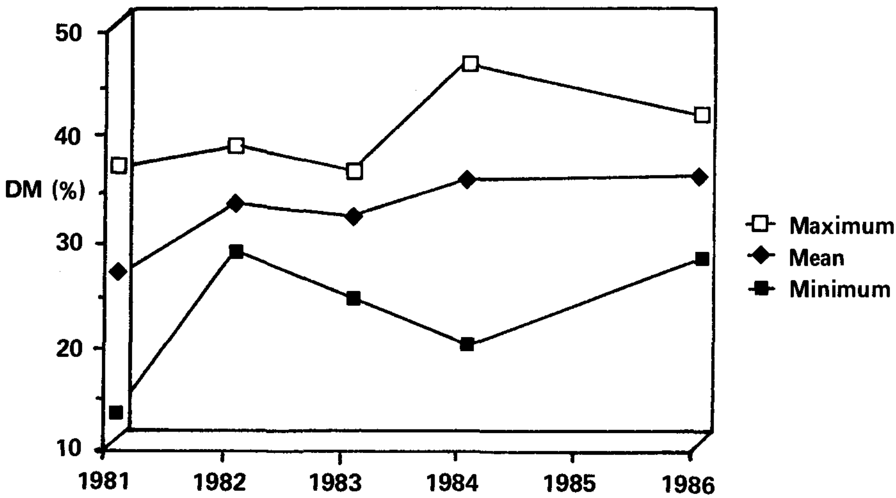


Figure 2. Dry matter content of AVRDC selections in preliminary yield testing stage during the hot, wet season.

Protein digestibility. Cultivars and accessions that exhibit lower trypsin inhibitor activity and better starch property for digestibility have been identified. Preliminary results indicate that it is possible to develop cultivars that do not require cooking before feeding them to hogs (AVRDC, 1985).

- Improvement of sweet potato as vegetable greens

Sweet potato greens (leaves, stems, and petioles) have high nutritional value, especially vitamins A and B_2, and can tolerate adverse tropical environments and their asssociated constraints such as diseases and pests, better than other leafy vegetables (Villareal, 1982b). Inspite of these advantages, lack of high-yielding, tender cultivars makes sweet potato greens unpopular. Research in this area has also been generally neglected.

After the preliminary studies on yield, nutritional, and eating quality of the tips of breeding lines and selected accessions, AVRDC scientists have recognized the need for further work to enhance the utilization of sweet potato greens (Villareal et al., 1979a-c). An expanded improvement program for vegetable greens was, therefore, initiated to select cultivars with better tenderness as well as bush or semi-bush plant habit which generally show better tip yield than the conventional prostrate types.

Several lines that exhibit bush habit with good eating quality and with edible tip yields of 10-13 t/ha (AVRDC, 1984; 1985) were identified. CN1367-2, a yellow-leafed clone, shows superior tenderness. This special purpose clone has been distributed for international adaptability trials.

INTERNATIONAL COOPERATION

International distribution for wide-scale testing of improved sweet potato breeding materials has always been constrained by strict quarantine regulations. AVRDC plant physiologists and virologists have developed a system of generating pathogen-tested initial stock materials from tissue-cultured meristems (AVRDC, 1986a).

A virus-indexing scheme has been instituted by AVRDC scientists as a self-imposed requirement to ensure that only "clean" stocks are provided to AVRDC's international cooperators. The international distribution of AVRDC's advanced sweet potato clones has been suspended since mid-1985 until all important stocks have been through the scheme. Virus-indexed materials were made available for international distribution in 1986 (AVRDC, 1987).

Intensive distribution of the most advanced clones from the AVRDC sweet potato program commenced three years ago. Since then, 11 clones have been officially released (Table 1).

FUTURE PLANS

The areas of research activities presented above remain as the major thrusts of the AVRDC sweet potato program. In addition, the intensification and expansion of research in the general areas given below are expected in the coming years.

Table 1. Official releases of AVRDC sweet potato germplasm in the past 3 years.

AVRDC ID No.	Local name	Year	Country	Special attributes
BNAS White		1985	Bangladesh	high yield, good shape and root size, yellow flesh
AIS 0122-2	Kamala Sundari	1985	Bangladesh	high yield, excellent shape and uniformity, deep orange flesh, moist dessert type, for wet and dry season
Tinirining		1985	Bangladesh	high yield, good shape and root size
CI 693-9	BPI SP-2	1985	The Philippines	high yield and good adaptability
I 367	Lo 323	1983	The Philippines	deep orange dessert type, good moist taste, for wet and dry season
CN 942-47	CN 942-47	1984	Tahiti	high yield/dry matter, light orange dessert type, good slightly dry taste, for wet and dry season
CN 1028-15	CN 1028-15	1984	Tahiti	high yield/dry matter, yellow orange animal feed type, good slightly dry taste, moisture tolerant/wide adaptation
CN 1038-16	CN 1038-16	1984	Tahiti	high yield/dry matter, yellow animal feed type, poor dry taste, for wet and dry season
CI 590-33	CI 590-33	1984	Tahiti	high yield/dry matter, early
CI 591-14	CI 591-14	1984	Tahiti	high yield/dry matter, early
CI 591-14/Au Marie Vareau	No 7	1984	Tahiti	high yield/dry matter, early

Crop Improvement Program

- Further stabilization of yield and widening of adaptability through resistance to environmental stresses such as excess moisture, poor soil fertility, and drought, and broadening of disease and pest resistance.
- Further improvement of dry matter yield, storability, and eating and nutritional quality.
- Enhancement of genetic exchange not only through virus-indexed materials but also through improved true seed gene pool for selection by national programs.
- Further improvement of the in vitro germplasm multiplication scheme to enable rapid and safe preservation of clones. The virus-indexing method is expected to include as many of the potential virus problems as possible.
- Expanded studies into the potential contributions of *Ipomoea* species in sweet potato improvement.

Production Systems Program

- Further improvement of cultural practices for sweet potato production under humid tropical conditions.
- Studies on cropping systems, including that on sweet potato, such as intercropping to maximize production efficiency of available resources.
- Improvement of production and quality of sweet potato tips as green vegetable through cultural managements.
- Development of appropriate postharvest technology for the tropic.
- Socioeconomic studies to generate information related to the major sweet potato consumption and production patterns in AVRDC's target countries.

REFERENCES

AVRDC (Asian Vegetable Research and Development Center). 1982. Progress Report for 1981. Shanhua, Tainan, Taiwan, Republic of China. 84 p.

AVRDC. 1984. Progress Report for 1982. Shanhua. Tainan, Taiwan, Republic of China. 337 p.

AVRDC. 1985. Progress Report for 1983. Shanhua, Tainan, Taiwan, Republic of China. 444 p.

AVRDC. 1986a. Progress Report for 1984. Shanhua, Tainan, Taiwan, Republic of China. (*in press*).

AVRDC. 1986b. Progress Report for 1985. Shanhua, Tainan, Taiwan, Republic of China. (*in press*).

AVRDC. 1987. Progress Report for 1986. Shanhua, Tainan, Taiwan, Republic of China. (*in press*).

FAO (Food and Agriculture Organization). 1973. FAO Production Yearbook. No. 27. Rome, Italy.

FAO. 1986. FAO Production Yearbook. No. 40. Rome, Italy.

Garcia, A.G. and A.A. Gomez. 1980. Cropping systems research at UPLB. *In* Symposium on Cropping Systems. Bangkok, Thailand. 12-17 August 1980.

Gomez, A.A. 1980. National network for technology verification in farmers' fields. Food & Fert. Tech. Center Ext. Bull. 151. 10 p.

Lin, S.S.M., C.C. Peet, D.M. Chen and H.F. Lo. 1983. Breeding goals for sweet potato in Asia and the Pacific: A survey on sweet potato production and utilization. Proc. Amer. Soc. Hort. Sci. Trop. Region 27. Part B. pp. 42-60.

Luh, C.L. and J.C. Moomaw. 1979. Present and future outlook for sweet potato in tropical Asia: Research and development needs. *In* 5th Symp., Int. Soc. Root Crops. Manila, the Philippines.

Opeña, R.T., S. Shanmugasundaram, J.Y. Yoon and G.C.F. Fernandez. 1986. Crop improvement program to promote vegetable production in the tropics. Proc. Int. Symp. Hort. Breeding. Taichung, Taiwan. (*in press*).

Talekar, N.S. 1986a. Resistance in sweet potato to sweet potato weevil. Insect Science and Its Application. (*in press*).

Talekar, N.S. 1986b. Feasibility of the use of resistant cultivar in sweet potato weevil control. Insect Science and Its Application. (*in press*).

Villareal, R.L. 1982a. Sweet potato in the tropics: progress and problems. *In* Villareal, R.L. and T.D. Griggs (eds.). Sweet Potato. AVRDC. Shanhua, Taiwan, Republic of China. pp. 3-15.

Villareal, R.L. 1982b. Sweet potato tips as vegetables. *In* Villareal, R.L. and T.D. Griggs (eds.). Sweet Potato. AVRDC. Shanhua, Tainan, Taiwan, Republic of China. pp. 313-320.

Villareal, R.L., S.K. Lin, L.S. Chang and S.H. Lai. 1979a. Use of sweet potato (*Ipomoea batatas*) leaf tips as vegetables. I. Evaluation of morphological traits. Exp. Agric. 15:113-116.

Villareal, R.L., S.C.S. Tsou, S.K. Lin and S.C. Chiu. 1979b. Use of sweet potato (*Ipomoea batatas*) leaf tips as vegetables. II. Evaluation of yield and nutritive quality. Exp. Agric. 15:117-122.

Villareal, R.L., S.C.S. Tsou, S.C. Chiu and S.H. Lai. 1979c. Use of sweet potato (*Ipomoea batatas*) leaf tips as vegetables. III. Organoleptic evaluation. Expt. Agric. 15:123-127.

Yoon, J.Y., S.S. M. Lin, C.S. Hung and S.C.S. Tsou. 1986. Establishment of sweet potato polycross nursery and evaluation of clones in the early vegetative generation. Proc. IBPGR/SEAP Workshop on Tuber and Root Crop Characterization. (*in press*).

EXPLORATION AND COLLECTION OF SWEET POTATO GERMPLASM

Fermin de la Puente*

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the three most important root crops in the world. It ranks seventh in total production among the world's food crops, with Africa and Asia accounting for 92 percent of this production (FAO, l986). It has a great potential as food, feed, and an industrial crop. Notwithstanding these, little research has been done to stimulate its development.

This crop is not known in a wild state but there seems little doubt that it originated as a domesticated plant in the new world. High genetic diversity of this crop occurs in northwest South America (Colombia, Ecuador, and Peru) with secondary centers in Mexico, Guatemala, and southern Peru. About 50 species that belong to the same botanical genus (*Ipomoea*) have been reported in most temperate and tropical regions of the world. Austin (l987) recognized l2 species, two named hybrids, and an unnamed hybrid in section *Batatas*.

Efforts to preserve sweet potato germplasm are underway in some international institutions such as the International Institute of Tropical Agriculture (IITA) and Asian Vegetable Research and Development Center (AVRDC) and in some national programs in the world. The sweet potato germplasm available in Latin America is not complete and well organized. In general, little attention has been given to the collection and preservation of the wild *Ipomoea* species.

Since sweet potato germplasm is being lost so rapidly, expeditions for collection of these genetic resourses should be organized immediately.

Recognizing the present status of the conservation of sweet potato germplasm in Latin America, the International Potato Center (CIP) and the International Board for Plant Genetic Resources (IBPGR) have started developing the Latin American and Caribbean sweet potato gene bank in the area of main genetic diversity of this crop.

This paper summarizes the status of the main activities undertaken toward the establishment of this international gene bank in Lima, Peru, which was initiated early in 1985. A few references of this project are presented below.

---

*Taxonomist, International Potato Center (CIP), Lima, Peru.

The main objectives of the project are to collect sweet potato genetic resources in Latin American and Caribbean regions and to maintain this germplasm in usable form. The strategies that were considered for the establishment of the gene bank at CIP are acquisition of cultivated and wild accessions maintained in some other institutions and initiation of systematic explorations and collections of these genetic resources in areas of great genetic diversity in Latin American and Caribbean countries.

ACTIVITIES

Acquisition of Wild and Cultivated Genetic Resources

The acquisition of accessions of *Ipomoea batatas* available in other institutions was initiated in 1984. To date, 1,627 accessions have been introduced into the gene bank. These materials represent native cultivars and breeding stocks. The source, country of origin, and number of accessions received to date are presented in Table 1. True seeds of some wild *Ipomoea* species have also been received.

Table 1. List of the cultivated accessions received as donations (Huaman, 1987a).

Source	Country	Number of accessions
R. del Carpio's collection	Peru*	766
Univ. of Ayacucho	Peru	565
Univ. of Iquitos	Peru	45
Univ. of Lambayeque	Peru	31
Univ. of Tacna	Peru	19
Agr. Exp. Station, Cañete	Peru	47
Agr. Exp. Station, Chincha	Peru	24
Agr. Exp. Station, Yurimaguas	Peru	4
C.A.T.I.E.	Costa Rica*	34
Agricultural Development Center	Dominican Rep.	22
US Vegetable Laboratory (Charleston, S. Carolina)	USA	24
US Tropical Agric. Res. Station (Mayaguez, Puerto Rico)	USA	1
Y. Umemura	Japan	30
Several scientists	Japan	8
China	China	7
Total		1,627

*Includes accessions of several countries.

Explorations and Collections

Systematic explorations and collections in areas of great genetic diversity in Latin American and Caribbean regions have been carried out since March 1985. The following considerations were taken:

- Three major sources of genetic variability were chiefly considered for collection in the field, namely: cultivated accessions, feral plants, and allied species. Since no major effort was required, other *Ipomoea* species outside the section *Batatas* have been collected along with the above materials for their importance as virus indicators, fodder, binding sand, ornamentals, fendles, and for their utilization in breeding programs for flowering stimulation in the sweet potatoes.
- Herbarium samples and true seeds were collected from the wild germplasm while cuttings were taken from the cultivated ones. Recently, collecting in vitro in the field has been utilized with reasonable results.
- A duplicate sample of all collected cultivated materials is deposited in national institutions to insure its preservation.

  So far, 39 collecting trips have been carried out in Bolivia, Colombia, Dominican Republic, Ecuador, Peru, and Venezuela. The present status and future plans of these explorations and collections (Fig. 1) in the above countries are as follows:

  - A great area has been explored in Colombia, Ecuador, and Peru. Some specific localities in these countries have to be explored and reexplored. A few complementary explorations in these countries have been programmed for 1987.
  - The Dominican Republic, Bolivia, and Venezuela have been partially explored; special attention will be given to complete the explorations in these countries in 1987.
  - Explorations and collections in Brazil, Mexico, Guatemala, Cuba, and Argentina will be initiated this year.

As a result of these collections, 2,219 accessions of cultivated and wild *Ipomoea* species have been obtained. A total of l,546 accessions (68.4%) belong to *Ipomoea batatas* and the rest are included in 44 other *Ipomoea* species with seven of them belonging to the section *Batatas*. The distribution of these species is presented in Figure 2. The number of accessions collected per species and the countries where they are found are shown in Table 2.

These explorations also allowed the identification of some localities in the explored area where a large number of cultivated accessions were collected. These localities are reported in the report of de la Puente (l987) and indicated in Figure 3.

Figure 1. Present status and future plans for exploration and collection for the sweet potato germplasm.

Figure 2. Countries where *Ipomoea* spp. section *Batatas* were collected.

Table 2. List of collected wild and cultivated material up to April 1987.

Species	No. of accessions	Distribution
I. batatas	1,546	Bolivia, Colombia, Ecuador, Dominican R., Peru, Venezuela
I. cordatotriloba	1	Bolivia
I. leucanta	7	Colombia, Ecuador, Peru
I. ramossisima	17	Bolivia, Colombia, Ecuador, Peru
I. tiliacea	3	Colombia, Dominican R., Venezuela
I. trifida	65	Colombia, Dominican R., Venezuela
I. triloba	9	Ecuador, Colombia
I. trichocarpa lacunosa	1	Venezuela
Other 37 *Ipomoea spp.*	612	Variable for each species

The geographical distribution of the sweet potato germplasm is very important for its utilization; new collecting trips are planned. A total of 2,053 accessions (84.5%) of the cultivated materials were found up to 2,000 m of altitude (Fig. 4). Very few (378 or l5.5%) were seen higher than this altitude.

Preservation

The cultivated accessions are being maintained by clonal propagation at La Molina, Lima, Peru (latitude l2°05' and 240 m altitude). Part of these accessions has already been transferred to in vitro culture. This collected cultivated germplasm is also preserved in each explored country through the national programs. Technical assistance will be given to these national programs for this purpose through a CIP/IBPGR project. Wild accessions are mainly preserved as true seeds at CIP in Lima.

Characterization

Morphologic characterization and preliminary evaluation of the *Ipomoea batatas* accessions are underway (Huaman, l987a). For this purpose, a new list of descriptors developed by Huaman (l987b) at CIP is being utilized. With this information, potential duplicated genotypes have been identified and a wide phenotypic diversity has been observed.

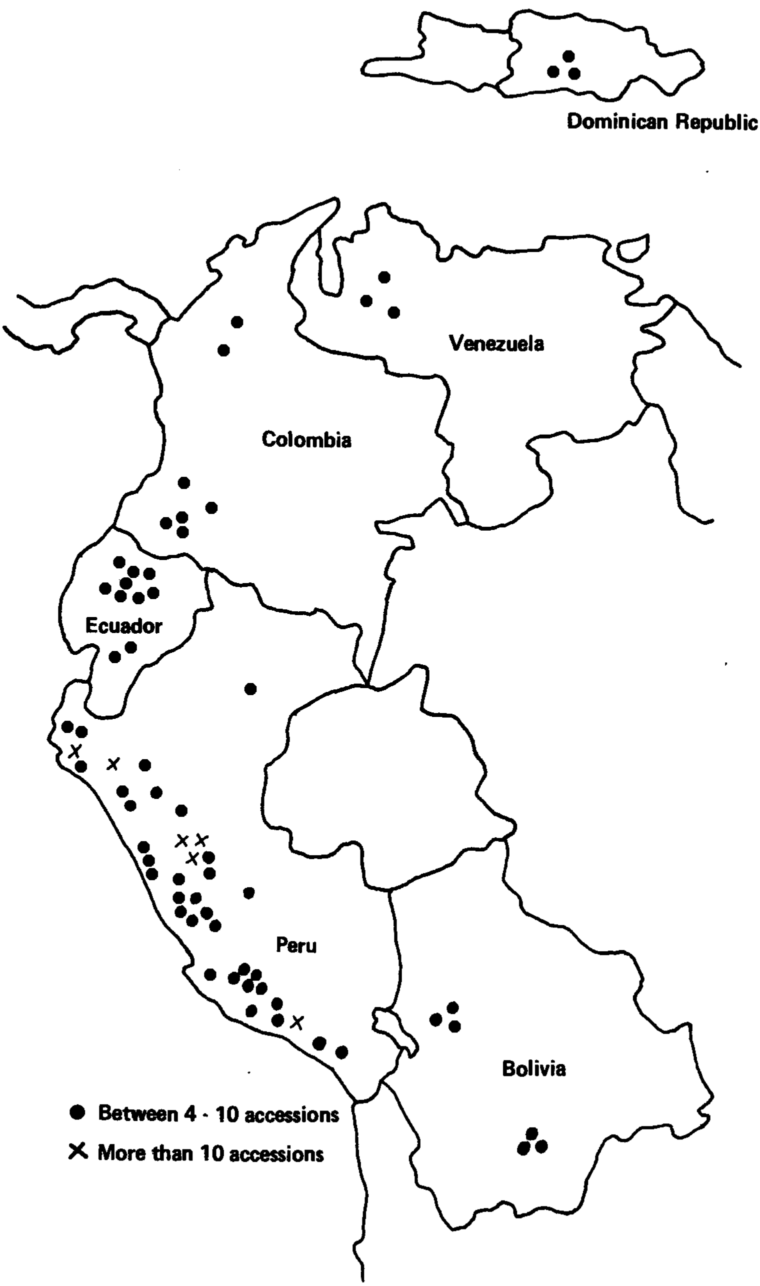


Figure 3. Localities where a high number of cultivated accessions were collected.

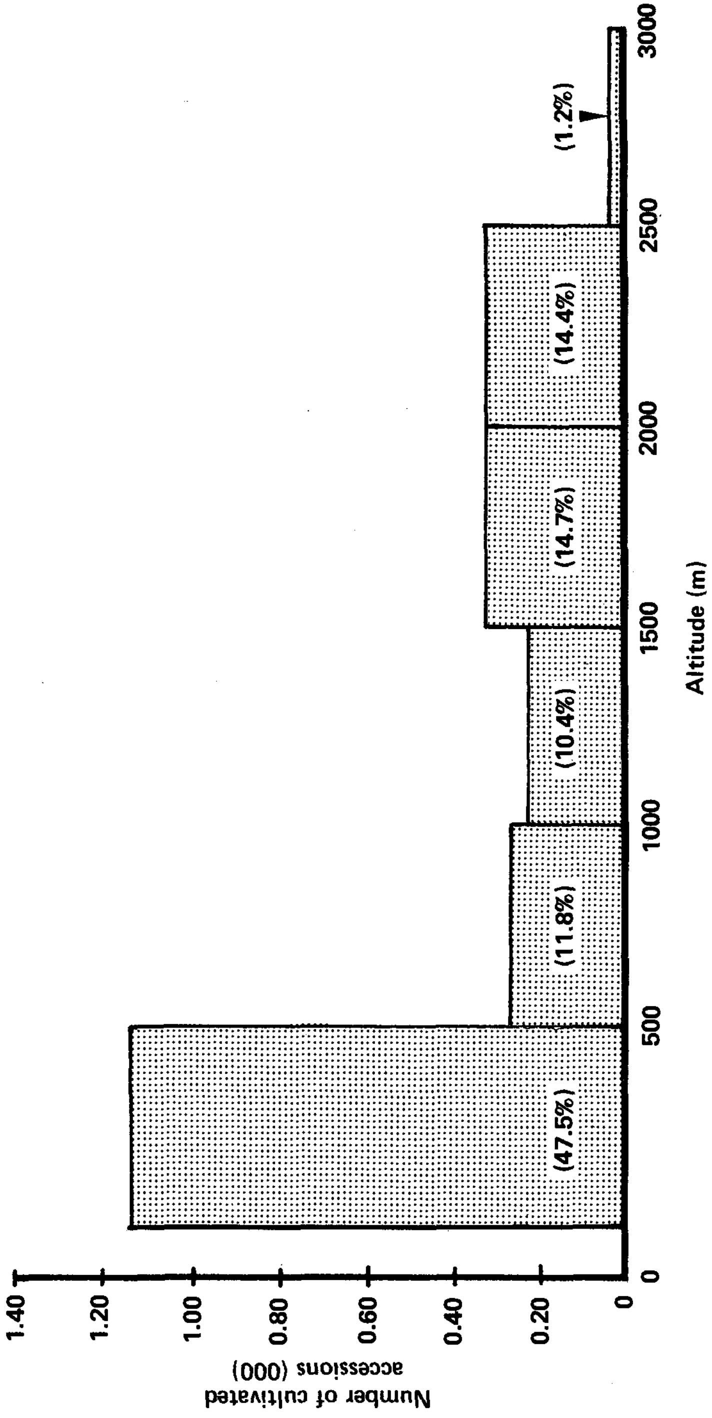


Figure 4. Distribution of the cultivated, collected accessions by altitude.

Documentation

All available data on provenience, taxonomic identification, morphologic characterization, and results of evaluations conducted are stored in a computerized data bank (Human, 1987a).

IMPORTANCE OF THE GENE BANK FOR ASIA AND AFRICA

The national programs of China, Japan, the Philippines, and international centers such as IITA and AVRDC are some of the places wherein important investigations on this crop have been carried out. As a result of these investigations, considerable development of this crop has been achieved. This development resulted from the utilization of improved varieties and application of specific agronomic tasks.

The cultivated germplasm has great genetic variability and many sweet potato breeders believe that most of the important traits for breeding can be identified in this material. The wild germplasm, however, may be the source of a gene pool to provide specific trait(s) to cultivars.

Initially, it utilized narrow genetic resources in the development of these new varieties in the region, but it was subsequently increased with the addition of foreign cultivated germplasm and wild material (Sakamoto, 1987; Lu et al., 1987). Japan and China are intensively utilizing the wild species *Ipomoea trifida* and *I. littoralis* in their breeding programs. They have obtained very interesting results and have shown the feasibility of utilizing this type of genetic resources. As a result of this work, increment in starch and protein content and resistance to root knot nematode (*Meloidogyne incognita*), black rot (*Ceratocystis timbriata*), and weevil (*Cylas formicarius*) were reported (Sakamoto, 1987; Lu et al., 1987; Iwanaga, 1987). Iwanaga (1987) presented a comprehensive study on the utilization of this type of germplasm in breeding programs.

Most of the sweet potato breeding objectives in this region are related to yield, earliness, eating quality, starch content, nutritional quality, storage capability, and resistance or tolerance to biotic and abiotic problems. To attain the above objectives, widely cultivated and wild genetic resources should be made available.

The CIP sweet potato germplasm bank has great cultivated genetic variability and there are also a considerable number of wild *Ipomoea* species that might possess the required germplasm to reach the proposed goals.

In summary, 3,846 accessions (collected and donated) of wild and cultivated genetic resources have been included in CIP's sweet potato germplasm bank (Table 3). A great area has been explored in the indicated countries, and some localities, with an apparently great genetic diversity of *Ipomoea batatas*, have been localized. Forty-four wild *Ipomoea* species, including seven of the section *Batatas*, have been taxonomically identified. Preservation, characterization, documentation, and preliminary evaluations are underway at CIP. The CIP sweet potato gene bank may play an important role in the breeding programs of this region.

Table 3. Number of accessions obtained by type of germplasm (Huaman, 1987a).

Type of germplasm	Number of accessions
Wild (section *Batatas*)	138
Wild (other sections)	508
Wild (undetermined)	233
Native cultivars	2,415
Improved cultivars	76
Breeding lines	476
Total	3,846

REFERENCES

Austin, D.F. 1987. The taxonomy, evolution and genetic diversity of sweet potatoes and related species. Paper presented in XXX Planning Conference on Exploration Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

De la Puente, F. 1987. Progress in explorations and collections of sweet potato genetic resources. The IBPGR/CIP Project. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

FAO (Food and Agriculture Organization). 1986. Vegetable production in Asia and the Pacific regions: Past trend and future prospects. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand.

Huaman, Z. 1987a. Current status on the maintenance of sweet potato germplasm at CIP. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

Huaman, Z. 1987b. Descriptors for the characterization and evaluation of sweet potato genetic resources. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

Iwanaga, M. 1987. Use of wild germplasm for sweet potato breeding. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

Lu S.Y., G.L. Shen and B.F. Song. 1987. The goals of sweet potato breeding in China. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

Sakamoto, S. 1987. Review of sweet potato breeding in Japan. Paper presented in XXX Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources. CIP, Lima, Peru.

IN VITRO SWEET POTATO GERMPLASM MANAGEMENT

John H. Dodds*

PROPAGATION

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

Propagation by Single Node Cuttings

Sweet potato germplasm can be introduced into an in vitro culture in the form of nodal cutting. When placed in an appropriate culture medium, the axillary bud is induced to grow, resulting in the development of a new in vitro plantlet. This type of propagation involves the growth of an existing morphological structure, the axillary meristem. The hormone and 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 (Kuo et al., 1985; Frison and Ng, 1981; Litz and Conover, 1978). Care must be exercised, however, so that the culture conditions do not allow the formation of callus and subsequent de novo regeneration of plantlets. This will be shown in a later section to affect the genetic stability of the genotype (Scowcroft and Larkin, 1982; Scowcroft, 1984).

Most laboratories grow in vitro plantlets under long day (16 hours 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 six weeks.

Several laboratories have shown that in vitro plantlets of sweet potato produced from single node cutting can easily be transferred to nonsterile conditions (e.g., transplanted to jiffy pots and, in some cases, plantlets have been transplanted directly in the field).

Propagation in Liquid Culture (Stem Segments)

From experience gained from other crops, especially potato, it is known that under certain conditions the speed and labor requirement for

*Tissue Culture Specialist, International Potato Center, P.O. Box 5969, Lima, Peru.

propagation by single node cuttings limit the potential production. As in potato, it is possible to micropropagate sweet potato in flasks (250 cc) containing liquid culture medium. Whole stem segments, five to eight 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 which breaks the dormancy of all the axillary buds along the length of the stem segment. Shoots develop from this and in three to four weeks, the flask is full of vigorously growing sweet potato shoots (Siquenas, 1987). The flasks containing shoots can be a source of plant materials either for preparation of single node cuttings or stem segments depending on the needs of the program.

Propagation by Plantlet Regeneration

Sweet potato is developmentally a highly "plastic" plant. It is possible to regenerate de novo in vitro plantlets from almost all plant parts when placed into culture. Several scientists have successfully regenerated plantlets of sweet potato from cultured stems, petioles, roots, and leaf discs (Hwang et al., 1983). In all cases, the first step is the formation of callus at the cut surface. The size and type of callus vary among treatments and genotypes. When given an appropriate hormonal stimulus, de novo formation of meristems can be induced within these calli which eventually form a regenerating plantlet.

Using this method as a standard propagation method has several disadvantages, however. First, the labor involved in dissecting these individual plantlets would make the method cost ineffective within a production program. Second, callus-derived plantlets are likely to undergo minor or major genetic aberrations during the callus stage (Bayliss, 1980) 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.

Somatic Embryogenesis

Plantlet regeneration de novo can take place through two possible routes: organogenesis (i.e., direct organ formation as described in the preceding section) or by embryogenesis (i.e., direct formation of embryos from somatic cells). The induction of somatic embryos has been reported in many plants (Street, 1985). 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 (Jarret et al., 1984). However, no analysis has been made as to the genetic stability of these embryos. Since they are also derived from a callus and cell suspension, there is a high probability that the plantlets are not all genetically identical.

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

This section 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 can 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 comes out of storage with a gene combination different from 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, however, is 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 (i.e., leaf form, tuber, or storage root color change), then we know that a genetic change has probably taken place. If the plants appear the same, however, this does not mean that no change has occurred but it means we cannot detect it. For example, a change in a virus-resistant gene cannot be detected on the basis of morphology.

Two biochemical methods of studying the genetic stability of potato and sweet potato are currently used, namely: soluble protein patterns and isoenzyme analysis. Although these are highly effective methods of looking for variation in gene products, they do not look for changes in the genes themselves. Novel methods such as restriction length polymorphism analysis are 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 the Peru-based International Potato Center (CIP), morphological, soluble protein, and enzyme analyses are routinely performed on both potato and sweet potato collections. If a more sensitive restriction enzyme method for gene analysis becomes available, its inclusion in CIP's routine methods should be considered.

In Vitro Conservation of Sweet Potato Germplasm

A number of clonal in vitro sweet potato collections exist in many national programs and international organizations (Kuo et al. 1985; Frison, 1981). There are many advantages of placing vegetatively propagated germplasm in an in vitro rather than in field-maintained form and these had been described previously (Wilkins and Dodds, 1982).

Various techniques exist for in vitro conservation, each with certain advantages or drawbacks.

Limiting Growth Media

Many years of research have gone into the development of propagation media for sweet potato where the objective has been to optimize rapid in vitro growth. In the case of conservation, the objective is to limit growth to a minimum while maintaining the viability of the cultures. By this means, it is possible to maximize the time between transfers (subcultures) of the in vitro plantlets. At CIP, for example, in the case of potato LTS (long term in vitro storage), transfers are needed only once a 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 (i.e., abscisic acid or ABA), growth inhibitors (i.e., B995, chloro choline chloride or CCC), or osmotic regulators such as high sucrose concentrations or the addition of osmotic sugars such as mannitol or sorbitol (Cram, 1984). The difficulty with these types of studies is that different genotypes 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. It should be emphasized, however, that the storage media should not allow induction of callus that might lead to genetic aberrations.

Reduced Temperature Storage

The growth rate of in vitro plantlets can be restricted by reducing the incubation temperature. The optimal growth temperature for sweet potato in vitro appears to be between 28° and 30°C. If the cultures are moved to a temperature of 30°C, survival time is less than one month. The optimal reduced temperature for genotypes studies to date appear to be 15°C, but this needs further confirmation. As in the case of other crops maintained in vitro (i.e., cassava, potato, and yams), it is possible to apply both reduced temperatures and osmotic/hormonal growth retardants at the same time. At present, the use of osmotic stress and reduced temperature

(5°C) appears to be the most realistic and cost-effective way of maintaining a large sweet potato germplasm collection.

Cryopreservation

In the past decade, there has been much interest in the use of cryopreserving (-196°C) plant materials in liquid nitrogen as a way of conserving germplasm (Kartha, 1985; Withers, 1985).

This type of cryoconservation is used routinely for storing animal cells and bacteria. The situation with plants, however, is more complex. It is now possible to freeze and thaw in viable condition plant cells from any plants. These single cells, however, pass through a callus to regenerate whole plants, causing genetic aberrations. If intact plant structures such as meristems or embyos 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 will revolutionize plant germplasm storage and as such deserves more investigation. In the short to medium term, however, this seems not to be a viable option to sweet potato clonal in vitro repositories.

Phytosanitary Status of Sweet Potato Germplasm Collections

The successful introduction of a sweet potato plant to in vitro culture implies that the plantlet is probably free from bacterial, fungal, and mycoplasma infections. The plantlets may still be infected with viruses or viroid. Maintenance of the plantlets in vitro (rather than in the field) limits further viral degeneration of the collection that can result from cross contamination. It is, therefore, possible to enhance the phytosanitary status of a collection by in vitro introduction. It will also benefit virus/viroid eradication programs if the germplasm is already in vitro. When a germplasm is to undergo evaluation, phytosanitary status is obviously required.

Management of Sweet Potato In Vitro Germplasm Collections

The size of any given germplasm collection varies and the problem of managing a collection of several thousand accessions is distinct from those with 50 accessions. With any in vitro germplasm collection, however, the following points must be considered:

- How many replicates should be kept for each accession?
- Should duplicate accessions be held by other institutions?
- What safeguards could be made against errors in data maintenance?

- How often should the collection be checked?
- Which accessions are the most valuable in case of emergency?

In the case of CIP, a computer database is being established on the sweet potato collection. This should allow us (using the potato collection as a model) to make the maximum amount of information and materials available to national programs of developing nations. It should also facilitate intercenter information flow on the status of any or all in vitro accessions.

REFERENCES

Bayliss, M.W. 1980. Chromosomal variation in plant tissue culture. Int. Rev. Cytol. 11A: 113-143.

Cram, W.J. 1984. Mannitol transport and suitability as an osmoticum in root cells. Physiol. Plant. 61:396-404.

Frison, E.A. 1981. Tissue culture: A tool for improvement and international exchange of tropical root and tuber crops. International Institute of Tropical Agriculture Research Briefs. Vol. 2, No. 1.

Frison, E.A. and S.Y. Ng. 1981. Elimination of sweet potato virus disease agents by meristem tip culture. Tropical Pest Management. 27(4):452-454.

Hwang, L., M. Skirvin, J. Casyao and J. Bouwkamp. 1983. Adventitious shoot formation from sections of sweet potato grown in vitro. Scientia Horticulturae 20: 119-129.

Jaret, R.L., S. Salazar and Z. Fernandez. 1984. Somatic Embryogenesis in sweet potato. Hortscience 19 (3):397-398.

Kartha, K.K. 1985. Cryopreservation of plant cells and organs. CRC Press, Inc. Boca Raton, Florida. 276 p.

Kuo, C. G., B.J. Shen, M.J. Shen, S.K. Green and D.R. Lee. 1985. Virus-free sweet potato storage roots derived from meristem types and leaf cuttings. Scientia Hort. 26:231-240.

Kuo, G., S. Lin and S. Green. 1985. Sweet potato germplasm for international cooperations. International Cooperator's Guide. AVRDC. pp. 85-238.

Litz, R.E. and R.A. Conover. 1978. In vitro propagation of sweet potato. Hortscience. 13(6):659-660.

Scowcroft, W.R. 1984. Genetic variability in tissue culture: Impact on germplasm conservation and utilization. AGPG: IBPGR/84/152. International Board for Plant Genetic Resources. Rome, Italy. p. 41.

Scowcroft, W.R. and P.J. Larkin. 1982. Somaclonal variation: a new option for plant improvement. *In* Vasil, I.K., W.R. Scowcroft and K.J. Frey (eds.). Plant Improvement and Somatic Cell Genetics. Academic Press, New York. pp. 159-178.

Siquenas, C. 1987. Propagation and conservation in vitro of two sweet potato cultivars. Thesis. National Agrarian University, La Molina, Peru. (in Spanish).

Street, H.E. 1985. Embryogenesis in cultures of carrots. *In* Hall, D.S. and S. Hawkins (eds.). Laboratory Manual of Cell Biology. English University Press, London, UK.

Wilkins, C.P. and J.H. Dodds. 1982. The application of tissue culture techniques to plant genetic conservation. Sci. Prog. Oxf. 68:281-307.

Withers, L.A. 1985. Cryopreservation of cultural cells and meristems. *In* Cell Culture and Somatic Cell Genetics of Plants. Vol. 2. Academic Press. pp. 253-315.

SWEET POTATO VIRUS INDEXING AND PREPARATION OF PATHOGEN-TESTED GERMPLASM

Angela Mason*

INTRODUCTION

Sweet potato is a vegetatively propagated crop and diseases are carried from one generation to the next. Generally, tuber quality and yield decrease with every season that the same material is replanted. Planting of saved cuttings usually results in the occurrence of many pathogens within the crop at the start of the season and these provide a source for further pathogen spread during the season.

The problem of carryover of pathogens from one season to the next, resulting in crop decline, is not usually as great with crops propagated by true seed because most pathogens are not seed-borne.

When working with vegetatively propagated crops, special programs must be developed if clean "pathogen-tested" germplasm is to be provided as planting material.

Most plant materials in the field are naturally infected with plant pathogens such as fungi, bacteria, nematodes, mycoplasmas, and viruses. Most of these pathogens can be eliminated simply by chemical treatments and culturing of sterilized buds. However, viruses (and to a lesser extent mycoplasmas) are difficult to eliminate because they live inside plant cells.

VIRUSES AND THEIR INTERACTIONS WITH PLANTS

What Is A Virus?

Virus particles consist of nucleic acid (genetic material) protected by a protein coat. They are submicroscopic in size. The particles vary in size from small spheres of 25 to 30 nm to long rods of up to 2000 nm (1 nm = 10^{-9} meters).

*Pathologist, Plant Research Institute, Department of Agriculture, Swan St. Burnley, Victoria 3121, Australia.

How Does A Virus Interact With a Plant?

Plant viruses occur inside the living cells of the plant. Viruses cannot multiply except in the living cells because they need to utilize components of the cells to complete their replications. Following are the three very important implications of the way viruses interact with their plant hosts.

- Viruses occur inside the plant cells and, therefore, the methods of control used for other types of pathogens cannot be implemented. In other words, chemical sprays cannot be used to eradicate viruses.
- Viruses depend on living plant host cells for their survival, therefore, they rarely kill the plant when they infect it.
- Plants have no mechanism for ridding themselves of viruses (i.e., they do not have an immunity system such as what animals have). Therefore, once a plant is infected with a virus, it is generally infected for life.

How Does A Virus Spread Within A Plant?

Viruses may either spread throughout the cells of the whole plant, or be restricted to the phloem, depending on the virus type. Viruses spread within the plant by two methods: they either move from cell to cell via thin strands of cytoplasm (called plasmodesmata) which run through the cell wall connecting adjacent cells, or they spread via the vascular tissue.

How Do Viruses Affect The Plant?

Nearly all viruses reduce the vigor of the plant and some also cause yield losses or a decrease in the quality of the harvested produce. Infection with two or more viruses may cause more severe disease symptoms than those caused by the viruses individually. Although symptoms vary with different virus/host combinations, they generally fall into the following categories: loss of yield, changes in leaf color, leaf deformations, stunting, death of foliage, tuber necrosis, and deformation and latent infections.

VIRUS ERADICATION

A combination of heat treatment of plants followed by the culturing of the plant meristems has been proven to be the most successful method of eradicating viruses from plants. Since viruses occur inside the living plant cells, a treatment that adversely affects the virus without killing the plant is required. It has been found that sustained high temperatures appear to prevent multiplication of the virus and enhance virus breakdown. Normally, as the virus replicates, new virus particles invade other plant cells.

However, after heat treatment, it is usually found that the actively dividing cells of the plant meristems are free of virus. Meristems do not contain vascular tissue so the virus is unable to spread into the meristematic tissue via the vascular route. This enables virus eradication through the use of heat treatment and meristem culturing.

Normally, rooted sweet potato cuttings are placed in a heat therapy cabinet at 38°C under good light for 8-12 weeks. The plant meristems are then dissected out under aseptic conditions and placed in a liquid growth medium under lights. The meristems are transferred to fresh media every three weeks until plantlets develop. This usually takes two to three months. The plantlets are then cut into nodal pieces and cultured in a rapid multiplication medium until each nodal piece develops into a plantlet. Some of these plantlets are maintained in vitro and some are planted out for testing to determine whether or not they are free of viruses. The plantlets are not tested for the presence of fungi or bacteria because the liquid growth medium used for culturing the plantlets is also ideal for the growth of these organisms. Therefore, if they are present, they form visible cultures in the vials, and these vials are then discarded.

VIRUS INDEXING

The testing of plants for the presence of viruses is known as virus indexing. Generally, the following methods are used for virus indexing.

Electron Microscopy

Leaf sap preparations are viewed using the electron microscope to detect the presence of viruses.

Indicator Plants

Often, host plants infected with a virus or viruses do not show many visible or easily identifiable symptoms. Indicator plants are other plant species that give consistent well defined symptoms when infected with a particular virus. The test is conducted by grafting material from the sweet potato under test to the indicator species or by mechanically inoculating the indicator plant with sweet potato sap. It is possible to determine whether or not virus is present in sweet potato host plant by the development or absence of symptoms on the indicator plant.

Serological Tests

Plant viruses can be purified and injected into an animal such as a rabbit whose immune system then produces antibodies to the virus. Blood is collected from the animal and the antibody fraction separated and used in tests to determine whether or not plant viruses are present in the plant sap. The binding of the antigen (in this case virus) with its specific antibody is the basis of a whole range of serological tests.

Seven sweet potato viruses have been documented and more will probably be discovered as further work is conducted on the crop. The known viruses are sweet potato feathery mottle virus (SPFMV), sweet potato mild mottle virus (SPMMV), sweet potato caulimolike virus (SPCLV), sweet potato latent virus (SPLV), sweet potato chlorotic stunt virus (SPCSV), sweet potato virus B (SPVB), and African sweet potato virus complex.

Sweet potato viruses are much more difficult to work with than many other plant viruses. Most virus indexing tests involve the use of plant sap. It has been found that the concentration of viruses in the sap is often low, that it varies throughout the plant, and that some factor in the sweet potato plant sap inhibits the inoculation of indicator plants with sweet potato sap. Sweet potato viruses also appear to have a narrow host range and this restricts the number of species that can be used as indicator plants.

The following indexing program is used at the Plant Research Institute (PRI), Burnley, for testing for sweet potato viruses:

- In vitro plantlets are screened for the presence of virus by viewing a sap dip preparation using the electron microscope.
- Plantlets are then planted out in a glasshouse.
- Sweet potato cuttings are subsequently grafted on to the indicator species *Ipomoea setosa*. Two grafts are made to each *I. setosa* plant using both young and old sweet potato tissue. Four *I. setosa* plants are grafted and viewed for virus symptoms for 10 weeks. The test is then repeated. All known sweet potato viruses cause the development of leaf symptoms on *I. setosa*.
- A number of serological tests are conducted on both the sweet potato plants and the grafted *I. setosa* plants. Enzyme-linked immunosorbent assays (ELISA) are conducted to determine the presence of SPFMV, SPMMV, and SPCLV. Immunosorbent electron microscopy is used to test the presence of SPFMV, SPMMV, SPCLV, SPLV, and SPCSV.
- It has not been found extremely difficult to mechanically inoculate herbaceous indicator plants with sweet potato sap. It is possible to mechanically inoculate indicators using *I. setosa* sap. SPMMV, SPCSV, and SPLV can be identified by their reactions to *Nicotiana* indicator species.

If plants yield negative results in all the above tests, they are designated "pathogen-tested" and placed in a repository of clean germplasm.

Production, Maintenance and Distribution of Pathogen-tested Germplasm

A collection of pathogen-tested sweet potato lines is being developed and maintained at PRI. All lines are maintained as in vitro plantlets. They are cultured on a slow growth medium, which is replenished every 6 to 12 months, and these are maintained in glass-doored refrigerators, under dim lights at 16°C.

If requests for any of these germplasms are received, plantlets of the required lines are recultured on a rapid growth medium and exported as tissue culture plantlets. The germplasm collection at PRI is not yet available for general use but will be in the future. As already discussed, a pathogen-tested planting material normally produces more vigorous plants and higher yields than a normal field planting material. However, a well organized germplasm multiplication program is required to produce this planting material. Mother stocks should be maintained in a pathogen-tested state, either as tissue cultures or as plants in an insect-proof screenhouse. The multiplication of these stocks may be carried out by in vitro multiplication of plantlets or by taking cuttings in the screenhouse, or by a combination of both methods.

Another benefit of the production of pathogen-tested germplasm is that it meets the quarantine requirements of most countries and this enables international exchange of germplasm. This material is beneficial to breeding and agronomic assessment programs. A material with specific characteristics such as disease resistance can be selected from the collection for incorporation into country programs.

SCREENING AND BREEDING FOR SWEET POTATO SCAB (ELSINOE BATATAS) RESISTANCE IN TONGA

Pita Taufatofua and Finau S. Pole*

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is an important staple food crop grown and consumed throughout Tonga all year round. It is even acceptable to the nobility and high ranks. Sweet potato is a complement to yam and *Alocasia* in traditional feasts. On the other hand, *Xanthosoma*, cassava, and bananas are not acceptable.

In comparison with other popular tropical root crops, sweet potato is quick to mature, requiring only four to five months from planting to harvest. This is an attribute that is particularly valuable for rapid recovery from the destruction wrought by cyclones.

There are several constraints to the production of sweet potato in Tonga, but the most serious is scab caused by the fungus *Elsinoe batatas*. Scab is a leaf disease that has become increasingly severe during the past decade and has been reported to cause major yield reduction in some areas of the Pacific. The severity of the disease is mainly felt in areas like Tonga where the genetic base of the crop is very narrow and the few traditional cultivars are mostly susceptible. Varietal susceptibility ranges from highly susceptible (several of the most popular types) to reasonably resistant (Hawaii) when exposed to typical disease pressure.

Following a cyclone in 1982, the Ministry of Agriculture mass multiplied planting material of the cultivar "Hawaii" and distributed it to the people, particularly in Tongatapu, where in late 1982, 95 percent of the sweet potato acreage was planted to "Hawaii." This was, however, only a short-term solution to the scab problem. First, the level of resistance of "Hawaii" is not sufficient to insure a good yield when disease pressure is high. Second, a large acreage of a single cultivar could encourage the rapid increase and spread of diseases and pests. Genetic uniformity is the basis of vulnerability to epidemics. The rapid multiplication and distribution of "Hawaii" were a valuable first step in the battle against scab but further steps were necessary to provide farmers with additional resistant cultivars

*Biochemist and Assistant Specialist, respectively, MAFF, Tonga.

and to broaden the genetic base of the crop in order to reduce the risk of epidemics.

Importation of Scab Resistant Clones

Clonal materials that have been shoot tip-cultured and disease-indexed were obtained from Dr. F. Quack, Institunt roor Plantenziektekundig, Wageningen, the Netherlands (International Institute for Tropical Agricultural or IITA clones found resistant to scab in the Solomon Islands) and from Dr. O. Stone of Glasshouse Crops Research Institute, England (Solomon Islands clones resistant to scab). Further introductions are expected from the Plant Research Institute, Victoria, Australia, when regional materials are ready.

True botanical seeds were also obtained from the Solomon Islands (Dr. G. Jackson), Papua New Guinea (Dr. C.N. Floyd), International Institute of Tropical Agriculture (Dr. S.K. Hahn), and Asian Vegetable Research and Development Center (Dr. R.T. Opeña).

All introduced materials have been evaluated for possible release to farmers and are also used as genetic base of a breeding program.

Sweet Potato Breeding in Tonga

Breeding cultivars resistant to scab using conventional methods of hybridization and selection is a longer step but has the potential of producing cultivars that have higher levels of scab resistance and that are uniquely tailored to the environment, growers, and consumers of Tonga. With the expert guidance of Dr. J. Wilson and the availability of some exotic germplasms to broaden the genetic base, this breeding program has the potential to produce high-yielding, disease-resistant cultivars with agronomic and quality characters appropriate for Tonga.

According to the 1982 AVRDC sweet potato survey, cultivar improvement is the most important research priority for sweet potatoes in Asia and the Pacific. However, of the 300,000 true sweet potato seeds screened annually in Asia and the Pacific, less than 3 percent are screened in areas other than Taiwan and the Philippines.

The breeding program in Tonga was started in 1981 as a joint project of the Ministry of Agriculture, Tonga (MAFF), IRETA, and the Food and Agriculture Organization (FAO) root crop improvement project. Its objective was to produce improved clones of sweet potato having resistance to scab, high yields, agronomic characteristic, and culinary quality suitable for farmers in Tonga.

Current Status

The most recent series of trial was undertaken in April 1986; the crops were harvested four months later. The seedlings derived from clones in the trial included germplasm obtained as seeds from Papua New Guinea (PNG), as well as from the recurrent selection population, which is based on genetic materials from Tonga, the Solomon Islands, and Nigeria. In the preliminary, intermediate, and advanced trials, clones were evaluated for scab reaction, little leaf reaction, leaf shape, vine length, tuber shape, tuber skin and flesh color, weevil infestation, tuber smoothness, tuber cracking, yield, and suitability for market or ceremony. In the preliminary and intermediate trials, specific gravity was estimated in salt solution. In the advanced trial, eating quality after boiling and percentage dry weight were determined.

To generate seeds for further cycles of the breeding sequence, hand pollinations are currently being made in a crossing block containing selected genotypes. Moreover, seeds have been obtained from the IITA in Nigeria and AVRDC in Taiwan to continue broadening the genetic base of the breeding population. Steady progress has been made and three clones (TIS-2498, 83003-12, and 83003-13) from the breeding program will be evaluated in on-farm trials. There are also a number of promising clones coming up through the intermediate and advanced trials.

ACKNOWLEDGMENT

The help extended by the following persons is gratefully acknowledged:

Dr. J.E. Wilson of USP/IRETA, Coordinator/Senior Researcher of this project.

Dr. G.V.H. Jackson of UNDP/FAO/SPC-Regional Crop Protection Project.

Dr. C.N. Floyd of DPI, PNG, Dr. S.K. Hahn of IITA, and Dr. R. T. Opeña of AVRDC, for providing seeds for this program.

Dr. F. Quack of IPR, Wageningen, the Netherlands, and Dr. O. Stone of G.C.R.I., England, for supplying tissue cultured materials.

Table 1. Performance of sweet potato clones in Advanced-1 trial, rainy season, 1985, Viani, Tonga.

Clone no.	Tuber no./m^2		Tuber fresh wt. (kg/m^2)		Leaf scab score*	Dry wt. (%)	Selected for further evaluation
	Marketable	Total	Marketable	Total			
Hawaii	0.5	4.7	62.5	201.4	1.6	28.1	Local cv
Tongamai	0.0	0.0	0.0	0.0	3.0		Local cv
Amelika	2.0	10.9	187.5	520.8	2.3	29.7	Local cv
Siale	0.1	2.2	6.9	76.4	2.6	20.9	Local cv
Kaloti	1.4	9.2	131.9	395.8	2.2	26.7	Local cv
Halasika	0.5	2.0	97.2	159.7	1.5	26.3	Local cv
81020-3	0.2	3.0	3.5	90.3	2.3		No
TIS 2498	2.7	10.4	277.8	527.8	1.3	25.6	Yes
81019-24	0.7	4.7	69.4	187.5	2.3	26.0	Repeat in Intermediate Trial
81010-33	0.04	1.5	3.5	34.7	2.8		No
81009-7	0.4	5.2	41.7	104.2	2.1		No

*Subjective rating scale of 1 to 3, where 1 = no to very mild symptoms and 3 = severe symptoms.

Table 2. Performance of sweet potato clones in Advanced-1 trial, dry season, 1985, Vaini, Tonga.

Clone no.	Tuber no/m^2		Tuber fresh wt (kg/m^2)		Leaf scab score	Selected for further evaluation
	Marketable	Total	Marketable	Total		
Tongamai	0.1	4.5	–	0.06	1.8	Local cv
Hawaii	8.8	11.4	1.28	1.44	0.3	Local cv
TIS-2498	7.3	10.4	1.14	1.31	0.7	Yes
83003-12	4.3	6.2	0.83	0.99	0.5	Yes
84003-13	4.3	6.9	0.67	0.90	0.4	Yes

Table 3. Performance of sweet potato clones in Advanced-1 trial, rainy season, 1986, Vaini, Tonga.

Clone no.	Tuber no/m^2		Tuber fresh wt (kg/m^2)		Leaf scab score	Dry wt. (%)	Selection for further evaluation
	Marketable	Total	Marketable	Total			
Tongamai	0.6	1.1	0.05	0.06	3.1	17.8	Local cv
Hawaii	9.8	15.1	1.35	1.47	0.8	26.8	Local cv
TIS-2498	8.6	11.2	1.40	1.47	1.0	28.0	Yes
83003-19	5.7	8.2	1.09	1.15	0.2	24.7	Yes
83009-1	2.0	5.8	0.24	0.32	1.3	21.1	No

STUDIES ON THE MAJOR DISEASES AND INSECT PESTS OF SWEET POTATO AT VISCA, THE PHILIPPINES

Ruben M. Gapasin*

INTRODUCTION

Historically, root crops have played an important role as a source of food for man. Consequently, these crops are still widely and extensively grown. In the Philippines, among the root crops, sweet potato (*Ipomoea batatas* (L.) Lam) tops the list in terms of cultivation and production.

With the establishment of the Philippine Root Crop Research and Training Center (PRCRTC) and the conduct of research programs funded by international and national agencies, such as the International Development Research Centre (IDRC) of Canada and the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), the demand for sweet potato has tremendously increased not only as a food crop but also as a substitute ingredient for corn in the formulation of commercial animal feed. With the increased interest in sweet potato production, however, problems related to production such as diseases and insect pests began to surface. Yield losses owing to diseases and insect pests are estimated to reach as high as 50 percent and in some cases, they cause a total yield loss.

This paper presents and discusses studies on yield loss assessment and methods of control of the major diseases and insect pests of sweet potato that have been conducted at ViSCA.

DISEASES

Stem and Foliage Scab Disease (Sphaceloma batatas (Sawada) Jenkins and Viegas)

Symptomatology, host range, and epidemiology

The stem and foliage scab disease is one of the most prevalent and destructive diseases of sweet potato. It mainly affects the above-ground parts, particularly the vine tips, making them not acceptable for human consumption. The disease is recognized through scabby lesions on the

*Associate Professor, Department of Plant Protection, ViSCA, Baybay, Leyte 7127-A, the Philippines.

lower surface of the leaf laminae, as well as on the petioles and stems. The affected parts are usually stunted and deformed. In rare instances, the stems grow upright instead of lying flat, as with healthy plants. As a result of scab infection, plants may die or tuber production may be greatly reduced (Nayga and Gapasin, l986; Pongcol, l982).

Of the l8 plant species tested, only one plant species, *Ipomoea aquatica* (kangkong), belonging to the family Convulvulaceae was infected with the scab disease by natural infection. Back inoculation to sweet potato was successful and symptoms appeared similar to inoculated test plants (Pongcol, l982). It appears that *Sphaceloma batatas* has a narrow host range. Under field conditions, the pathogen may survive on the diseased leaves and stems on the ground so that the absence of alternate hosts will not result in the reduction of inoculum for the next cropping season.

The scab pathogen was effectively disseminated by water using a rubber hose and a sprinkler (Regis, l982). Shorter incubation period, greater number and bigger size of lesions, and higher percentage infection were observed in the test plants where a rubber hose was used. Natural air movement in which diseased sweet potato plants were placed very near the test plants failed to disseminate the scab pathogen. It is apparent that faster spread of the disease in the field can be expected during the rainy season.

Yield loss assessment

The effect of the scab disease on the growth and yield of sweet potato variety VSP-l was conducted under pot experiment (Nayga and Gapasin, l986). Sweet potato plants inoculated with the scab pathogen caused deformation of leaves and stunted growth of plants. Scab infection also caused early death of the main vines.

Significant differences in disease severity ratings, leaf area, and number and weight of marketable roots were observed among the treatments (Table l). Total root yield of plants inoculated with scab at 2 and 4 weeks after planting was reduced by 28 percent and 25 percent, respectively, compared with the control. Eight week-old inoculated plants had a yield reduction of only 4 percent (Table 2).

Control method

In l982, a study was started to screen promising sweet potato hybrids and germplasm collections for resistance to scab disease. Supportive to this was the development of a rapid technique for screening a large number of hybrids derived from polycross breeding. Promising breeding lines and other genotypes were initially observed under field conditions and their degrees of resistance were confirmed under an artificially induced scab disease.

Table 1. Scab disease severity rating, leaf area, and fresh vine weight (kg) of sweet potato variety VSP-1 inoculated at different growth stages with *Sphaceloma batatas.* *

Treatment	Initial disease severity rating**	Average scab disease severity rating***	Fresh vine weight (kg/plant)	Average leave area+ (cm^2)
T_0 (control)	1.00d	1.00d	0.1325	38.50a
T_1 (2 weeks)	8.40a	8.85a	0.1375	22.55bc
T_2 (4 weeks)	8.60a	8.80a	0.0700	23.39bc
T_3 (6 weeks)	6.80b	7.70b	0.1150	24.11bc
T_4 (8 weeks)	5.40c	6.05c	0.1050	25.41b

*Means followed by common letters and those without postscript are not significantly different at 5% level (DMRT).

**Initial disease severity ratings were taken in test plants 2 weeks after inoculation.

***Scab disease severity ratings were taken biweekly after inoculation until harvest.

+Average area per leaf based on 10 leaves/plant and 10 plants/treatment.

Hybrids developed from polycross breeding and planted in the field and varieties and germplasm collection maintained in the field were rated for resistance or susceptibility to the scab disease using the l-9 rating scale. Table 3 summarizes hybrids/accessions/varieties that were evaluated under field condition at ViSCA and other places from l982 to l986.

Considering the bulk of materials to be evaluated for their resistance to the scab disease, the development of a rapid and mass screening technique using infector plants was initiated.

This technique proved effective as shown in Table 4. Hybrids that might have escaped infection in the field could be discarded while those that have remained resistant could be further confirmed by artificial inoculation. Also, in this method, the test plants had earlier been rated compared to when they were in the field; hence, resistance or susceptibility to the scab could be evaluated earlier and faster.

Artificial inoculation of the scab pathogen was unsuccessful because the organism grew slowly in an artificial culture media. Paningbatan (l987), however, reported that sweet potato stem agar and exposure to continuous darkness supported the most abundant conidial production of *Sphaceloma batatas* Saw.

Table 5 shows the hybrids that remained resistant to the scab disease after artificial inoculation. These hybrids are maintained in one area at ViSCA as source of resistant gene in future breeding work.

Table 2. Yield and yield components of sweet potato variety VSP-1 as affected by scab disease caused by *Sphaceloma batatas*.*

Treatment	Marketable roots		Nonmarketable roots		Total root yield (kg)	% Yield reduction
	Number	Weight (kg)	Number	Weight (kg)		
T_0 (control)	5.90a	0.7003a	0.90	0.00053	0.7008	—
T_1 (2 weeks)	2.90a	0.4915d	1.20	0.01447	0.5057	27.84
T_2 (4 weeks)	3.50cd	0.5137cd	1.40	0.01380	0.5290	24.51
T_3 (6 weeks)	4.30bc	0.6101bc	1.10	0.01490	0.6187	11.72
T_4 (8 weeks)	5.10ab	0.6598ab	1.10	0.01060	0.6700	4.39

*Means followed by common letters are not significantly different at 5% level (DMRT).

Table 3. Reaction of hybrids/varieties/accessions to the scab disease under field conditions, using the infector technique and artificial inoculation from 1982-1986.

Year/Method	Total entries	Resistance rating*				
		HR	R	MR	S	HS
Field						
1982	970	–	554	–	–	–
1983	752	472	60	30	27	193
1984	1,074	611	196	78	37	155
1985	786	126	208	172	200	80
1986	1,103	37	370	244	125	327
Infector plants	586	0	193	118	102	73
Artificial inoculation	319	0	89	116	43	71

*Rating based on 1.00-2.5 = HR; 2.51-4.50 = R; 4.51 6.5 = MR; 6.51-7.50 = S and 7.51-9.00 = HS.

Table 4. Comparison of resistance ratings of different sweet potato hybrids under field conditions using infector plants (new technique).*

Hybrid	Field**		Infector plants	
	Mean rating	Reaction	Mean rating	Reaction
20-607	1.0	HR	7.4	S
–575	3.0	R	6.2	MR
–600	1.0	HR	8.6	HS
–621	1.0	HR	5.8	MR
–645	1.0	HR	8.6	HS
–640	1.0	HR	7.8	HS
–632	1.0	HR	7.8	HS
–626	1.0	HR	7.4	S
–560	1.0	HR	7.0	S
–569	1.0	HR	7.4	S
–561	1.0	HR	3.4	R
–553	1.0	HR	5.4	MR
–634	4.2	R	8.2	HS
–549	1.0	HR	7.8	HS
–533	1.0	HR	7.4	S
–551	1.0	HR	5.8	MR

*Sample from 156 hybrids.

**Ratings taken after 12 weeks compared to 6 weeks using infector plants; reaction based on 1.00-2.5 = HR; 2.51-4.50 = R; 4.51-6.50 = MR; 6.51-7.50 = S and 7.51-9.0 = HS.

Table 5. Hybrids from polycross breeding that remained resistant after artificial inoculation with the scab pathogen.

V5– 13	V12– 101	V15– 10	V23– 2
– 26	– 118	– 63	– 3
– 30	– 123	– 70	– 4
– 39	– 146	– 86	– 12
– 42	– 162		– 24
– 50	– 163	V16– 8	– 30
– 53	– 169		– 33
– 55	– 206	V17– 23	– 35
– 59	– 275		– 36
– 61		V20– 19	– 42
	V13– 8	– 27	– 50
V8– 12	– 32	– 86	– 79
– 18	– 35	– 110	
– 23	– 42	– 147	V24– 37
	– 126	– 293	– 51
V10– 29	– 127	– 305	– 53
– 42	– 128	– 307	– 54
– 44	– 151	– 374	
– 251	– 158	– 377	
– 287	– 180	– 436	
– 316	– 182	– 511	
–	– 185	– 553	
V11– 136	– 191	– 561	
– 172	– 210	– 661	
– 193		– 737	
– 201	V14– 7		
– 243	– 38	V22– 137	
– 256	– 64		
– 270			
– 398			

Nematodes (Meloidogyne spp. and Rotylenchulus reniformis)

Symptomatology and epidemiology

Root-knot (*Meloidogyne* spp.) and reniform (*Rotelynchulus reniformis*) are the two most important nematodes that attack sweet potato. The above-ground symptoms are similar to those caused by many other root diseases or environmental factors that reduce the amount of water available to the plants. Infected plants show reduced growth and fewer, small, pale green, or yellowish leaves that tend to wilt in warm weather.

Infected roots swell at the point of invasion and develop into the typical root-knot galls which are two or three times as large in diameter as the healthy root. When tubers or other fleshy undergrown organs are attacked, they produce small swellings over their surface, which become quite prominent at times and may cause distortion of the organs or cracking of the skin.

The adult female produces eggs that are laid in a gelatinous protective coat. The eggs may be laid inside or outside the root tissues depending on the position of the female. Eggs may hatch immediately or they may overwinter and hatch later. A life cycle is completed in 25 days at 27°C, but it takes longer at lower or higher temperatures. When the eggs hatch, the infective second-stage larvae may migrate from within galls to adjacent parts of the root and cause new infections in the same root, or they may emerge from the root and infect other roots of the same plants or roots of other plants. The ability of root-knot and reniform nematodes to move on their own power is limited, but they can be spread by water or by soil clinging to farm equipment or otherwise transported into uninfested areas.

Identification and pathogenecity

Nematodes are one of the important pests that cause damage to sweet potato. In a survey on sweet potato conducted in Leyte by Gapasin (1979), *Meloidogyne incognita* and *Rotylenchulus reniformis* were found to be the most prevalent and widely distributed in the area (Table 6). Gapasin and Valdez (l979) found that *M. incognita* reduced tuber production from l0.2 to 47.7 percent depending on the nematode population attacking the crop while *R. reniformis* reduced tuber yield from l3.4 to 60.6 percent.

Control methods

Several methods are employed to control *Meloidogyne incognita* and *Rotylenchulus reniformis*. Gapasin (l98l) found that the application of Nemagon 75 EC and Temik l50 increased the root tubers and top weight of sweet potato and reduced nematode population by 65-85 percent compared to Furadan 5G and Bunema 40 EC, which gave 45-70 percent reduction (Tables 7 and 8).

A control method that can be effective, economical, and environmentally safe is the use of resistant varieties (Gapasin, l984). Using Taylor and Sasser's (l978) egg mass index, 52 sweet potato cultivars were screened against *M. incognita* and l3, 4, 7, and 28 cultivars were found susceptible, moderately susceptible, moderately resistant, and resistant, respectively (Table 9).

Table 6. Population density, occurrence, and distribution of plant parasitic nematodes associated with sweet potato in Leyte and Southern Leyte.

Nematode genera/crop	Count per 300 cc soil		% Occurrence	% Distribution
	Dry	Wet		
Rotylenchulus	249.01	496.55	79.65	97.64
Meloidogyne	51.67	90.84	14.57	70.58
Helicotylenchus	20.26	23.34	3.74	92.76
Hoplolaimus	1.01	4.58	0.73	47.64
Hemicycliophora	1.30	2.67	0.42	19.41
Xiphinema	1.79	1.40	0.22	34.11
Hemicriconemoides	0.03	1.40	0.22	18.23
Criconemoides	0.29	1.07	0.27	17.64
Pratylenchus	0.89	0.70	0.11	13.52
Longidorus	0.04	0.31	0.05	10.00
Rotylenchus	0.02	0.25	0.04	4.70
Tylenchorhynchus	0.53	0.21	0.03	7.64
Dolichodorus	0.03	0.00	0.01	0.38

Table 7. Effects of different treatments on potted soil infested with *Meloidogyne incognita* and grown to sweet potato.

Treatment	Galling index	Eggmass index	Fresh weight (g)*			No. of nematodes recovered**	% Control
			Roots	Tubers	Tops		
Untreated	2.6	4.6	10.6	46.6	34.3	2066.3	–
Nemagon 75 EC	1.3	1.3	12.3(13.8)	80.0(41.7)	56.0(38.7)	398.0	80.7
Temik 156	2.0	1.6	11.3(6.2)	75.3(38.1)	35.6(3.6)	537.0	74.0
Furadan 5G	2.3	2.6	11.0(3.6)	64.6(27.9)	34.6(0.9)	665.3	67.8
Bunema 40 EC2	2.3	2.6	11.00(3.6)	52.6(11.8)	37.6(8.8)	762.0	63.1
Hostathion 5G	2.6	4.0	10.3	52.3(10.9)	37.3(8.0)	939.3	54.5
Chicken manure	2.3	2.6	11.68(8.6)	74.6(35.5)	44.3(22.6)	818.3	60.4

*Numbers in parenthesis denote percent increase over the untreated control.

**Based on 300 cc soil per pot.

Table 8. Effects of different treatments on potted soil infested with *Rotylenchulus reniformis* and grown to sweet potato.

Treatment	Fresh weight (g)*			No. of nematodes recovered**		% Control
	Roots	Tubers	Tops	Soil	Roots	
Untreated	12.0a	58.6a	39.6	3037.3	404.0	–
Temik 15 G	13.0(7.7)a	90.3(35.1)b	43.0(7.9)	529.6	239.6	85.6
Nemagon 75 EC	18.6(35.5)b	87.6(33.1)b	43.3(8.5)	678.6	229.6	77.7
Bunema 40 EC	14.3(16.1)b	69.6(15.8)a	41.6(4.8)	1719.3	299.3	43.4
Furadan 5G	13.0(7.7)a	68.3(14.2)a	40.3(1.7)	1384.6	349.0	54.4
Hostathion 5G	11.3a	58.0a	32.0	2776.6	383.6	8.6
Chicken manure	24.6(51.2)c	101.6(42.3)b	55.6(28.8)	1172.6	265.0	61.4

*Numbers in parenthesis denote percent increase; means followed by the same letter are not significantly different using DMRT.

**Based on 300 cc soil and 1 g roots per plant.

Table 9. Cultivars found resistant, moderately resistant, moderately susceptible, and susceptible to *Meloidogyne incognita* based on egg mass index 45 days after inoculation.*

Resistant		Moderately resistant	Moderately susceptible	Susceptible
W–86	Karja	UPLB 131	Ifugao 25	Davao 1
L4–89	Lubang	Centennial	UPR	GAT
BPA–4	Jewel	UPLB 243	Calibre	Kinabakab
Sinibastian	Madregor	VSP 1		Tres Colores
Miracle	Jasper	VSP 3		UPLB 143
Travis	UPLB 247	Binulakan		VSP 2
UPLB 67	B–30	San Isidro		AIS–209–3
Tor Poak x	UPLB 239	Hsinchu		High Yielding Yellow
Centennial	UPLB 57			BNAS–51
LO–323	PI 286621			Catanduanes
Georgia Red	UPLB 252			
UPLB 55	Garcia Yellow			C 1596–9
UPLB 316	Caragold			Binicol
Maligaya				Gold Rush
UPLB 90				
UPLB 88				

*Resistance rating based on egg mass index of 5000 eggs inoculated 10 days after planting. 0-1.9 = R; 2.0-2.9 = MR; 3.0-3.9 = MS; and 4.0-5.0 = S.

INSECT PESTS

Sweet Potato Weevil (Cylas formicarius elegantulus Fabr.)

Damage

One of the limiting factors in the successful production of sweet potato is the weevil, which attacks the tubers and stems of the plant. Females lay eggs on tissues at the base of the stems where initial infestation occurs and later spreads in the developing tubers. Upon hatching, the larva bores deeper into the stem or tuber. The infested tuber gives off a characteristic disagreeable odor and tastes bitter even after cooking, thus becomes unfit for human consumption. Heavy infestation by the insect, if left uncontrolled, can cause tremendous yield loss.

At ViSCA, it was observed that the weevil caused a yield reduction of as high as 50 percent during the dry season planting. In small farming areas, yield losses may even be higher because farmers cannot afford to use effective but expensive chemicals to control the pest.

Control methods

Use of resistant varieties. The use of resistant varieties has great potential in reducing weevil infestation. This method of weevil control is economical and can easily be adopted by the farmers. Despite its great advantage, however, limited work has been done in developing varieties resistant to weevil.

At ViSCA, screening for resistance to weevil has been given priority over other insect pests because of the greater damage that it causes to sweet potato.

Sweet potato hybrids developed from polycross breeding were planted in the field and were rated for their resistance to weevil. Those found resistant were further planted in I2 dia clay pots and artificially infested with weevil. Table I0 shows the reaction of sweet potato hybrids planted in the field and pots from I982 to I986. It is apparent from these data that some hybrids, when planted in pots and artificially infested with weevil, reacted differently or became susceptible. This susceptible reaction could be attributed to forced feeding by the confined weevils or when under field conditions, there was insufficient number of weevils to cause damage.

Table 10. Performance of sweet potato selections planted in the field and pots to weevil(*Cylas formicarius elegantulus* Fabr.).

Year	No. of selections planted in the field	Rating*		No. of selections planted in plots	Rating *	
		MR	S		MR	S
1982	103	37	66	37**	16	18
1983	63	48	15	48	31	17
1984	55	26	29	26	16	10
1985	105	36	69	36	11	25
1986	57	26	31	26	13	13

*MR = Moderately Resistant; S = Susceptible

**3 hybrids did not produce tubers.

In another test, Gerona (l987) found that from the 39 promising lines/accessions tested, at least five (V3-3, V7- 7, V5-55, PRS #507, and PRS #508) consistently showed resistance to weevil after four trials.

Microbial control. Since sweet potato is considered a low value crop, very seldom, if at all, do farmers use any control method to suppress pests. Furthermore, the high cost of pesticides prohibits farmers from using them. A more practical and economical method of controlling the pest should therefore be developed. One promising method is the use of microbial pathogens, such as *Metarrhyzium, Beauveria,* and other entomopathogenic fungi.

Based on two laboratory trials, Villacarlos (l987) found that *M. anisopliae* was the most effective fungus, causing 86 percent adult mortality within 7-l4 days of exposure. *M. flavoridae* var. *major* caused lower mortality at 49 percent while the rest of the fungi resulted in less than 40 percent mortality (Table ll).

Table 11. Percent mortality of adult weevils within 7-14 days of exposure to different entomopathogenic fungi.

Fungus	% Mortality*
Metarrhizium anisopliae	85.23
Metarrhizium flavoviridae var. *major*	48.6
Beauveria bassiana	36.6
Paecilomyces lilacinus	34.6

*Average of 3 trials

Cultural control. Cultural control measures used in weevil control include rotation of crops, clean cultivation, deep planting, and destruction of plant residues and alternate hosts. These methods offer a practical solution to the weevil problem. Remoroza (l978) mentioned that deep tuber formation resulted in low weevil infestation. Likewise, Burdeos and Gapasin (l980) reported that soil depth could affect the degree of sweet potato weevil infestation. The deeper the tubers are buried the fewer will be the infested tubers. Furthermore, soil depth affected weevil population in the stem and tubers (Tables l2 and l3). These imply that burying tubers deeper, such as hilling up at the base of sweet potato during tuber formation, can reduce weevil infestation.

Some environmental factors, such as climate, temperature, soil moisture, and soil pH, could influence the population and severity of damage of the sweet potato weevil. Abella (l982) compared the effect of varying soil pH level on the population of weevil and on the growth and tuber yield of sweet potato. She found that the greatest weevil infestation measured in terms of weevil counts in stem and tubers, number and weight of infested tubers, and degree of damage on tubers were at the highest pH range (4.6-5.5), declining gradually with decrease in acidity or toward alkalinity (pH 8.6-9.5). Apparently, the change in some physical factors in the soil could be detrimental to the weevil, suggesting the possibility of reducing tuber damage.

Table 12. Number and weight of infested and noninfested tubers per pot of sweet potato grown at different soil depths.

Soil depth (cm)	Infested tubers		No. of weevil/kg infested tubers	Noninfested tubers		Total	
	No.	Wt(g)		No.	Wt(g)	No.	Wt(g)
15 (control)	2.45	204.01	45.00	1.66	123.17	4.11	327.18
20	2.00	190.28	37.00	3.00	272.85	5.00	463.13
23	1.20	93.69	51.00	2.25	228.95	3.45	322.64
26	0.50	21.18	78.00	3.35	285.52	3.85	306.70
29	0	0	0	4.45	347.10	4.45	347.10

LSD for weight of infested tubers: 0.05 = 35.523; 0.01 = 49.125

Table 13. Number of larvae, pupae, and adult weevils found per stem and in tubers per pot of sweet potato grown at different soil depths.*

Plant part	Soil depth (cm)				
	15 (control)	20	23	26	29
Stem	3.50	2.15	1.80	1.35	0.95
Tuber	9.23	7.10	4.85	1.65	0

*Data based on a total of 20 plants per treatment.

CONCLUSION

The sweet potato industry is beset with various problems, the most pressing being increased productivity. As is most often the case, sweet potato growers get a low return from their investment because of losses incurred owing to infection by disease-causing microorganisms and attack by insect pests. Monitoring these diseases and insect pests thus becomes very important.

The scab diseases caused by *Sphaceloma batatas* Saw have become a perennial problem, especially during the rainy season. Research, therefore, should be directed toward the development of effective control methods against the disease. Fungicide application should be looked into since sweet potato is now planted commercially. Also, practices such as cultural management (i.e., removal of infected vines and application of organic fertilizer) should be worked on.

Nematodes may reduce the yield of sweet potato. Yield loss attributed to nematodes, particularly the root-knot nematode (*Meloidogyne* spp.) under field conditions, should be studied. Biological control methods that have shown promise for the control of nematodes in other crops should likewise be considered. *Paecilomyces lilacinus* has been isolated from egg masses of root-knot nematodes attacking sweet potato. With this as a starting point, researchers should look into the potential of this fungal parasite for root-knot control. It is, however, important to remember that suppression of nematode populations with biotic organisms will not immediately be attained, as the effects of these organisms will be manifested slowly over a long period of time.

The weevil (*Cylas formicarius elegantulus* Fabf.) has always been a big problem in sweet potato production; therefore, evaluation for resistance to this pest should be a continuing activity of researchers. Development of an effective screening method considering the bulk of materials to be screened against the pest should be initiated. In so far as identifying a resistant cultivar to the weevil is concerned, only very few have been identified here at ViSCA.

The search for more effective biocontrol agents should be continued. While we have these entomopathogenic fungi as biocontrol agents, we should keep in mind that reducing weevil to levels below the damage threshold should only constitute a portion of the overall control strategies in integrated pest management program. Incorporation of the biotic organisms, the proper use of pesticide (perhaps in reduced doses and in combination with the biotic organisms), plant resistance, and other cultural practices should be seriously considered if we hope to meet the food requirements of the ever-increasing world population.

To attain the objective of effective control against diseases and pests, dedication, persistence, and hard work must be carried out by those concerned.

REFERENCES

Abella, L. 1982. Effect of six soil pH levels on weevil population and severity of damage on sweet potato. BS Thesis. ViSCA, Baybay, Leyte, the Philippines. 33p.

BAEcon. 1982. Statistical Data. Quezon City, the Philippines.

Burdeos, A.T. and D.P. Gapasin. 1980. Effect of soil depth on the degree of sweet potato weevil infestation. Ann. of Trop. Res. 2:224-231.

Gapasin, R.M. 1979. Survey and identification of plant parasitic nematodes associated with sweet potato and cassava. Ann. Trop. Res. 1:120-134.

Gapasin, R.M. and R.V. Valdez. 1979. Pathogenecity of *Meloidogyne* spp. and *Rotylenchulus reniformis* on sweet potato. Ann. Trop. Res. 1:20-25.

Gapasin, R.M. 1981. Control of *Meloidogyne incognita* and *Rotylenchulus reniformis* and its effect on yield of sweet potato and cassava. Ann. Trop. Res. 3:92-100.

Gapasin, R.M. 1984. Resistance of fifty-two sweet potato (*Ipomoea batatas* (L.) (Lam.) cultivars to *Meloidogyne incognita* and *M. javanica.* Ann. of Trop. Res. 6:1-19.

Gerona, R.G. 1987. Identification of sweet potato accessions with resistance to weevil (*Cylas formicarius elegantulus* Fabr.) and analysis of the mechanisms involved. MS Thesis. ViSCA, Baybay, Leyte, the Philippines. 56 p.

Nayga, J.C. and R.M. Gapasin. 1986. Effect of stem and foliage scab disease on the growth and yield of VSP-1 sweet potato variety. Ann. of Trop. Res. 8:115-122.

Olasiman, A.S. 1981. Susceptibility of BNAS-51 sweet potato variety to root-knot nematode. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Paningbatan, R.A. 1987. Infectivity and in vitro production of sweet potato scab fungus (*Sphaceloma batatas* Saw.) inoculum. Ann. Trop. Res. 9:24-33.

Pongcol, E.C. 1982. Pathogenicity and host range of the sweet potato scab pathogen (*Sphaceloma batatas* Saw.). BS Thesis. ViSCA, Baybay, Leyte, the Philippines. 34 p.

Regis, T.M. 1982. Dissemination of and infection by the sweet potato stem and foliage scab pathogen (*Sphaceloma batatas* Saw.). BS Thesis. ViSCA, Baybay, Leyte, the Philippines. 25 p.

Remoroza, V.M. 1978. Susceptibility of vines and tubers of sweet potato (BNAS-51 variety) at different stages of growth to *Cyclas formicarius elegantulus* Fabr. BS Thesis. ViSCA, Baybay, Leyte, the Philippines. 34 p.

Taylor, A.L. and J.N. Sasser. 1978. Biology, identification and control of root-knot nematodes (*Meloidogyne* species). Dept. of Plant Pathology, North Carolina State University, Raleigh. USA. 36 p.

Villacarlos, L.T. 1987. Microbial control of the sweet potato weevil, *Cyclas formicarius elegantulus* Fabr. Ongoing PCARRD-funded study at ViSCA, Baybay, Leyte, the Philippines.

POSTHARVEST HANDLING AND STORAGE OF SWEET POTATO ROOTS

Emma S. Data, Julie C. Diamante, and Paz S. Eronico*

INTRODUCTION

Sweet potato is a perishable commodity. Keeping it in good quality and acceptable for human consumption after harvest is a major problem in the tropics. The high perishability of fresh roots greatly limits their market flexibility. Incidentally, fresh sweet potato roots are widely used as human food in the Philippines. Despite the high demand for fresh sweet potato roots, these are usually not available in markets in cities and population centers even if the crop is not highly seasonal.

Several researches on the proper handling and storage of sweet potato have been done throughout the world but very few have been conducted under tropical condition like that in the Philippines. The development of appropriate methods of handling and storing sweet potato under Philippine condition is the main concern of this paper.

HARVESTING

In the Philippines, the system of harvesting sweet potato is categorlzed into two: staggered and one-time harvesting (Data et al., 1982). In the first system, the usual practice is to harvest just the big roots, leaving the plants to continue growing for a few months until roots are produced on the lateral vines. A blunt bolo or a spading fork is used to dig the roots. The advantages of this system of harvesting are: (a) it requires less labor, and (b) only marketable roots are harvested. The disadvantages, on the other hand, include the following:

- Roots left in the field are prone to weevil infestation, especially during the dry season,
- Roots easily rot during the wet season.
- The field is tied up to one crop for a long period.

*Associate Professor, Science Research Specialist, and Research Assistant, respectively, Philippine Root Crop Research and Training Center (PRCRTC), Visayas State College of Agriculture (ViSCA), Baybay, Leyte, the Philippines.

- Some roots become fibrous or "cottony" in the core portion because of overmaturity.

In the second system, all sweet potato roots, regardless of size, are harvested at one time. Sweet potato vines are cut first and rolled to one side of the field. The roots are then dug using either a blunt bolo, spading fork, harvesting hoe, or any implement (Bartolini, 1981). In large farms, the crop is harvested by passing a moldboard plow along the rows. Sometimes, a tractor-drawn harvester adjusted to the width of the rows is used. The advantage of this system is that the field can immediately be planted to another crop soon after harvest. Moreover, weevil infestation can be avoided, hence roots are usually of good quality.

The engineering section of the Philippine Root Crop Research and Training Center (PRCRTC) has developed a carabao-drawn sweet potato harvester, which is five times faster than manual harvesting. This implement caused less than 5 percent root damage when tested under clay soil condition. It was estimated to harvest 0.5 ha of sweet potato per day, a job that requires 20-25 men (Orias, 1982 as cited by Quevedo, 1985). A carabao-drawn manually operated single-row sweet potato harvester was also designed by Tongco in 1979. The harvester, which is made of steel, has the following parts: beam or main frame, share or blade welded with slide rods, landslide, and steering handle (Tongco, l979). The width of the replaceable share is in three sizes: 100 mm, 80 mm, and 60 mm. The harvester was tested using different share sizes along with a local moldboard plow in two types of soil planted to two varieties of sweet potato. The moldboard plow caused a high percentage of bruised roots. Among the share sizes, the 60-mm width caused the least bruising of roots but it required the highest horsepower. The 80-mm share caused the least exposure of roots.

SORTING AND GRADING

After harvesting, sweet potato roots are sorted to facilitate the removal of diseased and damaged ones as well as to separate them into different sizes using a grade standard for sweet potatoes (Appendix A). Grading is important since it makes marketing of the different grades to different types of buyers possible. Ungraded products usually require detailed examination by the buyers and this practice is not only time consuming but also damages the produce. In addition, ungraded roots, when stored, deteriorate faster than the graded ones.

CURING

Curing is a process of wound healing that helps reduce storage losses of slightly damaged roots. It involves tuberization and thickening of the root skin, followed by the development of a wound periderm, which consequently retards moisture loss. The primary purpose of curing is to allow rapid healing of cuts, bruises, and skinned areas on sweet potato roots, thereby reducing secondary deterioration losses by preventing invasion by pathogens.

Buescher (l980), reporting on the beneficial effects of curing, stated that cured sweet potato roots exhibited lower weight loss and higher percentage salability after 6 months of storage than uncured sweet potato roots.

For years, the general recommendation for curing sweet potato has been to store the roots at 30°C and a relative humidity (RH) of 90-95 percent for 10-15 days. However, attempts were made to shorten the period because curing longer than necessary does not only waste heat but may also result in excessive sprouting owing to the high relative humidity. Boswell (1950, as cited by Mc Combs and Pope, 1958) recommended the shortening of the curing period from 10 to 6-8 days. Lutz et al. (1951) suggested curing of roots for 4 days at a temperature of 29°C. Under this condition, minimum loss owing to decay during subsequent storage was observed. Mc Combs and Pope (1958) also reported that a 4-day curing period at 30°C and 90-92 percent RH is appropriate for Porto Rico variety. They stated further that the length of curing, whether 4 or 10 days, had only a minor effect on weight loss of the stored roots, although roots cured for 4 days lost an average of l percent more weight during storage than roots cured for 10 days.

The effect of injury and relative humidity on weight and volume loss of sweet potato roots during curing and subsequent storage has also been studied by Kushman (1975). He revealed that weight and volume losses of variety Centennial during curing were reduced by increasing the relative humidity. A significant reduction in weight and volume losses was observed at 80 percent RH.

At ViSCA, the following methods of curing healthy and injured sweet potato roots were evaluated: 2-hour exposure of unwashed roots to the sun, ash treatment of unwashed roots, 2-hour exposure of washed roots to the sun, ash treatment of washed roots, unwashed roots without any treatment, and washed roots without any treatment. Results showed that, generally, healthy roots have significantly lower weight loss, degree of shrivelling, and percentage decay during storage than the injured roots (Data and Quevedo, 1987). It was also observed that among the injured roots, those that were washed (whether treated with ash or not) had significantly high percentage weight loss and degree of shrivelling, probably because washing might have removed the thin exodermis of the roots. The removal of the exoderm layer might have enhanced transpirational water loss, thus higher weight loss was incurred than in unwashed roots. On the other hand, washing healthy roots did not result in significantly greater weight loss. Washed roots that were exposed to the sun and those that were untreated had the lowest weight loss among the roots cured using different methods. Among the curing treatments, ash treatment on washed and unwashed roots caused the lowest percentage decay. Ash might have protected the roots against infection by microorganisms. On the other hand, washing and sun-drying the roots might have adversely affected their tissues and thus made them more susceptible to the attack of microorganisms.

PACKAGING

Packaging refers to the containment of a product in packages that are used not only to contain but also to protect, identify, and sell it. For sweet potato roots, packaging starts from the farm or from storage to the market then to the final consumers. Suitable packages or containers lessen scratches, bruises, and injuries during transport from one point to another. Thus, different types of containers are needed. If packaging is for storage, a good packaging material will give longer storage life to the product.

The most common packaging materials for sweet potato are wooden crates/boxes, *kaings* (baskets made of rattan or bamboo), and jute or burlap sacks. An ongoing study on the marketability of sweet potato conducted at ViSCA utilizes nylon net bags as packing materials for marketing sweet potato roots (Saladaga, personal communication). Most farmers, however, prefer to use a sack as container because it has greater capacity (50-70 kg of roots) and occupies relatively less space during storage and transport than the other containers (Data et al., 1982). A preliminary study comparing the performance of roots transported in three types of containers (wooden crates, *kaings*, and sacks) showed that sweet potato roots transported in sacks had the least damage during transport. Further holding of the roots in the laboratory, however, resulted in higher temperature and percentage weight loss of the stored roots. Crates were found to be much better transport containers than sacks and *kaings* based on the damage observed after transport (Data et al., 1981). Lutz et al. (1951) reported that packing sweet potato roots in sacks resulted in very high losses. He further stated that roots did not decay, were badly skinned, and of poor appearance, hence they could no longer be stored for any length of time before using.

In the United States, the main packaging materials of sweet potato are bushel baskets, hampers, crates, or fiberboard boxes holding 50 lb, corrugated cartons holding 40 lb, and wooden wire-bound rectangular boxes. Sacks are seldom used except for nearby markets of low-priced trade (Charney and Seelig, 1967).

US Department of Agriculture investigators observed that injuries, cuts, or damages of roots packed in wire-bound boxes were 13 percent lower than those of roots packed in bushel baskets (Charney and Seelig, 1967). Injuries and decay serious enough to downgrade the roots were twice as prevalent among sweet potato roots in baskets as among those in crates. Loss of weight and damage are serious enough to downgrade the sweet potatoes in baskets. Moreover, the wire-bound box allowed mechanical handling, thus reducing labor costs and permitting efficient use of storage area.

In packaging sweet potato roots by any means, enough ventilation must be provided to prevent air condensation and excess dampness which are likely to cause rotting and sprouting. However, care must be taken to avoid over–ventilation as it can result in excessive weight loss. In marketing, some of the benefits of packaging are reduction of shrinkage from drying out and of damage from customer handling. Packaging sweet potato in consumer-size units has been tried many times in the US since the introduction of plastic films (Kushman et al., 1975 as cited by Charney and Seelig, 1967). However, the development of soft rot in the packaged roots usually prevented successful commercial packaging. Using perforated polyethylene bags improved the keeping quality of sweet potato, both by preventing accumulation of carbon dioxide and by avoiding excessively high humidity. Data and Quevedo (1987) reported that sweet potato roots packed in plastic bags with or without perforations and in jute sacks had significantly lesser weight loss than roots packed in paper bags and open trays. Plastic bags and jute sacks minimized air movement and provided high humidity within the container.

STORAGE

In temperate countries, sweet potatoes are usually stored in cold storage rooms where temperature and relative humidity are controlled. Kushman and Deonier (1975) reported that the optimum storage conditions are 15°C and 85-90 percent RH. Below this, decay, internal breakdown, and impaired edibility may occur because lower temperatures favor the growth of fungi that cause decay in sweet potatoes. On the other hand, temperatures above 15.5°C reportedly shorten the storage life of sweet potato because it causes considerable weight loss. Mc Combs and Pope (1958) also observed that the dry matter content of sweet potato generally decreases during storage. The decrease in dry matter is usually higher at 18.5°C than at lower temperatures. This is attributed to the increase in respiration rate as manifested by increased moisture loss of sweet potato stored at higher temperature. Kushman and Deonier (1975), in a study of the effects of storage temperature on Porto Rico, Allgold, and Goldrush sweet potato, revealed that roots of all three varieties kept very well at 15.5°C and nearly as well at 21°C but not at 10°C.

In some cases, sweet potato is stored at the prevailing low temperature instead of using cold storage rooms. Sealed pit or clamp storage was done by small holders of the crop. Sweet potato roots, especially those applied with maleic hydrazide as foliar spray before harvest and with methylester of α-naphthalene acetic acid after harvest, had low percentage weight loss and degree of sprouting when stored for 8 weeks using this method (Gooding and Campbell, 1964).

In tropical countries like the Philippines, cold storage for sweet potato is not economically feasible. Hence, different storage methods were studied by several workers to maintain high relative humidity and low temperature conditions during storage. De la Cruz and Bautista (1980 as cited by Bautista, 198l) tried storing sweet potato in moist sawdust, sand, and soil. Results revealed that storing BNAS-51 sweet potato in sand, sawdust, and at ambient conditions resulted in weight losses of 11.4, 9.88, and 40.71 percent, respectively, after 6 weeks of storage. Roots stored in sand and moist sawdust were still acceptable after 6 weeks of storage while those stored at ambient condition (control) were no longer marketable. De la Cruz and Bautista (1980) warned, however, that storage in this system must not last longer than the dormancy period of sweet potato after which sprouting and rotting may take place because of high relative humidity.

Pit storage of sweet potato was tried by Colting and Bautista (1980 as cited by Bautista, 198l) at Los Baños, Laguna, and Trinidad, Benguet, during the summer months when the temperature was 27°C in Los Baños and 20°C in Benguet. Results were not very encouraging since the roots sprouted profusely after 5 weeks of storage. Moreover, termites infested the stored crop.

Village level storage structures using locally available materials such as cogon, nipa, coconut leaves, and bamboo were also tried (Data, 1982). Storage structures made from these materials have much lower temperature and relative humidity compared with the outside environment. Ventilation in these structures is thus maintained by movable flaps or doors that can be opened or closed to control the flow of air into the structure. To maintain high relative humidity, water is placed in bamboo troughs provided in each storage structure. This storage system appears promising as sweet potato stored in these structures lasted for 3 months without much loss in quality. The walling of the storage structure was modified to further minimize sprouting of the stored roots (Data and Barcelon, 1985). It was found that slatted walling provided the stored roots with diffused light which inhibited sprouting roots to a certain extent.

Barreda (1983) enumerated the benefits of using storage huts for sweet potato as follows: 1) assures good quality roots, 2) increases palatability of stored roots, 3) minimizes exposure of roots to pests and diseases, 4) enables the farmers to practice one-time harvesting, and 5) provides additional income and options to farmers since they can wait for higher prices before marketing or bartering their stored roots with other necessities.

It should be noted that the condition of the product entering storage is one of the most important factors governing the success of the storage method used. Preharvest factors such as soil conditions during harvest can influence postharvest quality and storability of sweet potato. Ahn et al. (1980) reported that sweet potato roots harvested from warm-flooded soil showed more rotting during curing and subsequent storage than roots from cold-flooded and warm-dry soils. While roots harvested from cold-dry soil showed no rotting during curing, the number of roots with rots increased sharply after 52 days. At the end of the 83-day storage period, the rots from the warm-flooded soil treatment showed the highest accumulated percentage. It was followed closely by the cold-flooded treatment. Sprouting, on the other hand, was highest (27.4%) in roots harvested from cold-dry soil condition and lowest in roots from warm-flooded soil.

The amount of water supply prior to harvesting was also found to influence the decay and sprouting of sweet potato during storage. Longer duration of rain before harvesting resulted in a high incidence of decay and sprouting during storage (Acedo, 1985). Similarly, Diamante and Data (1986) reported that roots exposed to a long period of rain before harvesting exhibited high values of decay severity, percentage of sprouting (35.75%), and percentage of decay during storage (23%). They further reported that an early onset of decay (29.68% after 30 days of storage) occurred when roots were washed before storage. High cumulative weight loss was likewise observed in roots with high moisture content and in roots that were moistened before or during harvest.

Fertilizer application also affects the storage behavior and quality of sweet potato roots. Quevedo et al. (1987) reported that weight loss, percentage and severity of root decay, and degree of shrivelling of sweet potato were significantly affected by fertilizer treatments. Sweet potato roots from unfertilized plants exhibited the highest weight loss, percentage and severity of decay, and degree of shrivelling (after 45 days of storage); while roots from plants fertilized with 45 kg/ha K gave the least values although the latter showed a relatively higher degree of sprouting than the former. On the other hand, the dry matter, starch, sugar, and carotene contents of the roots at harvest and during subsequent storage were not significantly affected by fertilizer application. Similarly, fertilizer application did not significantly affect the sensory qualities of stored steamed sweet potato roots.

Varietal effects have also been recognized as an important factor in the successful storage of sweet potato. Wide varietal difference in the ability to resist losses during storage had significant variation in weight loss among different varieties of sweet potato roots stored at 21.1°C. Data (1985) reported variations in the ability to retain the fresh quality during storage among different varieties used as parent in developing new sweet potato genotypes at ViSCA. In 10 days of storage, some varieties already started to shrivel, develop some sprouts, and become green while others did not. In 45 days, shrivelling started to become severe in some of the varieties while in 90 days, severe shrivelling and sprouting occurred in almost all of the varieties studied. High severity of decay was observed in Acc. #9, Acc. #54, Acc. #10, Acc. #29, and L4-89 varieties, while Acc. #80, Jewel, and Travis did not show any decay even after 90 days of storage. Weight loss, on the other hand, was high only in Acc. #9, Acc. #10, and Acc. #37 (weight loss of 20%) while the rest of the varieties incurred weight loss values within tolerable limit.

Under highland conditions, Bayogan and Salda (1986) observed differences in the length of postharvest life of the different newly developed sweet potato genotypes entered in the Philippine Seedboard Regional Yield Trial. They reported that storability of the roots was limited by the onset of sprouting, greening, shrivelling, and susceptibility to decay-causing pathogens, and that among the 20 sweet potato entries studied, VSP-1 and CI 693-9 deteriorated fastest. No more acceptable roots were left after two months of storage. Sprouting was high in Kabiti, while V8-14 and BNAS-51 showed no sprouting even after 4 months of storage. Differences in the storage performance of these genotypes were also noted under ViSCA conditions (Data, 1987). Of the different genotypes studied, Calbooy, Kinabakab, G113-2B, G145r-4, and VSP-2 decayed before the end of the 3-month storage period. Of those which lasted up to 3 months, V7-27 (VSP-4) exhibited the least values in weight loss, degree of shrivelling, and degree of decay; while CI 1088-11 showed the highest values in weight loss and degree of shrivelling. VSP-1, V3-180, V5-26, G67-1a, and Tinipay did not produce any sprout even after 3 months of storage.

Diamante and Data (1986) reported that the effectiveness of a storage method depended to some extent on the variety stored owing to varietal differences in susceptibility to a disease, length of dormancy period, and transpiration rate. Thus, a storage method for a variety with a potentially short shelf life may not be as effective when used for one with a longer shelf life.

Planting location was also found to affect the quality and storage life of sweet potato (Quevedo and Data, 1985). A study comparing the quality and storage life of VSP-1, VSP- 2, and VSP-3 sweet potato varieties stored in huts for 3 months at four locations (Bohol, Albay, Tiaong, and ViSCA) revealed that sweet potato grown and stored in Albay exhibited the lowest percent weight loss (11.08%) and percent rotting (2.08%) during storage. Sweet potato stored in Bohol showed the greatest loss in weight (25.03%) with moderate rotting, while roots stored in ViSCA showed the highest percentage rotting (57.34%). Percent sprouting, however, was significantly lower in roots stored in ViSCA (8.33%) and Bohol (10.76%) while it was significantly higher in Albay (42.14%) and Tiaong (41.42%).

Location effect was also manifested in the quality of the roots during storage (Quevedo and Data, 1985). Roots stored in Albay and Bohol showed significantly higher dry matter and starch content than those stored in other locations. Moreover, sugar content was significantly lower in roots stored in Bohol but comparable with those stored in ViSCA, Albay, and Tiaong. In contrast, Diamante and Data (1986) noted that the location of sweet potato storage structures seemed to play a minor role in the structures' effectiveness in slowing down root deterioration. They observed no significant differences in the incidence and severity of decay and sprouting, as well as in cumulative weight loss of roots stored in Bontoc, Southern Leyte, and Igang and Baybay, Leyte, although higher percentage of decay and sprouting was observed in Bontoc than in Baybay. Season was also found to influence the storage quality of sweet potato roots. Diamante and Data (1986) observed differences in the physical characteristics and chemical composition of roots stored during the wet (November to January) and dry (March to May) seasons. A high incidence of decay (after 45 and 60 days storage) was noted during the dry season in VSP-1. A significant increase in the incidence and severity of sprouting and cumulative weight loss was also observed as storage of V-11 and VSP-1 progressed during the dry season. The high amount of weight loss and sprouting was accompanied by a considerable decrease in moisture and increase in dry matter content of the stored roots, which was attributed to the generally high relative humidity and low temperature observed during the dry season.

A similar seasonal effect was noted in the storage of the different sweet potato genotypes entered in the Philippine Seedboard Regional Trials (Data, 1987). Generally, higher percent weight loss, degree of shrivelling, and percent decay were observed among genotypes during the dry season than during the wet season except for V5-88, G50-1a, and VSP-1, which exhibited comparable reactions in both seasons, and Kabiti and V7-21, which showed lower percent decay during the dry season. The degree of sprouting among genotypes, however, was relatively higher in the wet than in the dry season.

APPENDIX A - Grade standard for sweet potatoes (camote)

A. Quality Specifications

Definition of terms

Similar varietal characteristics	-	Sweet potato in any container is similar in shape and in color of skin and flesh.
Firm	-	The sweet potato is not flabby or shrivelled.
Fairly smooth	-	Reasonably free from any defects that cause the skin to appear rough.
Fairly clean	-	Sweet potato is not smeared or caked with dirt; dirt or other foreign material does not detract its appearance.
Fairly well formed	-	Sweet potato is not more than slightly curved, crooked, constricted, ridged, or misshapen.
Diameter	-	The greatest dimension of the sweet potato measured at right angles to the longitudinal axis.

It must be free from the following defects:

a. Decay	-	Sweet potato with decay regardless of spread.
b. Secondary	-	When more than five short rootlets are present in the individual sweet potato or a lesser number of long rootlets, which affect the appearance to a greater extent, than five short rootlets.

c. Sprouts	- When more than l0 percent of the sweet potato have sprouts over 2 cm in length.
d. Growth cracks	- When unhealed, deep, or shallow but extending to more than one-third of the sweet potato length.
e. Scurf	- When more than 15 percent of the surface in the aggregate is affected by solid light brown discoloration.
f. Insect damage	- Damage owing to insect infestation affecting 5 percent more of surface area.
g. Badly misshapen	- The individual sweet potato is so badly curved/crooked, constricted, ridged, or malformed as to seriously affect its appearance or to cause a loss of more than 10 percent of its total weight.
h. Dirt	- When more than slightly dirty, when caked or smeared with dirt, mud stains or other foreign material.
i. Mechanical	- Cuts, bruises, and other damages caused by improper handling.
j. Internal	- When such discoloration cannot be removed without causing more than 5 percent waste in the ordinary preparation for use, including peel that covers a defective area.
k. Serious damage	- Any defect that seriously affects the appearance or edibility of the sweet potato, or cannot be removed without a loss of 10 percent in the the ordinary preparation for use, including peel that covers a defective area.

B. Size Classification

	Diameter (cm)	Weight (g)
Small	3.0-5	
Medium	5.1-7	
Large	7.1 and above	700 or less
Extra large	7.1 and above	more than 700

C. Sample Size: 10 % of total volume

D. Grade Specifications

	Grade 1	Grade 2	Grade 3
Appearance - fresh, firm, fairly smooth, fairly clean, and fairly well shaped	Very good >90%	Good <90%, > 80%	Fair <80%
Decay	2%	5%	>5%
Damage	5%	10%	>10%

Grade 3 will be rejected unless otherwise covered by special arrangements.

Percentages are percentages by weight in the lot sampled.

REFERENCES

Acedo, A. 1985. Preharvest factors affecting the quality and postharvest behavior of root crops. Paper presented during the NFA National Seminar/Workshop, 5-9 November 1985. PRCRTC, ViSCA, Baybay, Leyte, the Philippines.

Ahn, J.K., W.W. Collins and D.M. Pharr. 1980. Influence of preharvest temperature and flooding on sweet potato roots in storage. Hort. Sci. 15(3).

Barreda, M.D.B. 1983. Store sweet potato of good quality in huts. Paper presented at the First Farmer's Training Workshop on Postharvest Technology of Root Crops. IDRC-PCARRD Funded Res. Proj., PRCRTC, ViSCA, Baybay, Leyte, the Philippines.

Bartolini, P.U. 1981. Growing sweet potato for profit. PRCRTC Farmers Bull. 3:11.

Bautista, O. K. 1981. Fruit and vegetable storage and ripening methods for the barrios. Paper presented at the San Miguel Foundation Inaugural Professorial Chair Lecture, ASEAN-Postharvest Horticulture Training and Research Center. I7 June 1981.

Bayogan, E.V. and V. B. Salda. 1986. Storability of sweet potatoes under highland conditions. *In* PCARRD State-of-the-art Abstract Bibliography: Sweet Potato Research. Crops Bibliography Series No. 9. Los Baños, Laguna, the Philippines. 78 p. (Abstract)

Charney, P. and R. A. Seelig. 1967. Fruits and vegetables facts and pointers (sweet potato) of the United Fresh Fruit and Vegetable Association, North Washington at Madison, Alexandria, Virginia, USA.

Data, E.S. 1982. Postharvest technology at the village level. Lecture presented at the Reg. Root Crop Prod. Training Course, ViSCA, Baybay, Leyte, the Philippines. 23 May-3 June 1982.

Data, E. S. 1985. Varietal screening of different sweet potato genotypes for longevity in storage without much loss in weight and other quality factors. IDRC-PCARRD Funded Res. Proj., PRCRTC Annual Report for 1985. ViSCA, Baybay, Leyte, the Philippines.

Data, E. S. 1987. Varietal screening of different sweet potato genotypes for longevity in storage without much loss in weight and other quality factors. IDRC-PCARRD Funded Res. Proj. Research Report presented at the 1986-87 In-house Research Review and Evaluation of Ongoing Researches. PRCRTC, ViSCA, Baybay, Leyte, the Philippines. I3-I5 May I987.

Data, E.S., F.Q. Arrienda and E.S. Estebes. 1981. Proper use of transport materials for root crops to minimize losses. Radix 3(2):7-8.

Data, E.S. and E.G. Barcelon. 1985. Control of sprout growth in sweet potato roots using diffused sunlight. Radix 7(2):5-6.

Data, E.S. and M.A. Quevedo. 1987. Village-level postharvest practices for root crops. PRCRTC Project. Terminal Report.

Data, E.S., R.J. Villegas, M.D.B. Barreda and R.V. Dizon. 1982. Assessment of postharvest practices and losses in cassava and sweet potato in Region VIII (Provinces of Leyte and Southern Leyte, the Philippines). Terminal Report, IDRC-PCARRD Funded Res. Proj., PRCRTC-ViSCA, Baybay, Leyte, the Philippines.

Diamante, J.S. and E.S. Data. 1986. Sweet potato storage. II Field Verification. *In* Data, E.S. Root Crop Storage: Philippines. pp. 121-146.

Gooding, H. J. and J.S. Campbell. 1964. The improvement of sweet potato storage by cultural and chemical means. J. Exptl. Agric. 32(125).

Kushman, L.J. 1975. Effect of injury and relative humidity during curing on weight and volume loss of sweet potatoes during curing and storage. Hort. Sci. 10(3).

Kushman, L.J. and M. T. Deonier. 1975. Effects of storage temperature on Porto Rico and Goldrush sweet potatoes. US Dept. of Agric. Meridian, Miss, U.S.A.

Lutz, J.M., J.K. Park and M.T. Deonier. 1951. Influence of methods of harvesting sweet potatoes on their storage behavior. Proc. Amer. Soc. Hort. Sci. 63:297-30l.

Mc Combs, C.L. and D.T. Pope. 1958. The effect of length of cure and storage temperature upon certain quality factors of sweet potatoes. Proc. Amer. Soc. Hort. Sci. 72:426-434. Expt. Station.

Quevedo, M.A. 1985. Harvesting and handling of root crops. Paper presented at the Farmers' Technicians Training in Storage Technology of Root Crops. San Roque, Macrohon, So. Leyte, the Philippines 27 Nov. 1985.

Quevedo, M.A. and E.S. Data. 1985. Effects of planting location on the quality and storage life of sweet potato. Research Report presented at the 1986-87 In-house Review and Evaluation of Ongoing Researches. PRCRTC, ViSCA, Baybay, Leyte, the Philippines. l3-l5 May 1987.

Quevedo, M.A., E.S. Data and R.B. Itong. 1987. Effect of fertilizer application on the storage behavior and quality of sweet potato. Paper presented during the 3rd FCSSP Annual Conference held at UPLB, Los Baños, Laguna, the Philippines. 28-30 April 1987.

Saladaga, F.A. 1981. Longevity in storage of sweet potato (*Ipomoea batatas* L.) fleshy root kept at higher-than-conventional storage temperature. Phil. J. Crop Sci. 6(1-2):62.

Tongco, A.F. 1979. Design, construction and testing of a sweet potato harvester. M.S. Thesis. University of the Philippines at Los Baños, College, Laguna, the Philippines.

CHEMICAL COMPOSITION OF COOKED AND UNCOOKED SWEET POTATO AND ITS SIGNIFICANCE FOR HUMAN NUTRITION

J. Howard Bradbury*

INTRODUCTION

Sweet potato and cassava are the two most important tropical root crops in terms of world production. However, sweet potato is much more important than cassava in Asia because more than 90 percent of the world's sweet potato is produced there. It is the major crop in Papua New Guinea (Bourke, 1982; 1985). It is the staple food of the people in PNG, in parts of the Philippines (Villareal, 1982), and in Solomon Islands and Tonga. It is grown in the tropics under a very wide range of environments from sea level to about 2700 m (Bourke, 1985) and in temperate climates in the absence of frost, particularly in China, Japan, the United States, New Zealand, and Australia. The leafy green tips and stems of sweet potato are also eaten in many countries, particularly during food shortages (Villareal et al., 1982).

Some previous analyses of sweet potato tubers have not covered all nutrients and changes in composition owing to cooking have not been fully studied. Accordingly, the chemical composition of sweet potato and other major tropical root crops in countries in the South Pacific was determined before and after cooking (Bradbury et al., 1987). The project was supported by the Australian Centre for International Agricultural Research (ACIAR) and the results will appear in a monograph (Bradbury and Holloway, 1987).

MATERIALS AND METHODS

Sweet potato samples were harvested in PNG, Solomon Islands, Fiji, Western Samoa, and Tonga and sent by air to Canberra, Australia, for analysis. The weight of each tube was recorded soon after harvest and the moisture lost during transit was determined. In some cases, multiple tubers of one cultivar were bulked together for analysis or more common analyses were made on different tubers (3-10) of the same cultivar and the results averaged. The cultivars analyzed were usually popular in the

*Reader in Chemistry, Chemistry Department, Australian National University, Canberra, A.C.T. 2601, Australia.

country of origin or sometimes were elite cultivars obtained from research stations.

The moisture content was determined by drying the shredded material to constant weight at 100°C. The nitrogen content was determined using the semi-automatic Kjeldahl procedure (Bradbury and Holloway, 1987) and the protein content by multiplying the nitrogen percentage by 6.25. The lipid content was obtained through extraction with diethyl ether (Bradbury and Holloway, 1987). Starch was determined by gelatinizing the starch at 100°C, hydrolysing with α-amylase and glucoamylase at 60°C, and colorimetrically estimating the glucose. The neutral detergent method was used for dietary fiber (Bradbury and Holloway, 1987; Holloway et al., 1977). Total sugar was determined by modifiying the anthrone method (Holloway et al., 1985) and the individual sugars by high performance liquid chromatography (HPLC) (Tamate and Bradbury, 1985).

The energy content was obtained by multiplying the amount of protein, fat, starch, and sugar present by the energies (FAO/WHO/UNU, 1985) produced from eating 1 g of protein (17 kJ), fat (38 kJ), starch (17 kJ), and sugar (16 kJ). The energy (E) was also calculated from the percentage moisture content (M) by the relation (Bradbury, 1986):

$$E = 17.38\,M + 1699 \qquad (1)$$

The two methods gave results that were in good agreement. The ash content was obtained by igniting at 550°C and the residue was used to determine minerals using either inductively coupled argon plasma emission spectroscopy at the University of New South Wales or atomic absorption spectroscopy (Bradbury and Holloway, 1987).

Vitamin A (retinol) and Beta-carotene, along with vitamin D, were determined by HPLC (Singh and Bradbury, 1987). The vitamin B group, thiamin, riboflavin, and nicotinic acid were analyzed by spectrophotometry and fluorescence spectroscopy (Bradbury and Singh, 1987). Vitamin C (ascorbic acid + dehydroascorbic acid) was determined by HPLC (Bradbury and Singh, 1986). Amino acid analyses were done using standard procedures (Bradbury and Holloway, 1987; Bradbury et al., 1985) and amino acid scores for each essential amino acid were calculated using recent values for preschool children (FAO/WHO/UNU, 1985). For a particular protein, the lowest amino acid score is called the chemical score; this gives a measure of the quality of the protein. Organic acids were determined by a HPLC method (Holloway et al., 1987). The amount of trypsin inhibitor present (in trypsin inhibitor units (TIU) per gram) was based on the degree of inhibition of the enzymatic activity of bovine trypsin (Bradbury et al., 1984). The chymotrypsin inhibitor content (CIU/g) was calculated from the amount of inhibition of chymotrypsin (Bradbury et al., 1985). All results were recorded on the basis of the sample's fresh weight.

RESULTS AND DISCUSSION

Composition of Tubers and Edible Leaf Tips

Table I shows the chemical composition of 164 different sweet potato tuber samples from the South Pacific and results of other workers for comparison. If allowance is made for the large variations possible between samples from different cultivars and countries, the results appear to be in reasonable agreement. In Table I, the only notable differences are in the sugar and the vitamin A (β-carotene) contents between the white-fleshed cultivars that we have analyzed and the yellow-fleshed varieties reported by Paul and Southgate (1979) and Peters (1957). The yellow color is due to the presence of colored β-carotene in the tuber. These sweet potatoes are the dessert type commonly used in developed countries and also have a much higher sugar content than the staple-type sweet potato used in the South Pacific.

The analyses of sweet potato edible tips based on reports of different authors are given in Table 2. If variability expected among different plant samples will be disregarded, the different reports seem to concur. As compared with sweet potato tubers, the edible tips contain much larger amounts of moisture, protein, some minerals (Mg, K, and Fe), vitamin A, riboflavin, and nicotinic acid, and much less energy than tubers. Edible types have not yet been analyzed for amino acids and trypsin inhibitor.

Effect of Cooking on Composition of Tubers

Sweet potato tubers were peeled and cut into four approximately equal cubes of not less than 60 g. One piece was designated the control and the other three pieces were subjected either to boiling in water for 20 minutes, steaming for 25 minutes, or baking (uncovered) in an oven at 200°C for 30 minutes. The samples were well cooked and edible after these treatments. The samples were air-dried and weighed before and after the treatment. They were then mashed and analyzed. The difference between the cooked and the control samples was obtained for each of the five tubers used. These differences among the five tubers were averaged and tested for significance using the Students t-test. The steaming and baking treatments simulated cooking leaf wrapped root crop in an earthen oven over heated stones and cooking in coals, respectively.

As expected, the moisture content increased with boiling and steaming, and decreased very significantly after dry baking (Table 3). The ash content was significantly reduced by boiling and steaming. This was consistent with the loss of water-soluble minerals, particularly potassium and sodium which were probably lost mainly as chlorides. The dietary fiber content increased very substantially after cooking owing to the formation

Table 1. Chemical composition of sweet potato tubers from present work and literature.

Parameter	Present work 164 samples, 5 South Pac. countries	Paul and Southgate (1979)	Wenkam (1983) 1 sample, Hawaii	Peters (1957) 3 samples, Central America
Moisture	71.1	70.0	70.2	68.4
Energy (kJ/100 g)	457	387	477	—
Protein (%)	1.43	1.2	1.6	1.03
Starch (%)	22.4	11.8	—	—
Sugar (%)	2.38	9.7	—	—
Carbohydrate (%) (diff)	—	—	27	—
Dietary fiber (%)	1.6	2.5	—	—
Crude fiber (%)	—	—	0.8	0.85
Fat (%)	0.17	0.6	0.14	0.12
Ash (%)	0.74	—	1.1	0.93
Minerals (mg/100 g)				
Ca	29	22	30	22
P	51	47	37	31
Mg	26	13	12	—
Na	52	19	47	—
K	260	320	380	—
S	13	16	—	—
Fe	0.49	0.70	0.40	1.1
Cu	0.17	0.16	—	—
Zn	0.59	—	—	—
Mn	0.11	—	—	—
Al	0.82	—	—	—
B	0.10	—	—	—

Table 1 (continued).

Vitamins (mg/100 g)					
Vitamin A (ret. + β—car./6)		0.01	0.67	0.08	0.69
Thiamin		0.09	0.10	0.10	0.11
Riboflavin		0.03	0.06	0.03	0.70
Nicotinic acid		0.60	0.8	0.45	0.66
Vitamin C		24	25	15	34
Vitamin D		0	0	—	—
Organic acids anions (mg/100 g)					
Oxalate		81			
Malate		116			
Citrate		81			
Limiting amino acids	Lys	70*			
Score	Leu	80			
Trypsin inhibitor (TIU/g)		13.4			
Chymotrypsin inhibitor (CIU/g)		0–1			

*Results based on 33 analyses of PNG sweet potato (Bradbury et al., 1984; 1985) and on eight analyses of Solomon Islands and Tongan sweet potato. Other results (Oomen et al., 1961; Goodbody, 1984) recalculated with new standard values (FAO/WHO/UNU, 1985) also show that lysine is limiting (chemical score 61%) and that the S-containing amino acids are the second limiting amino acid.

Table 2. Chemical composition of sweet potato edible tips based on literature.

Parameter	Wenkam (1983)*	Villareal et al. (1979)**	Peters (1957)***	Oomen & Grubber (1978)
Moisture (%)	87.8	85.5	86.3	86.7
Energy (kJ/100 g)	151	—	—	176
Protein (%)	4.0	2.8	4.0	3.2
Carbohydrate (%) (diff.)	6.6	—	—	—
Crude fiber (%)	1.2	1.9	1.6	1.6
Fat (%)	0.3	—	0.8	—
Ash (%)	1.3	1.7	1.2	—
Minerals (mg/100 g)				
Ca	37	75	110	85
P	94	—	30	—
Mg	62	—	—	—
Na	9	—	—	—
K	530	—	—	—
Fe	1.0	3.9	2.9	4.5
Vitamins (mg/100 g)				
Vitamin A (ret. + β—car./6)	0.18	1.67	1.7	2.7
Thiamin	0.16	—	0.09	—
Riboflavin	0.37	0.35	0.26	—
Nicotinic acid	1.14	—	1.1	—
Vitamin C	11	41	58	20

*Based on one sample from Hawaii.
**Based on 10 cultivars from Taiwan.
***Based on two samples from Central America.

Table 3. Effect of cooking on composition of Tongan sweet potato.[a]

Parameter	Control[b]		% Difference		
			Boiled – control	Steamed – control	Baked – control
Moisture (%)	68.4	(2.9)	4.3**	1.6*	–7.3**
Ash (%)	0.76	(0.07)	–0.12**	–0.07*	0.04
Starch (%)	23.7	(1.8)	–10.9**	–6.9**	–13.2**
Dietary fiber (%)	1.40	(0.20)	2.06**	2.07**	1.12*
Fructose (%)	0.22	(0.12)	–0.08*	–0.04	–0.07*
Glucose (%)	0.45	(0.11)	–0.06	0.04	–0.08
Sucrose (%)	2.03	(0.58)	0.11	0.19	0.40
Maltose (%)	0.64	(1.02)	6.43**	6.88**	6.45**
Minerals (mg/100 g)					
Ca	45	(6)	0.5	–6.7	–2.0
P	29	(3)	1.0	1.4	1.0*
Mg	36	(6)	2.8	–3.7	–0.6
Na	73	(16)	–12.7	–10.4	–2.7
K	243	(19)	–36	47*	37
S	13	(2)	1.1	1.1	0.8
Zn	0.29	(0.07)	–0.05**	0.01	0.06
Mn	0.26	(0.14)	0.01	–0.03	–0.01
Al	0.24	(0.12)	0.18	–0.10	–0.03
B	0.14	(0.02)	0.00	–0.01	–0.01

[a]Differences followed by one asterisk indicate a significant change in cooking at 5% level, two asterisks at 1% level.

[b]Other results are % crude protein, 1.77 (0.24); Fe, 0.70 (0.26) mg/100 g; Cu, 0.22 (0.06) mg/100 g; standard deviations given in brackets.

of some starch which was resistant to enzymatic action (Bradbury et al., 1987).

The large decrease in the starch content with cooking was primarily due to the large amount of starch breakdown to maltose and partly due to the production of starch which was resistant to enzyme action. This large increase ($\sim$6.5%) in maltose content has been observed previously by various workers (Tamate and Bradbury, 1985; Walker et al., 1975; Picha, 1985) and is considered to be due to enzymatic breakdown of starch catalyzed by β-amylase. Cooking cassava, taro, and yam using the same procedures did not increase maltose (Bradbury et al., 1987). This is probably due to the absence of β-amylase in these root crops.

Losses of thiamin, riboflavin, and nicotinic acid on boiling amounted to about 40 percent if water was discarded, 20 percent if water was retained, and 25 percent on baking. The loss of vitamin C (ascorbic acid + dehydroascorbic acid) on boiling was about 65 percent if water was discarded, 20 percent if water was retained, and 50 percent on baking (Bradbury and Singh, 1986; 1987).

What is the significance of these changes to human nutrition? The changes in mineral and dietary fiber content are probably not important. There is a large increase in maltose content and hence in sweetness but this does not greatly affect the energy intake since starch content is reduced. The most important changes are in the vitamin content with losses of 40-65 percent on boiling if water is discarded, about one-half of this loss if water is retained, and 25-50 percent loss on baking. These losses are particularly important for the vitamin B group because of the relatively small amount of these vitamins present in the root crops, compared with the recommended daily allowances of 1.4 mg for thiamin, 1.6 mg for riboflavin, and 19 mg for nicotinic acid.

Selection/Breeding for Improved Chemical Composition

There is considerable variability in the composition of sweet potato tubers of the same cultivar grown in different environments and of different cultivars grown in the same environment. The range of protein contents of over 54 samples of 12 cultivars from the Kaintibi district in PNG, a district wherein there is considerable malnutrition, was 0.34-1.25 percent. The average protein content of these tubers (0.62%) was less than one-half of the accepted average normally used in nutritional calculations.

The protein content of sweet potato tubers varied from 0.34 to 2.93 percent (Bradbury and Holloway, 1987). With such a wide range of protein contents, it was apparently possible to increase the protein content by selection/breeding. This would have a beneficial effect on human nutrition, particularly in areas such as Kaintibi where sweet potato grown has a very low protein content probably because of poor environment and inferior cultivars.

In selection/breeding for improved performance, it is necessary to show that one cultivar is significantly superior over another grown in the same environment. This has been shown to be true for different cultivars in terms of their energy, protein, sugar, and calcium contents (Bradbury and Holloway, 1987). A second requirement is that the superior performance should be maintained across a number of different environments. A study of this type on 10 PNG cultivars across five environments showed that two cultivars performed reliably with regard to protein content over all environments (Bradbury et al., 1985).

Nutritional Aspects of Different Types of Tropical Plant Foods

The nutrient contents of the major tropical root crops and other major classes of tropical plant foods are compared in Table 4. For simplicity, only the major components of the diet (energy, protein, minerals, and vitamins) are compared. The energy values are inversely proportional to the moisture content (equation which accounts for the much lower energies of root crops than of uncooked rice or beans). After boiling, however, the moisture contents of rice and beans are about the same (70%, Paul and Southgate, 1979) as that of boiled sweet potato. Thus, the boiled root crop has about the same energy content as boiled rice, while that of legumes is somewhat less because of their dietary fiber content (Bradbury, 1986). The low energy content is probably due to its high moisture and fiber contents.

The percentage of the total energy of the food provided by protein (PE%) indicates the adequacy of the food as a protein source. Most satisfactory diets provide 10-15 percent of the energy from the protein present in the food (Passmore and Eastwood, 1986). On this basis, it is clear from Table 4 that edible green leaves and beans are very good sources of protein; yam and rice are marginal sources, and the other root crops, especially cassava, are inadequate. It should be noted, however, that the values of PE% reported by different workers show considerable variation because they are the ratio of two quantities (protein and energy), each of which varies widely between different samples. For example, the PE% of cassava and taro are reported elsewhere at 3.3 and 6.8, respectively (Passmore and Eastwood, 1986). The conclusion that a diet of sweet potato is inadequate in terms of protein intake was confirmed by Huang (1982) for subjects of growing age (teenage boys) but was found to be adequate for adults with slight supplementation with fish and vegetables.

Legumes are the best source of iron and a good source of calcium as are edible green leaves, followed by root crops and polished rice. Edible green leaves are the best source of vitamins, followed by root crops and

Table 4. Comparison of nutrient contents of different foods.

Parameter	Sweet potato tuber*	Cassava tuber*	Yam (*D. esculenta*) tuber*	Taro (*Colocasia*) corn*	Rice polished raw**	Beans (kidney, lima or mung)***	Taro, edible green leaves****
Moisture (%)	71	63	74	69	12	12	85
Energy (kJ/100 g)	460	610	414	490	1500	1200	110
Protein (%)	1.4	0.5	2.0	1.1	6.5	22	4.2
Percent of energy of food provided by protein (PE %)	5.3	1.5	8.5	3.9	7.2	31	65
Dietary fiber (%)	1.6	1.5	1.2	1.5	2.4	22	5.0
Minerals (mg/100 g)							
Ca	29	20	8	32	4	100	182
Fe	0.4	0.2	0.8	0.5	0.5	8	0.6
Vitamins (mg/100 g)							
Vitamin A (retinol equiv.)	0.01	trace	0.02	0.01	0	0.008	0.5
Thiamin	0.09	0.05	0.05	0.03	0.08	0.5	0.14
Riboflavin	0.03	0.05	0.03	0.03	0.03	0.2	0.3
Nicotinic acid	0.6	0.6	0.4	0.8	3.0	2	1.0
Vitamin C (ascorbic acid)	24	15	20	15	0	trace	37

*Bradbury and Holloway, 1987.
**Paul and Southgate, 1979.
***Paul and Southgate, 1979; South Pacific Commission, 1983.
****Bradbury and Holloway, 1987; Wenkam, 1983.

legumes, each of which shows deficiencies in two vitamins. Polished (white) rice is short of three vitamins. Brown rice, however, is rich in thiamin and nicotinic acid because of retention of the germ and aleurone layer which are rich in these vitamins (Bradbury et al., 1984).

The situation may be summarized as follows (Bradbury and Holloway, 1987):

Energy	rice (boiled) ~ root crops ~ legumes > edible greens
Protein	legumes > edible greens > rice (boiled) > root crops
Minerals (Ca,Fe)	legumes > edible greens ~ root crops > rice
Vitamins	edible greens > root crops ~ legumes > rice

Root crops are a good source of energy, an average source of minerals and vitamins, and the poorest source of protein. From the nutritional point of view, it is important to improve the protein content of sweet potato by selection/breeding, particularly for those who depend on root crop as their staple food.

SUMMARY

The chemical composition of 164 samples of sweet potato from five countries of the South Pacific was determined. A wider range of nutrients was analyzed and where possible, results were compared. White-fleshed cultivars from the South Pacific contained much less sugar and β-carotene than the yellow-fleshed varieties common in America. Edible leaf tips contained much larger amounts of moisture, protein, Fe, K, Mg, vitamin A, riboflavin, and nicotinic acid and much less energy than tubers. Cooking of tubers caused considerable losses of thiamin, riboflavin, and nicotinic acid which are nutritionally important because of the small amounts of these vitamins present. There was also a decrease in starch and increase in maltose content of tubers upon cooking. The latter increase was not observed in cooking cassava, yam, or taro. Selection/breeding for improved chemical composition was discussed with particular reference to protein content which was found to be very variable (0.34-2.9%) and was low in a region subject to malnutrition.

The nutritional aspects of tropical root crops (including sweet potato) were compared with representative tropical plant foods, rice, legumes, and edible green leaves. Root crops were found to be a good source of energy, an average source of minerals and vitamins, and the poorest source of protein.

ACKNOWLEDGMENTS

I wish to thank my coworkers in the laboratory, K. Bradshaw, B. Hammer, W.D. Holloway, W. Jealous, and T. Phimpisane for obtaining the data summarized in this review paper, and collaborators M.P. Levett and B.M. Thistleton (PNG), P.R. Linton (Solomon Islands), P. Sivan (Fiji), J.E. Wilson (Western Samoa), and P. Taufatofua (Tonga) for the provision of sweet potato samples.

Finally, my thanks go to Dr. G. Persley of the Australian Centre for International Agricultural Research, for his useful comments and to ACIAR for financial support of the ACIAR/ANU Program on Nutrition of Tropical Root Crops in the South Pacific.

REFERENCES

Bourke, R.M. 1982. Root Crops in Papua New Guinea. *In* Bourke, R.M., and V. Kesavan (eds.). Proc. Second P.N.G. Food Crops Conf., Port Moresby, Dept. Primary Industry. pp. 51-63.

Bourke, R. M. 1985. Sweet potato production and research in Papua New Guinea. PNG. J. Agric. Forestry and Fisheries.33:89-108.

Bradbury, J.H. 1986. Determination of energy from moisture content in foods containing small amounts of fat and dietary fibre. J. Agric. Food Chem. 34:358-361.

Bradbury, J.H. and U. Singh. 1986. Ascorbic acid and dehydroascorbic acid content of tropical root crops of South Pacific. J. Food Sci. 51:975-978.

Bradbury, J.H. and U. Singh. 1987. Thiamin, riboflavin and nicotinic acid contents of tropical root crops from the South Pacific. J. Food Sci. (*in press*)

Bradbury, J.H. and W.D. Holloway. 1987. Chemical composition of tropical root crops from the South Pacific: Significance for human nutrition, ACIAR, Canberra, Australia. (*in preparation*).

Bradbury, J.H., J.G. Collins and N.A. Pyliotis. 1984. Digestibility of proteins of the histological components of cooked and raw rice. Brit. J. Nutr. 52: 507-513.

Bradbury, J.H., B. Hammer, T. Nguyen, M. Anders and J.S. Millar. 1985. Protein quantity and quality and trypsin inhibitor content of sweet potato cultivars from the highlands of Papua New Guinea. J. Agric. Food Chem. 33:281- 285.

Bradbury, J.H., J. Baines, B. Hammer, M. Anders and J.S. Millar. 1984. Analysis of sweet potato from the highlands of Papua New Guinea:

relevance to the incidence of *enteritis necroticans*. J. Agric. Food Chem. 32: 469-473.

Bradbury, J.H., K. Bradshaw, W. Jealous, W.D. Holloway and T. Phimpisane. 1987. Effect of cooking on nutrient content of tropical root crops from the South Pacific. J. Sci. Food and Agric. (*submitted for publication*).

FAO/WHO/UNU. 1985. Energy and protein requirements. Report of a Joint FAO/WHO/UNU Expert Consultation, Geneva, WHO Technical Report Series 724. 206 p.

Goodbody, S. 1984. Nutritional characteristics of a sweet potato collection in the Papua New Guinea highlands. Trop. Agric. (Trin.) 61:20-24.

Holloway, W.D., J.C. Tasman-Jones and K. Maher. 1977. Towards an accurate measurement of dietary fibre. N.Z. Med. J. 85: 420-423.

Holloway, W.D., W.T. Jealous and J.H. Bradbury. 1987. Calcium oxalate and organic acids in tropical root crops. J. Agric. Food Chem. (*in preparation*)

Holloway, W.D., J.A. Monro, J.C. Gurnsey, J.E.W. Pomare and N.H. Stace. 1985. Dietary fiber and other constituents of some Tongan foods. J. Food Sci. 50:1756-1757.

Huang, P.C. 1982. Nutritive value of sweet potato. *In* Villareal, R.L. and T. D. Griggs (eds.). Sweet Potato. Proc. First Int'l. Symposium. AVRDC, Shanhua, Taiwan. pp. 35-36.

Oomen, H.A.P.C. and G.J.H. Grubben. 1978. Tropical Leaf Vegetables in Human Nutrition. Amsterdam, Konnikliyk Institut voor de Troppen. p. 36.

Oomen, H.A.P.C., W. Spoon, J.E. Heesterman, J. Ruinard, R. Luyken and P. Slump. 1961. The sweet potato as the staff of life of the highlands Papuan. Trop. Geogr. Med. 13: 55- 66.

Passmore, R. and M.A. Eastwood. 1986. Davidson and Passmore Human Nutrition and Dietetics, 8th ed., Edinburgh, Churchill Livingstone.

Paul, A.A. and D.A.T. Southgate. 1979. McCance and Widdowson's the Composition of Foods, London, Her Majesty's Stationery Office. 417 p.

Peters, F.E. 1957. Chemical composition of South Pacific foods - an annotated bibliography. Noumea, New Caledonia, South Pacific Commission. 102 p.

Picha, D.H. 1985. HPLC determination of sugars in raw and baked sweet potatoes. J. Food Sci. 50:1189-1190.

Singh, U. and J.H. Bradbury. 1987. Determination of carotenoids and vitamin D in South Pacific root crops by HPLC. J. Food Sci. (*in press*).

South Pacific Commission. 1983. Food Composition Tables for Use in the Pacific Islands. Noumea, New Caledonia. 33 p.

Tamate, J. and J.H. Bradbury. 1985. Determination of sugars in tropical root crops using ^{13}C NMR spectroscopy: comparison with the HPLC method. J. Sci. Food Agric. 36:1291-1302.

Villareal, R.L. 1982. Sweet potato in the tropics - progress and problems. *In* Villareal, R.L., and T.D. Griggs (eds.). Sweet Potato. Proc. First Int'l. Symp. AVRDC, Shanhua, Taiwan. pp. 1-15.

Villareal, R.L., S.C.S. Tsou, H.F. Lo, and S.C. Chiu. 1982. Sweet potato tips as vegetables. *In* Villareal, R.L. and T.D. Griggs (eds.). Sweet Potato. Proc. First Int'l. Symp., AVRDC, Shanhua, Taiwan. pp. 313-320.

Villareal, R.L., S.C.S. Tsou, S.K. Lin and S.C. Chiu. 1979. Use of sweet potato leaf tips as vegetables. II. Evaluation of yield and nutritive quality. Exp. Agric. 15:117-122.

Walker, W.M., A.E. Purcell and A.M. Nelson. 1975. Effects of amylolytic enzymes on moisture and carbohydrate changes of baked sweet potato cultivars. J. Food Sci. 40:793-796.

Wenkam, N.S. 1983. Foods of Hawaii and the Pacific Basin Volume I: Composition, Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Research Extension Series 038. 172 p.

BIOCHEMICAL STUDIES ON SWEET POTATO FOR BETTER UTILIZATION AT AVRDC

Samson C.S. Tsou, Kuang-Kung Kan, and Shu-Jen Wang*

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a traditional crop in Asia and the Pacific Islands. It plays an important role in the diet of the people in the region. This crop has many desirable characteristics such as high yielding potential, wide adaptability, multifunctional usage, and a wide range of nutritional compositions, which make it very attractive for the tropical world.

World production reached the present level in the early 1970s; since then, it has not increased. There are two groups of countries that can be identified based on yield levels. The yield levels in Japan, Korea, and Taiwan are about double those of other Asian countries (Lin et al., 1985). Regardless of the higher yield in these three countries, production areas sharply declined after the mid-1960s, which indicates that yield is probably not mainly responsible for decrease in production. It has been demonstrated that certain simple management techniques, such as weeding and chemical fertilizer, can easily improve the yield of this crop. The low yield in other countries can be improved through technology transfer (AVRDC, 1977). The low intensity of sweet potato production in tropical Asia can be very complex, low demand being one of the factors.

Traditionally, sweet potato has been considered as a survival crop in Chinese culture. It can be used as food, feed, and for starch extraction. The utilization pattern depends on the socioeconomic environment. Sweet potato is used as a staple food during war or natural disasters. It comprised 17.55 percent of the Taiwanese diet during the period 1935-39. The production of sweet potato increased with economic development and reached its peak in 1967. More than 60 percent of sweet potato crop produced during that period was used as feed (CAPD, undated). Only 16 percent was consumed directly as food; it contributed 5.45 percent of the total food intake. Sweet potato in Taiwan sharply declined after the mid-1960s. The production area in 1986 was 22,198 ha, which is only 9.37 percent that of 1967 (TPG, 1986).

*Biochemist, Assistant Specialist, and Principal Research Assistant, respectively, Asian Vegetable Research and Development Center, Taiwan, Republic of China.

Most sweet potato produced is used as vegetable and for starch extraction. Its use as animal feed has become insignificant. Taiwan's experience has indicated that sweet potato could play an important role in a subsistence and post-subsistence socioeconomic system, but it is a rather poor competitor in a highly market-oriented society. The prospect for this crop depends on how well people can use it in the current socioeconomic system and how well it can be improved to fit better in a market-oriented society (Bouwkamp, 1985).

The sweet potato improvement program of the Asian Vegetable Research and Development Center (AVRDC) has adopted the multidisciplinary approach, viewing the potential role of sweet potato in the entire agricultural system. Progress has been made in many areas such as yield improvement, wet season production, pest control, cultural practices, and nutritional quality. Studies on biochemical properties for better utilization are summarized and discussed in this paper.

Mass Screening Method Used at AVRDC

A wide range of chemical composition available in germplasm is a desirable characteristic in a sweet potato improvement program. Table I shows the variation in major constituents of storage roots in AVRDC's sweet potato germplasm collection. Chemical analysis is still the most practical way of estimating most of these constituents. Thus, an efficient analytical system is essential for an effective improvement program. An analytical system based on dried sweet potato flour is used at AVRDC for routine work (Fig. I). This system covers most of the major constituents, including Beta-carotene, with a capacity of analyzing 100-200 samples a day. Samples can be placed in a storable form within 24 hours after harvest to avoid further changes during storage. Data reported in this paper were mostly obtained through this method

Table 1. Percentage mean and variation of major constituents of AVRDC sweet potato collection.

Constituents*	Mean (%)	Variation (%)
Dry matter	29.87	14.99 – 41.98
Crude protein	4.22	1.34 – 11.08
Sugar	15.26	8.78 – 27.14
Starch	66.08	44.59 – 78.02
Crude fiber	3.99	2.70 – 7.60

*On dry weight basis except dry matter.

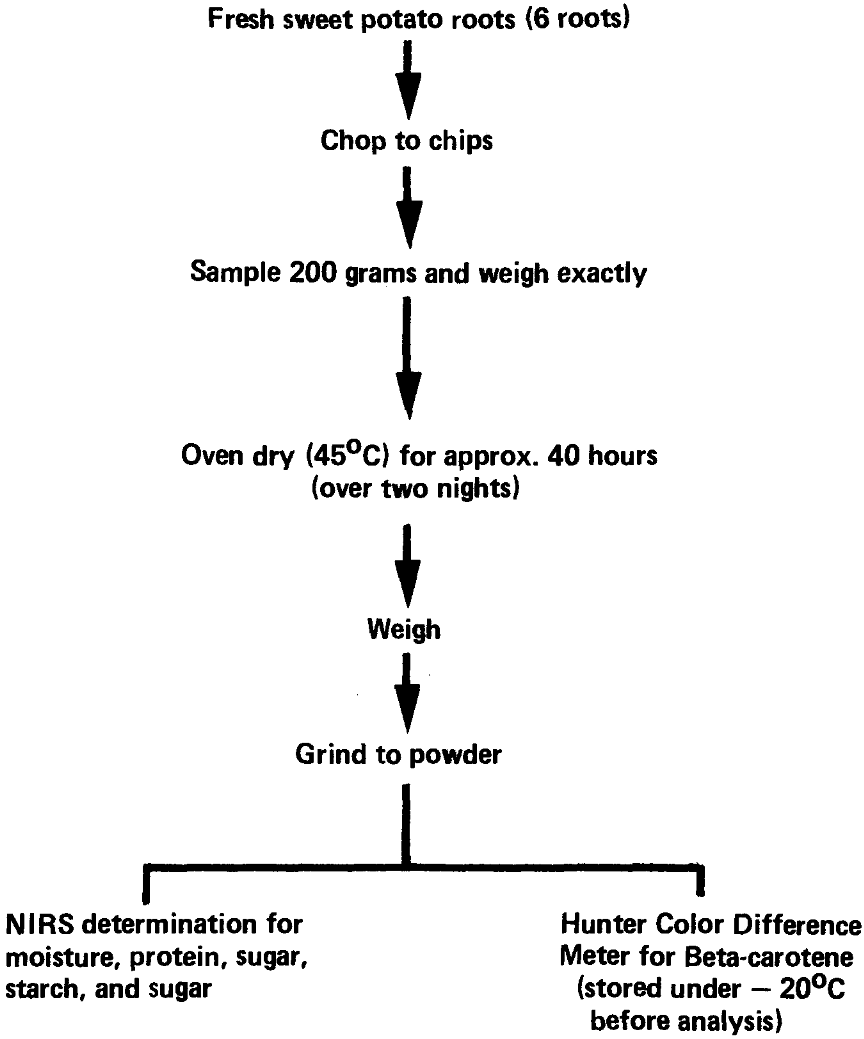


Figure 1. Fast screen method for compositional analysis of sweet potato.

Improvement on Dry Matter Content

Except for a few specific products such as canned sweet potatoes, high dry matter content is always a desirable property and the most important factor to make sweet potato a better competitor in the feed and starch industry. Although the price of sweet potato on the production level is generally based on fresh weight, the price based on dehydrated chips is used in the decision-making process of the feed industry. It is generally practiced in Taiwan that the processor may use sweet potato chips in his feed formulation if its price reaches below 70-75 percent that of corn grains. High dry matter content means higher chip yield without a significant increase in the processing cost. Results at AVRDC showed that the dry matter content of sweet potato could be improved without reduction of yield through an intensive breeding program (Opena et al., 1987). The mean dry matter contents of breeding lines improved from 25.9 percent to 35.1 percent within five years. Theoretically, this program increased the chip yield for animal feed by 40 percent without sacrificing farmers' income.

Although sweet potato lines with high protein content are available in the AVRDC germplasm collection, this characteristic is not very stable. In order to supply a balance diet to the animals, a proper and locally available protein source is needed. Pressed soybean cakes and sweet potato vines are traditional sources of the Chinese farmer. Farming systems that produce both sweet potato and legumes are desired in order to use sweet potato more effectively as animal feed.

Protein Digestibility of Sweet Potato Diet

A series of experiments was conducted in Taiwan during the mid-1970s to assess the performance of sweet potato in feed formulation for hogs (Lee et al., 1963; Lin, 1978; Sheu, 1979; Chien and Lee, 1980; Yen, 1982). Several conclusions were reached:

- Low protein and fat content, and poor protein digestibility are major defects of sweet potato.
- Replacement of 25 percent corn with dried sweet potato chips does not significantly reduce the nutritional quality of feed.
- No effective process technology to improve protein digestibility is available.
- The chemical and physical properties of the sweet potato chip need further improvement for current management systems of the modern feed industry.

The second conclusion conforms with findings in other countries (Ware, 1947; Han et al., 1976; Koo and Kim, 1973).

The wet heating process cooking to improve feeding efficiency in a sweet potato diet was discovered long ago by Chinese farmers, and adapted for traditional backyard animal feeding. It improves nitrogen digestibility from 27.6 percent to 52.8 percent (Yeng, 1976). This process, however, requires additional fuel, and possibly can only be adopted in a subsistence culture system.

The presence of a trypsin inhibitor in sweet potato root was discovered in 1954 and its properties were extensively studied (Sugiura et al., 1973). It was proposed that this antinutritional factor may be associated with the protein digestibility of a sweet potato diet (AVRDC, 1975). Analysis of the trypsin inhibitor activity revealed that it is positively correlated with protein contents of the roots (AVRDC, 1975). It is, however, possible to select varieties with low trypsin inhibitor activity but with high protein content (Bouwkamp et al., 1985). The inhibitory effect of partially purified trypsin inhibitor on the protein efficiency ratio is presented in Table 2. Addition of inhibitor significantly reduced the protein efficiency ratio. A slight increase of pancreatin, although not statistically significant, was also observed. It is important to note that the specific activity of trypsin inhibitor of this diet was 1.28 units/mg protein, which was 4-5 times higher than the ordinary sweet potato diet and 16-20 times higher than a mixed diet of corn and sweet potato. It is unlikely that a trypsin inhibitor is the only factor responsible for the low protein digestibility of a sweet potato diet.

Table 2. Effect of sweet potato trypsin inhibitor on protein efficiency ratio (PER).*

	Control	Treatment
PER (4 weeks)	1.84	1.17
PER (8 weeks)	1.56	1.20
Pancreas wt./body wt. %	0.197	0.237

*Protein content in test diet was 10%.
Long-Evans 4-week old rats were adopted.
Specific activity: 1.28 unit/mg protein.

It is known that sweet potato starch is not easily digested by chickens (Polk, 1943) but is comparable to corn's digestibility in the case of pigs (Lin, 1978; Wang, et al., 1979). The in vitro digestibility of sweet potato starch, however, is only about 20 percent, which can be improved to 50 percent through popping (Yeh et al., 1977). Diarrhea is commonly observed in young laboratory rats on a sweet potato diet. The effect of cooking in vitro on digestibility of three selected starches is shown in Figure 2. These results suggest that sweet potato starch is less digestible than rice or wheat starch but can be improved through cooking.

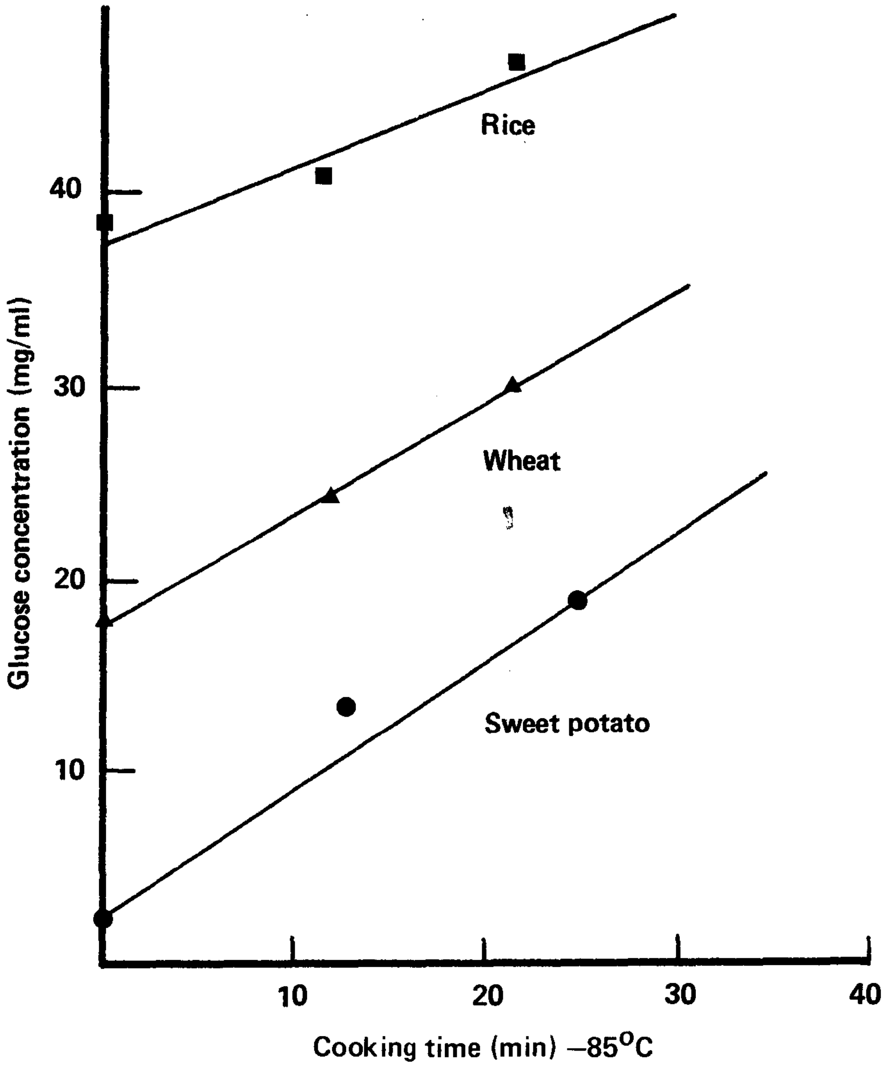


Figure 2. Digestibility of sweet potato and rice starch (in vitro). Digest condition: Glucoamulase (37°C, 35 min)

The effect of starch on protein digestibility in a laboratory rat was studied and is summarized in Table 3. Casein was the sole protein source in this experiment. Experimental animals fed with sweet potato starch had a low protein digestibility. A significant improvement on protein digestibility can be achieved through cooking of sweet potato starch. It is proposed that the properties of sweet potato starch may be another factor contributing to the low protein digestibility of a sweet potato diet.

Table 3. Effect of sweet potato starch on protein digestibility.

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

*Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Note: TD — true digestibility; AD — apparent digestibility; BV — biological value; FE — feeding efficiency.
Casein was used as protein source for all the treatments.

Further studies have shown that the effect of starch on protein digestibility varied genotypically. Results of a typical experiment are summarized in Table 4. C 63-74 and CN l232-9 fed to laboratory rats have a protein digestibility comparable to that of corn starch. Starch in New 3l is low in protein digestibility. These types of experiments imply that the quality of sweet potato starch can be improved through proper breeding programs. This assumption was confirmed by feeding experiments involving only a sweet potato diet over a long period. A comparable protein efficiency ratio was observed using starch of CN l232-9 with or without cooking (Table 5). It was noted, however, that protein digestibility of the CN l232-9 diet, although not statistically different from that of the corn starch diet, tended to have a lower value. This suggests that the quality of this line may be somewhat lower than that of corn, but not detectable by experiments conducted in the AVRDC laboratory.

Table 4. Protein digestibility of sweet potato starch diets.

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

*Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Note: SD — starch digestibility; FN — fecal nitrogen; AD — apparent digestibility; TD — true digestibility; BV — biological value.

Casein was used as protein source for all the treatments.

Table 5. Protein efficiency ratio of sweet potato diet.

Variety	Protein efficiency ratio*			
	Week 1	Week 2	Week 3	Week 4
CN 1232-9 (raw)	2.05a	2.20a	2.39ab	2.46ab
CN 1232-9 (cooked)	2.28a	2.02a	2.18bc	2.27bc
941-32	2.03a	2.04a	2.22abc	2.11c
Corn	2.77a	1.97a	2.64a	2.60a

*Means followed by the same letter are not significantly different at 5% level.

Flatulence Factors in Sweet Potato

The nature of flatulence factors in legumes has been studied by many scientists (Blair et al., 1947; Calloway, 1972). It is generally accepted that oligosaccharide (e.g., starchyose, raffinose, and verbuscose) are the principal flatulence factors in legume (Murphy, 1964; Rackis et al., 1970; Becker et al., 1974; Reddy et al., 1980). Flatulence caused by sweet potato is well known to the Asian consumer, but its nature is not fully understood (Palmer, 1982). The oligosaccharide content of sweet potato is very low, suggesting that the flatulence factor in sweet potato is different from that of legumes.

Hydrogen production by laboratory rat after ingesting various amounts of sweet potato indicates that starch and edible fiber are probably the major flatulence-causing substances in sweet potato (Table 6). Table 7 presents the hydrogen content in exhaled air of laboratory rat fed with different kinds of starch. Starches isolated from sweet potato, potato, and banana have shown flatulence-inducing properties. The effect of these starches on gas formation can be reduced through cooking. Thus, the effect of cooked sweet potato on flatulence may result mainly from other constituents such as edible fiber. Since there are many substances that may be responsible for flatus, a biological assay is still the best method to quantify flatulence factors. The technique available, however, was found not to be satisfactory for variety evaluation. The standard deviation of the replications was too high to detect a difference among varieties (Tsou and Yang, 1984). Research on better techniques and the nature of flatulence factor is needed.

Effect of Weevil Damage on Palatability of Sweet Potato Diet

Poor palatability of sweet potato caused by weevil is considered another of its defects. This reduces the intake rate, resulting in poor daily weight gain and feeding efficiency (Lin, 1978; Lee and Yang, 1980). An ex-

Table 6. Hydrogen produced by rat after ingesting various sweet potato fractions.

Sweet potato fraction	Fraction of dry wt. (%)	H_2 (ml/g) intake	Contribution (%)
Free sugar extract	3.99	< 0.0425	< 0.00434
Beta-starch	50.69	65.4 ± 39.4	85.07
Edible fiber	10.03	59.6 ± 42.0	15.28
Alpha-starch		6.5 ± 4.1	
Basal casein-corn diet		7.7 ± 7.2	

Table 7. Hydrogen production induced by various starch sources.

Starch source	Hydrogen production (ml)/g intake
Sweet potato	69.71a*
Banana	59.46a
Potato	56.84a
Wheat	15.89b
Cassava	9.93b
Mung bean	5.58b
Rice	5.04b
Corn	1.36b

*Mean of eight rats.

Mean separation within column by Duncan's Multiple Range Test (5% level).

periment using free selection showed that properly prepared sweet potato flour made from undamaged root was better palatable than corn starch (Table 8). This result suggests that the low palatability of sweet potato diet may be due to certain minor compounds produced during injury caused by weevil. It is known that certain compounds such as terpenoids and polyphenols can be produced in sweet potato root as a defense mechanism to weevil invasion (Akazawa, 1960). These compounds are generally localized in tissues near the injury.

Table 8. Mixed diet of sweet potato and corn starch fed to the rat for the preference selection.

Treatment	Ratio of mixed diet Sweet potato	Corn	Amount of feed intake* (g)	Feed intake* (%)
Control	0	5	15.65b	12.98b
1	1	4	15.70b	12.58b
2	2	3	24.57b	20.12b
3	3	2	62.87a	54.33a

*Data from seven replications at a 7-day period.

Traditionally, farmers remove this part by hand before feeding the tubers to animals. This process is impractical and laborious. Terpenoid compounds produce bad flavor and also are toxic to animals. The effect of these compounds on palatability was studied using sweet potato with different levels of weevil damage. Results demonstrated that even very low terpene concentrations drastically reduced the palatibility of sweet potato (Fig. 3). Laboratory rats fed with infested sweet potato had a lower intake rate and body weight (Fig. 4). A calibration curve shows that the optical density of 527 nm of lowest terpenoid treatment in this experiment is equivalent to l5 weevil/kg of fresh sweet potato root. Therefore, an effective control method for weevil infestation is an important factor for sweet potato quality.

CONCLUSION

Although sweet potato has played an important role in the agricultural economy of East Asia, the potential of this crop has not been fully realized in tropical Asia. Many approaches can be adopted to promote the sweet potato, depending on the socioeconomic environment and government policy. Cooked sweet potato, together with rice, is a common staple food consumption pattern in Asia. This approach may be adopted in areas which lack energy resources but it may be difficult to promote sweet potato in rice-eating countries. Partial substitution of wheat flour with sweet potato flour has been proven to be technically feasible (Taylor, l982). Since sweet potato is produced locally, this approach may reduce the foreign exchange necessary to import wheat. The success of this approach partly depends on the stable supply of quality sweet potato flour. Flatulence-inducing properties of sweet potato deserve further investigation; low flatus cultivars are needed.

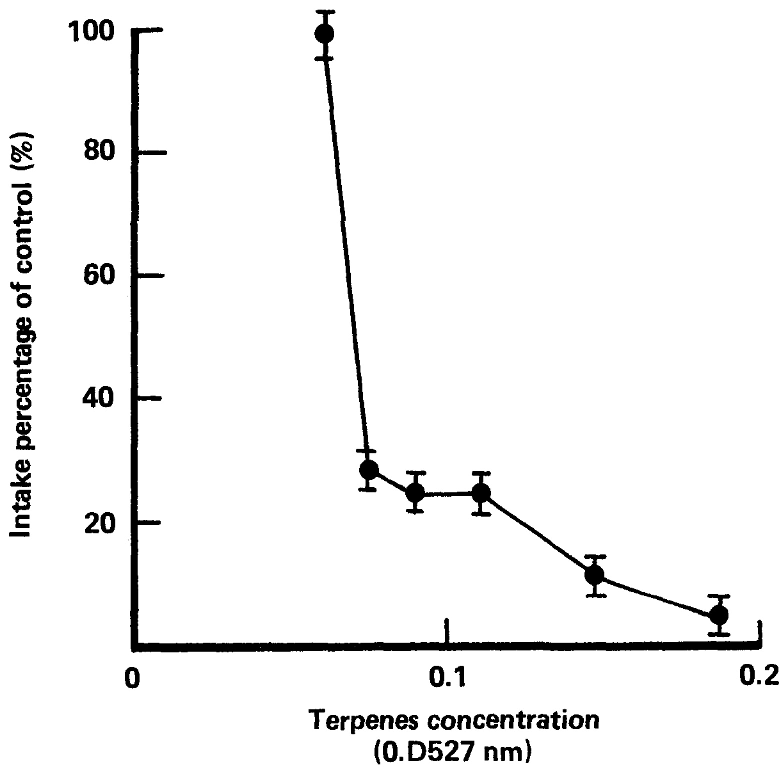


Figure 3. Relationship between terpenes concentration and feed intake (preference test).

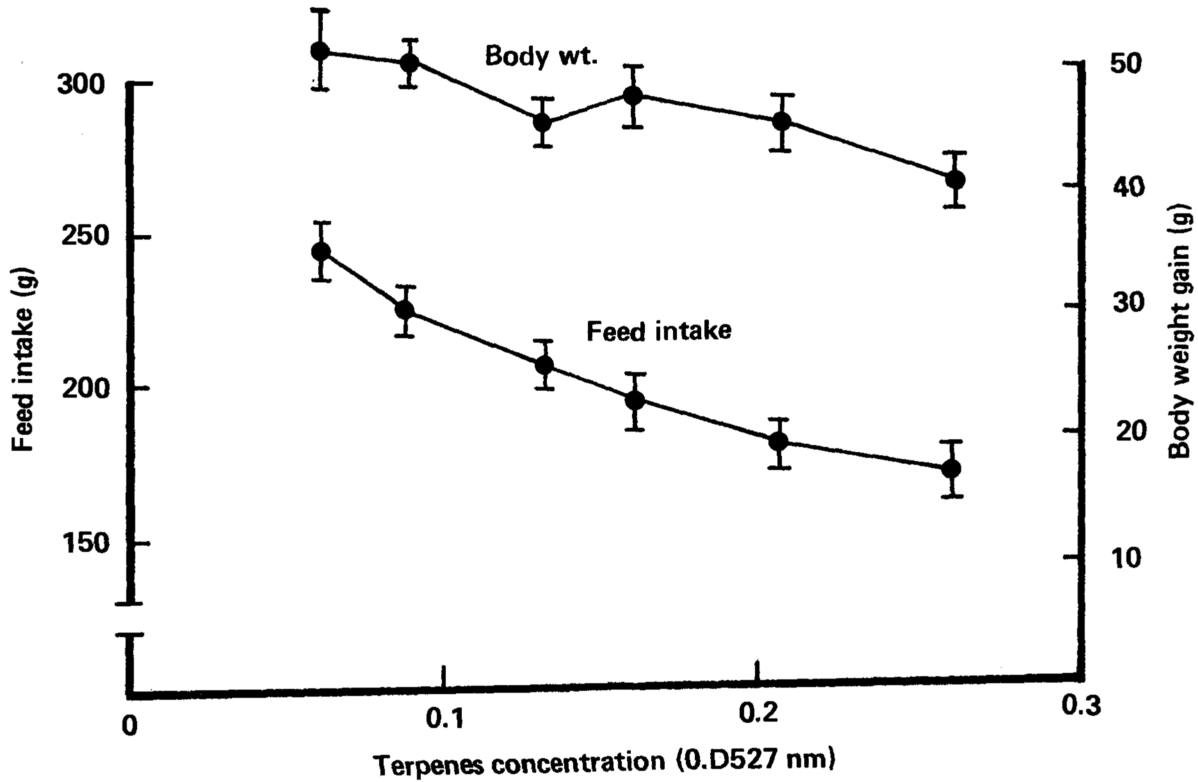


Figure 4. Relationship between terpenes concentration, feed intake amount, and weight gain of rats (intake test).

Promoting sweet potato as an energy source of animal feed is a feasible approach in many areas. Experimental results have shown that the mixture of 25 percent sweet potato chips and 75 percent corn is a reasonable feed for hogs. Price and supply systems of sweet potato chips with uniform quality are major concerns. There are several factors limiting the utilization of sweet potato as animal feed in subsistence farming systems. Availability of low-cost, protein-rich commodities is an essential factor. Incorporating legumes such as soybean in cropping systems is one feasible solution. Cultivars with easily digestible starch may reduce resistance to the adaption of this utilization pattern. Growing sweet potato after rice is still the most effective way of controlling weevil at the present stage. Thus, the development of new cultivars and better cultural practices, as they fit into post-rice production, needs to be strengthened.

The AVRDC sweet potato improvement program has demonstrated that high dry matter yield can be achieved even during the wet season (AVRDC, 1984). This result implies that sweet potato can be produced year-round in the tropics. More research in the areas of mechanization, starch properties, protein content, flatulence, storage, and processing methods is needed in order that the full potential of this crop can be utilized to serve the needs in the tropics.

REFERENCES

Akazawa, T. 1960. Chromatographic isolation of pure ipomeamarone and reinvestigation on its chemical properties. Archives of Biochemistry and Biophysics. 90:80-82.

AVRDC (Asian Vegetable Research and Development Center). 1975. Progress Report. AVRDC, Tainan, Taiwan, R.O.C.

AVRDC. 1977. Sweet Potato Report. 1976:33-35. AVRDC, Tainan, Taiwan, R.O.C.

AVRDC. 1984. Annual Progress Report 1983. AVRDC,Tainan, Taiwan, R.O.C.

Becker, R., A.C. Olson, D.P. Freferick, S. Kon, M.R. Gumbmann and J.R. Wagner. 1974. Conditions for the autolysis of alphagalactosides and phytic acid in California small white beans. J. Food Sci. 39:766.

Blair, H.A., R.J. Dern and P.L. Bates. 1947. The measurement of volume of gas in the digestive tract. Am.J. Physiol. 149:688.

Bouwkamp, J.C. 1985. Sweet Potato Products: A Natural Resource for the Tropics. CRC Press Inc. Boca Raton, Florida. pp. 255-259.

Bouwkamp, J.C., S.C.S. Tsou and S.S.M. Lin. 1985. Genotype and environment effects on the relationship between protein concentration and trypsin inhibitor levels in sweet potatoes. HortScience. 20(5).

Calloway, D.H. l972. Gas-forming property of food legumes. Proc. Symp. on Nutritional Improvement of Food Legumes by Breeding. PAG, United Nations System, FAO, Rome, Italy.

CAPD (Council of Agriculture Planning and Development). Executive Yuan. Undated. Taiwan Food Balance Sheet. Taipei, Taiwan, R.O.C.

Chien, S.L. and P.K. Lee. 1980. The effect of physical treatment on the available lysine and trypsin inhibitor of sweet patoes. Taiwan Livestock Res. 13(1):75-83. (in Chinese)

Han, I.K., D.J. Yoon and C.S. Kim. 1976. Studies on the nutritive value of dried sweet potato meal. 1. Partial substitution of dried sweet potato meal for corn in the ration of growing swine. Seoul Nat'l. Univ. Coll. of Agric. Bull. 1(1):67-74. Seoul, Korea.

Koo, N.W. and D.K. Kim. 1973. The feeding value of dried sweet potato pulp for growing finishing swine. Korean Jour. Ani. Sci. 15(4):313-317.

Lee, P.K. and Y.F. Yang. l980. Comparison of high protein sweet potatoes and common sweet potatoes on nutritive value of the growing fattening pigs. Taiwan Livestock Res. l3(l):97-ll2. (in Chinese)

Lee, P.K., Y.F. Yang and S. S. Lin. 1963. Comparative studies on nutritional value of sweet potato chips and corn as animal feed. Taiwan Livestock Res. 1:1-18. (in Chinese)

Lin, Y.T. 1978. Effect of partial replacement of corn by sweet potato on feeding efficiency for hog raising. Scientific Agriculture. 26(3-4):139-141. (in Chinese)

Lin, S.S.M., C.C. Peet, D.M. Chen and H.F. Lo. l985. Sweet potato production and utilization in Asia and the Pacific. *In* Bouwkamp, J.C. (ed). Sweet Potato Products: A Natural Resource for the Tropics. CRC Press Inc. Boca Raton, Florida.

Murphy, E.L. l964. The isolation and testing of the flatulence factor in gas forming foods. Proc. 7th Research Conference on Dry Beans. pp.45-55.

Opeña, R.T., H. Takagi and S.C.S. Tsou. 1987. AVRDC sweet potato improvement program. Paper presented in the International Sweet Potato Workshop, ViSCA, Baybay, Leyte, the Philippines. 20-25 May l987.

Palmer, J.K. l982. Carbohydrates in sweet potato. *In* Villareal, R.L. and T.D. Griggs (eds.). Proc. First International Sweet Potato Symp. AVRDC, Tainan, Taiwan, R.O.C. p. l35.

Polk, H.D. l943. Dehydrated sweet potato for chicken. Miss. Rept. l943:28.

Rackis, J.J., D.H. Honig, D.J. Sessa and F.R. Steggerda. l970. Flavor and flatulence factors in soybean protein products. J.Agr. Food Chem. l9:977.

Reddy, N.R., D.K. Salunkhe and R.P. Sharma 1980. Flatulence in rats following ingestion of cooked and germinated blackgram and a fermented product of blackgram and rice blend. J. Food Sci. 45(5):1161.

Sheu, Chin-Tou. 1979. Studies on the effect of pre-heating of sweet potato raw material for the elimination of antitryphic factor and the improvement of feed efficiency. Memoirs of the College of Agriculture, National Taiwan University. 19(2):33-42. (in Chinese)

Sugiura, M., T. Ogiso, K. Takeuti, S. Tamura and A. Akiraito. 1973. Studies on trypsin inhibitors in sweet potato. 1. Purification and some properties. Biochimica et Biophysica Acta. 328:407-417.

Taylor, J.M. 1982. Commercial production of sweet potato for flour and feeds. *In* Villareal, R.L. and T.D. Griggs (eds.). Proc. First International Sweet Potato Symposium. AVRDC, Tainan, Taiwan, Republic of China.

TPG, (Taiwan Provincial Government). 1986. Agricultural Production Year Book 1985. Taipei, Taiwan, R.O.C.

Tsou, S.C.S. and M.H. Yang. 1984. Flatulence factors in sweet potato. Acta Horticulturae 163:1970.

Wang, M.K., P.K. Lee and Y.F. Yang. 1979. Comparative experiment on amounts of corn grains replaced by high protein sweet potato chips and common sweet potato chips respectively for pig feeding. Taiwan Agriculture 15(6):53- 64. (in Chinese)

Ware, L.M. 1947. Ala. Agr. Exp. Sta. Progress Report Series No. 2.

Yen, T.P. 1982. Utilization of sweet potatoes for animal feed and industrial use: potential and problem. *In* Villareal, R.L. and T.D. Griggs (eds.). Proc. First International Sweet Potato Symposium. AVRDC, Tainan, Taiwan, R.O.C.

Yeng, H.D. 1976. Assessment of sweet potato as hog feed. Field Crop and Livestock. 30:28-30. (in Chinese)

Yeh, T.P., S.C. Wung, F.K. Koh, S.Y. Lee and J.F. Wu. 1977. Improvements in the nutritive values of sweet potato chips by different methods of processing. Taiwan Livestock Res. 65-66:89-95. (in Chinese)

NEW DEVELOPMENTS IN PROCESSING SWEET POTATO FOR FOOD

Truong Van Den*

ABSTRACT

Reduction in sweet potato consumption in a number of Asian countries has been noticed in the past two decades. This has been attributed to psychological and technical reasons related to resistance to eating sweet potato. Strategies to increase consumption of sweet potato have been identified through extension of its present utilization and development of new food products. Acid food products such as dried sweet-sour sweet potato, sweet potato catsup, sweet potato jam, and sweet potato beverages and concentrates are new developments in processing of the crop for food. The appearance, taste, and nutrient content of the new sweet potato products are similar to those of various processed fruit items. Interestingly, their vitamin A content is even higher than that of common fruit and vegetable products. The products were rated with high sensory scores in acceptability tests. The technologies are simple and can be applied in small and large factories. Formulation, nutrient composition, and factors affecting the quality of the products are presented.

INTRODUCTION

Sweet potato is basically an Asian crop that is appreciated for its high yield and wide ecological adaptability. The consumption of sweet potato for food, however, is inversely related to the income levels of the population. A survey of food energy and sweet potato availability in selected Asian countries indicated a noticeable reduction in sweet potato consumption, except in China and India (Table I). With the increase in availability of food and probably a better standard of living, the trend indicated a discrimination against eating sweet potato (Tsou and Villareal, 1982). Indeed, sweet potato has been consumed in many parts of the world for centuries, yet it remains as a "survival" food or food of "the poor man."

*Associate Professor, Department of Agricultural Chemistry and Food Science, Visayas State College of Agriculture (ViSCA), Baybay, Leyte 7127 - A, the Philippines.

Table 1. Food energy and sweet potato availability in selected Asian countries in 1964-1966 and 1972-1974.

Country	1964-66 Availability		1972-74 Availability	
	Energy (cal/caput/day)	Sweet potato (kg/caput/year)	Energy (cal/caput/day)	Sweet potato (kg/caput/year)
China	2379	68.9	2278	80.2
India	1964	2.1	1967	3.0
Indonesia	1760	25.4	2301	17.1
Rep. of Korea	2329	76.1	2749	28.7
Malaysia	2200	3.7	2539	1.0
Pakistan	1995	3.7	2128	2.0
Philippines	1911	20.4	1957	5.1
Thailand	2226	16.2	2302	7.2

Source: FAO food balance sheets (1971, 1977)
(Adapted from Tsou and Villareal, 1982)

Tsou and Villareal (1982) cited both psychological and technical reasons for the decreased preference for sweet potato, particularly in poor countries. It was recommended at the First International Symposium on Sweet Potato in 1982 that efforts should be devoted to extend present utilization and to develop new food products in order to change the status of sweet potato from a subsistence to a market-oriented crop.

This paper thus reviews the utilization of sweet potato, with emphasis on new developments in processing of acid food products.

Present Utilization of Sweet Potato

In various parts of the world, sweet potato is boiled or cooked with rice and served as staple food. It can be used as snack or dessert items and is commonly consumed in fresh form as boiled, baked, broiled, or cooked with coconut milk and other ingredients like the traditional delicacies of "guinataan" in the Philippines. The crop is also prepared into fried chunks, chips (Alkuino and Truong, 1987), and French-fry-type product (Walter and Hoover, 1986).

Sweet potato has been processed into commercial food products such as flakes, canned, and frozen items in the United States (Edmond and Ammerman, 1971), and into starch in Japan and Korea at small scale. The varieties with high starch content and light flesh color are used for the manufacture of sweet potato starch. Its properties lie intermediate between white potato and corn/cassava starch in terms of viscosity and other characteristics (Radley, 1976).

Dehydration of fresh or blanched sweet potato roots by sun-drying has been traditionally practiced in developing countries to produce chips, which can be stored and ground into flour. Technology innovations on drying chips and flour processing on the village level has been reported (Tan, 1985). In many countries, sweet potato flour is used as supplement to cereal flours in bakery products, pancakes, puddings, and others (Truong and Del Rosario, 1986; Tsou and Villareal, 1982; Winarno, 1982). In Peru, sweet potato flour is a common item in grocery stores and used for many household purposes (Martin, 1984). Sweet potato flour can totally replace wheat flour in soy sauce production (Data et al., 1986).

To extend the utilization of sweet potato in urban centers, ready-to-cook products, such as dehydrated shredded sweet potato named "kaukau rice," were developed in Papua New Guinea. The product is available in 5-kg packs and cooked like rice (Siki, 1979). A technology on the use and packaging of dried sweet potato cubes for "guinataan" and other dessert preparations has been reported by Truong et al. (1985). The product was rated comparable with fresh root in "guinataan" preparation. Tools/equipment such as washer, dicer, and dryer have been designed for processing of the product on the village level.

New Food Products

Sweet potato is a starchy material whose proximate composition and contents of vitamins (e.g., thiamin, riboflavin, niacin, and ascorbic acid) are comparable with those of various fruits (Table 2). One hundred grams fresh roots can supply from 25 to 50 percent of the recommended daily allowance of vitamin C, depending on methods of processing (Anonymous, 1980). The vitamin A content of sweet potato correlates significantly with the flesh color of the root. The orange-type sweet potato contains a high level of B-carotene, which is comparable with that of carrot and superior to other common vegetables and fruits (Bureau and Bushway, 1986; Truong et al., 1985, unpublished data). The concentration of mineral elements, particularly calcium, phosphorus (Table 2), and potassium (Picha, 1985) in sweet potato is also high.

Acid food products from sweet potato, whose appearance, taste, and nutrient content are similar to those of processed fruit items, have been developed in ViSCA. Ingredients such as sugar and food grade acid, which are common in commercial fruit processing, are used in formulating the products.

Addition of food grade acids to enhance the quality of products from nonsour fruits is not uncommon. Tanafranca et al. (1985) reported that citric acid improves the flavor of dehydrated jackfruit. Acidification of juices from carrot and celery with citric acid minimized heating treatment and offered a variety of juices with different characteristics (Pederson, 1975). The technology, however, has not been applied to preparation of juices from tropical root crops, including sweet potato.

Acid food products from sweet potato such as dried sweet-sour sweet potato, sweet potato catsup, sweet potato jam, and sweet potato beverage/concentrate have been newly developed.

Dried Sweet-Sour Sweet Potato

The product has the sweet and sour taste of dried fruits. It was originally named Delicious S-P (Truong, 1984; Truong et al., 1986b). Processing is as simple as that involved in preparing dried fruits. Sweet potato roots are washed, peeled, sliced, and soaked in 2 percent metabisulfite solution and cooked in acid-containing syrup. The cooked slices are dried in a mechanical drier and packed in plastic bags. Sweet potato slices cooked in 60° Brix syrup containing 0.8-1.0 percent (w/w) citric acid produced the most acceptable product in terms of sensory attributes. Moy and Chi (1982) reported the "osmosol" process of producing dried sweetened sweet potato, which included boiling, peeling, and cutting the roots into pieces, soaking for 4 hours in $60\text{-}65^{\circ}$ Brix syrup, and drying in a solar drier. Their work, however, focused mainly on the solar dehydration technology.

Table 2. Nutrient composition of sweet potato as compared with various fruits (per 100 grams edible portion).

Crop	Moisture (%)	Food Energy (Cal.)	Protein (g)	Fat (g)	Total Carbo-hydrate (cm)	Fiber (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	Vit. A (I.U.)	Thiamin (mg)	Ribo-flavin (mg)	Niacin (mg)	Ascorbic acid (mg)
Sweet potato															
yellow (boiled)	68.1	126	1.0	0.6	29.4	0.6	0.9	66	58	0.8	1,025	0.09	0.04	0.6	31
white (boiled)	62.2	149	0.6	0.4	35.8	0.6	1.0	72	51	0.7	10	0.06	0.03	0.5	47
Apricot	85.3	51	1.0	0.2	12.8	—	—	17	23	0.3	2,700	0.03	0.04	0.6	10
Banana	73.2	95	1.2	0.4	24.4	0.6	0.8	23	36	0.9	340	0.06	0.04	0.6	32
Grapes	79.2	75	0.4	0.3	19.7	1.7	0.4	6	24	0.4	—	0.06	0.02	0.2	3
Philippine lemon (kalamansi)	89.8	32	0.4	1.0	8.3	tr	0.5	18	12	0.8	0	0.02	0.01	0.2	45
Mango	83.9	57	0.5	0.2	15.0	0.4	0.4	8	17	0.5	2,580	0.09	0.05	0.7	47
Orange	86.0	49	1.0	0.2	12.2	—	—	41	20	0.4	200	0.10	0.04	0.4	50
Papaya	86.4	48	0.6	0.2	12.2	0.6	0.6	23	10	0.7	425	0.03	0.03	0.4	89
Pineapple	86.0	50	0.4	0.2	13.0	0.4	0.4	19	9	0.2	15	0.08	0.04	0.2	21
Strawberry	91.3	30	0.8	0.2	7.2	1.6	0.5	34	21	1.2	15	0.03	0.03	0.3	107
Tomato	94.1	19	1.0	0.2	4.1	0.8	0.6	18	18	0.8	735	0.06	0.04	0.6	29

Sources: Food and Nutrition Research Institute, 1980; Salunkhe et al., 1974.

A number of varieties/accessions of sweet potato available at ViSCA were screened for use in processing Delicious S-P. The product prepared from VSP-1 obtained the highest sensory scores owing to its attractive orange color and soft texture. VSP-1 is a "moist" sweet potato variety with low dry matter and starch content. VSP-1 roots contain 24 percent dry matter, 56.6 percent starch, 20.4 percent sugar, 2.2 percent protein, 2.8 percent fiber, and 3.3 percent ash. The physicochemical characteristics of VSP-1 make it most suitable for processing into dried sweet-sour sweet potato.

The products processed from fresh roots or roots stored for 2-3 weeks at ambient conditions were rated similarly in terms of sensory attributes (Truong and Fementira, unpublished data).

Table 3 shows the composition of dried sweet-sour sweet potato compared with dried mango and apricot. Its total soluble solids, total carbohydrates, protein, fat, fiber, and ash were in the range of the dried fruits. The ascorbic acid content of Delicious S-P (7.2 mg/l00g) was lower than that of dried apricot (12.6 mg/100 g) and dried mango (28.9 mg/100 g). The dried sweet potato, however, contained 13,033 I.U. of vitamin A per 100 g which is even higher than the content of the two fruits.

Consumer testing of dried sweet-sour sweet potato revealed that the product is highly acceptable, with 11 percent respondents rating "like extremely;" 60 percent "like very much;" and 23.5 percent "like moderately." The technology has been transferred to a private company for commercialization.

Table 3. Composition of dried sweet-sour sweet potato, dried mango, and dried apricot.

Composition	Dried sweet-sour sweet potato	Dried mango*	Dried apricot***
Moisture (%)	17.5	9.4	16.6
Total soluble solids	70	68.5**	–
pH	2.8	3.6**	–
Total carbohydrate (%)	78.3	87.3	66.6
Protein (%)	1.2	1.6	5.3
Fat (%)	0.4	1.0	0.6
Fiber (%)	1.6	1.8	–
Ash (%)	0.9	0.7	–
Ascorbic acid (mg/100 gm)	7.2	28.9**	12.6
Vitamin A (I.U./100 gm)	13,033	41.6	10,900

*Source: Food and Nutrition Research Institute, Philippines, 1980.

**Source: Tanafranca et al., 1985

***Source: Ockerman, 1978.

Sweet Potato Catsup

Catsup processing from tomato is an established industry around the world (Gould, 1974). However, because tomato is expensive in tropical countries like the Philippines, cheaper material for catsup processing has been searched for. Sweet potato, which is rich in carotene, is a good source of raw material for catsup making. The process has been developed following the procedures of tomato and banana catsup processing with modifications. The roots are washed, trimmed, chopped into chunks, and steamed. The cooked chunks are blended with water, vinegar, spices, and food colors and boiled to desired consistency before bottling. Among the varieties tested (VSP-1 to 5), catsup prepared from VSP-1 was better in terms of consistency and general acceptability (Truong et al., 1986b). Sweet potato catsup has total soluble solids of 25-27^{o} Brix, pH 2.7-2.8, and its eating quality is comparable with that of a commercial banana catsup.

Sweet Potato Jam

Jam and jelly are important fruit preserved products. These semi-solid products are composed of at least 45 parts fruit and 55 parts sugar, and cooked until the final soluble solid content is 65-68 percent (Gross, 1974). The basic principle in fruit preserves is the interaction between pectic acid and sugar in water to form gel. Pectin-rich fruits are preferably used in processing these products.

The average pectin content of fruits is 0.5 percent (Pilnik and Voragen, 1970). Reddy and Sistrunk (1980) reported that sweet potato roots contain 0.53-l.00 percent water-soluble pectin (wet basis). Sweet potato pectin has gelling properties similar to those of apple pectin (Winarno, 1982).

Sweet potato was processed into jam using the fruit preservation process. The formulation consisted of sweet potato, 20.7 percent (w/w); sugar, 45 percent (w/w); water, 34 percent (w/w); and citric acid, 0.3 percent (w/w). The mixture was cooked until the specified total soluble solids in jam (68^{o} Brix) was obtained. Jam samples prepared from five varieties of sweet potato obtained acceptability scores of 6.8-7.1. The gel consistency was rated from fair to good. The low concentration of sweet potato (20.7%) compared to fruit in the formulation can be attributed to its high starch content. The latter may account for the difference in gel consistency between sweet potato and fruit jams.

Jam with various natural colors can be processed from different varieties of sweet potato. The orange flesh sweet potato (VSP-1 and VSP-2) gives a product with orange colors. VSP-4 and VSP-5 produce jam with yellow and pinkish color, respectively.

Sweet Potato Beverage and Concentrate

The process

In the United States, an alpha-amylase activation process involved in the preparation of sweet potato puree, an intermediate material in processing dehydrated sweet potato flakes, was reported by Hoover (1967). Other investigations have been subsequently conducted to study the rheological and chemical properties of the puree and their effects on the quality of sweet potato flakes (Gross and Rao, 1977; Ice et al., 1980; Szyperski et al., 1986). However, there has been no reports on development of nonalcoholic beverage from sweet potato.

A process of producing nonalcoholic beverage from sweet potato with taste and appearance similar to those commercial fruit drinks has been pioneered by Truong and Fementira (1986). The processing steps involved peeling, steaming, extracting, formulating with citric acid, ascorbic acid, and sugar, and packing in suitable containers. Sweet potato concentrate diluted with water (1:4) before consumption was also formulated.

The beverage samples prepared from several varieties of sweet potato were rated with sensory scores (higher than 6.5 in the Hedonic scale) for color, aroma, and general acceptability. The color of the beverage varied according to the flesh color of the roots, and ranged from yellow, orange to pinkish purple.

The developed beverage added with 0.3 percent (w/v) citric acid had pH 3.0-3.2 and total soluble solids of 12.5-13.5^{o} Brix. It was found that the juice of Philippine lemon (*Citrus microcarpa bunge*) could substitute citric acid in the formulation. The general acceptability of sweet potato–lemon beverage was significantly higher than that of the drink containing citric acid (Table 4). About 40 m of lemon juice is needed for every liter of sweet potato beverage to produce sourness similar to that of citric acid at 0.3 percent (w/v). The sweet potato-lemon beverage has the pleasant flavor of the citrus. Addition of pineapple at 20 percent (w/v) to the formulation also improved the acceptability of the product. Likewise, artificial orange flavor added at 0.10 percent (w/w) significantly affected the aroma scores of the sweet potato beverages (Table 4).

Blending various kinds of fruit juices to complement their acidity and flavor in formulating nectars is a common practice in fruit processing (Luh, l97l). However, blending starchy material with fruit juice to formulate a beverage has not been reported. Sweet potato fruit juice blend can now probably be added to the list of existing commercial nectars.

The nutrients

Vitamin A content of sweet potato beverage varies widely with the varieties. The beverage from VSP-l and VSP-2 contains l,844 I.U. and l.572 I.U. of vitamin A or about two-folds and seven-to nine-folds the values in tomato and orange juice, respectively. An intake of 8 oz (237 ml)

Table 4. Sensory qualities of sweet potato beverage as affected by added fruit juices and artificial orange flavor.

Treatment	Color*	Aroma*	General acceptability
Experiment I			
Sweet potato slurry + 0.3% w/v citric acid (T_o)		6.6a	6.9b
Sweet potato slurry + lemon juice (T_1)**		7.0a	7.4a
T_o + 10% w/v ripe papaya		6.4a	6.5bc
T_o + 15% w/v ripe mango		6.7a	6.8bc
T_o + 20% w/v mature pineapple		7.2a	7.7a
Experiment II			
Sweet potato slurry + 0.3% w/v citric acid (T_o)	7.2a	7.2bc	7.3a
T_o + 0.05% w/v orange juice flavor***	7.4a	7.3bc	7.2a
T_o + 0.10% w/v orange juice flavor	7.3a	7.9a	8.0a
T_o + 0.15% w/v orange juice flavor	7.0a	7.5bc	7.2a

*Hedonic scale
**Juice extracted from Philippine lemon, kalamansi (*Citrus microcarpa bunge*), was added to sweet potato slurry to obtain pH of 3.0.
***No. 4188, WJ Flavors, St. Louis, Missouri, USA (no recommendation implied).

of the VSP-I beverage contributes 43.7 percent of the recommended daily vitamin allowance (10,000 I.U.) for males (NAS, 1980).

Ascorbic acid content of sweet potato beverage is much lower than that of orange, lemon, passion fruit, and tomato juice but comparable to that of grape juice and sweet apple cider. Fortification of vitamin C, which is commonly practiced to enhance the nutritional value of commercial fruit juices/drinks (Phillips and Woodroof, 1981), was also applied to sweet potato beverage. Table 5 shows that addition of ascorbic acid to sweet potato beverage did not adversely affect product acceptability. Indeed, the taste panelists preferred the sample containing 0.25 percent (w/v) citric acid and 232 mg/l ascorbic acid over the control. With the fortification, an 8-oz bottle of sweet potato beverage can provide 30 mg ascorbic acid, the minimum adult daily requirement (NAS, 1980), assuming that 25 mg is used up owing to oxidation in the container (Phillips and Woodroof, 1981).

Table 5. Sensory attributes and acidity of sweet potato beverage containing ascorbic acid (232 mg/liter) and various levels of citric acid.

Treatment	Titrable acidity (as % citric acid)	Sensory attributes				
		Sweetness	Sourness	General acceptability	Ranking value	Test preference order
0.30% w/v citric acid (control)	0.32	7.4	6.7	7.2	0.19	3
0.30% w/v citric acid + ascorbic acid	0.35	6.3	6.0	6.3	−0.19	4
0.25% w/v citric acid + ascorbic acid	0.30	6.9	7.0	6.9	0.55	1
0.20% w/v citric acid + ascorbic acid	0.21	6.1	6.2	6.1	0.47	2
0.15% w/v citric acid + ascorbic acid	0.18	6.3	6.0	6.3	−0.86	5

The starch content of sweet potato beverage ranges from 0.8 to 1.4 mg/100 g. Though Truong et al. (1986a) hypothesized that the flatulence occurring after a large intake of cooked sweet potato is caused by the undigested starch which escapes from the small intestines. The starch content of the beverage is too low to cause such distress. In fact, the absence of flatulence after drinking sweet potato beverage has been confirmed by l0 volunteers who were administered an 8-oz bottle of the beverage daily for a week.

CONCLUSION

Sweet potato has been an "underrated" crop. Although its nutritive values have been recognized recently, utilization of sweet potato is still confined mainly near production areas. Increase in its consumption requires efforts in processing sweet potato into convenient, ready-to-cook forms and development of new food products.

The nutrient composition of sweet potato roots is unexpectedly comparable with that of various fruits. In fact, its vitamin A content even exceeds that of common fruits and vegetables. The crop can be processed into fruit-like products.

Development of acid food products from sweet potato is considered a new approach in improving the crop's economic value and upgrading its status. The reported technologies are simple and can be applied in small or large factories. Production of these new products would make available nutritious foods to the general populace and therefore help combat vitamin A deficiency. Nevertheless, consumer education is equally important to erase the bias of people against the crop and to enable sweet potato to find a better place in the people's daily diet.

REFERENCES

Alkuino, J. M., Jr. and Truong Van Den. l987. Indigenous technologies in rural processing of cassava and sweet potato: a survey and economic analysis. Ann. Trop. Res. (*in press*).

Anonymous. l980. Sweet Potato Quality. Southern Cooperative Series Bull. 249. S-l0l Technical Committee, Univ. Anthens. Ga.

Bureau, J. L. and R.J. Bushway. l986. HPLC determination of carotenoids in fruits and vegetables in the United States. J. Food Sci. 5l:l28-l30.

Data, E. S., J.C. Diamante and E.E. Forio. l986. Soy sauce production utilizing root crop flour as substitute for wheat flour. Ann. Trop. Res. 8:42-50.

Edmond, J. B. and C.R. Ammerman. l97l. Sweet Potatoes: Production, Processing and Marketing. AVI Publishing Co., Westport, Connecticut.

Food and Nutrition Research Institute. 1980. Food Composition Table. Manila, the Philippines.

Gould, W. A. 1974. Tomato Production, Processing and Quality Evaluation. AVI Publishing Co., Westport, Connecticut. pp. 172-181.

Gross, D. R. 1974. Fruit preserves and jellies. *In* Johnson, A.H. and J. Peterson (eds.). Encyclopedia of Food Technology. Vol. 2, AVI Publishing Co., Westport, Connecticut. pp. 469-472.

Gross, M.O. and V.N.M. Rao. 1977. Flow characteristics of sweet potato puree as indicators of dehydrated flake quality. J. Food Sci. 42:924-930.

Hoover, M. W. 1967. An enzyme-activation process for producing sweet potato flakes. Food Tech. 21:322-325.

Ice, J. R., D.D. Hamann and A.E. Purcell. 1980. Effects of pH, enzymes and storage time on the rheology of sweet potato puree. J. Food Sci. 45:1614-1618.

Luh, B. S. 1971. Nectars, pulpy juices and fruit juice blends. *In* Tressler, D.K. and M.A. Joslyn (eds.). Fruit and Vegetable Juice Processing Technology. AVI Publishing Co., Westport, Connecticut. pp. 347-396.

Martin, F. W. 1984. Techniques and problems in small scale production of flour from sweet potato. J. Agric. Univ. Puerto Rico. 68:423-432.

Nagy, S. 1978. Fruit Juices. *In* Peterson, M.S. and A.H. Johnson (eds.). Encyclopedia of Food Science. AVI Publishing Co., Westport, Connecticut. pp. 334-338.

NAS (National Academy of Sciences). 1980. Recommended Dietary Allowances. National Academy of Sciences, Washington, D.C. 9th ed.

Ockerman, H.W. 1978. Source Book for Food Scientists. AVI Publishing Co., Westport, Connecticut.

Pederson, C. S. 1975. Vegetable juices. *In* Luh, B.S. and J. G. Woodroof (eds.). Commercial Vegetable Processing. AVI Publishing Co., Westport, Connecticut, pp. 290-316.

Phillips, G. F. and J.G. Woodroof. 1981. Beverage acids, flavors, colors and emulsifiers. *In* Woodroof, J.G. and G. F. Phillips (eds.). Beverages: Carbonated and Non-Carbonated. AVI Publishing Co., Westport, Connecticut. pp. 152-207.

Picha, D. H. 1985. Crude protein, minerals and total carotenoids in sweet potatoes. J. Food Sci. 50:1778-1769.

Pilnik, W. and A. G. J. Voragen. 1970. Pectic substances and other uronides. *In* Hulme, A.C. (ed.). The Biochemistry of Fruits and their Products. Vol. I. Academic Press, New York. pp. 53-87.

Radley, J. A. 1976. Starch Production Technology. Applied Science Publishers, London.

Reddy, N.N. and W.A. Sistrunk. 1980. Effect of cultivar, size, storage and cooking method on carbohydrates and some nutrients of sweet potato. J. Food Sci. 45:682-684.

Salunkhe, D. K., S.K. Pao and G.G. Dull. 1974. Assessment of nutritive value, quality and stability of cruciferous vegetables during storage and subsequent to processing. *In* Salunkhe, D.K. (ed.). Storage, Processing and Nutritional Quality of Fruits and Vegetables. CRC Press, Ohio. pp. 1- 38.

Siki, B. F. 1979. Processing and storage of root crops in Papua New Guinea. *In* Plucknett, D. (ed.). Small Scale Processing and Storage of Tropical Root Crops. Westview Press, Boulder, Colorado. pp. 64-82.

Szyperski, R.J., D.D. Hamann and W.M. Walter, Jr. 1986. Controlled alpha amylase process for improved sweet potato puree. J. Food Sci. 51:360-363.

Tan, D.L.S. 1985. Establishment and piloting of a village level scale root crop flour mill. *In* Philippine Root Crops Research and Training Center. Rootcrops Annual Report 1985. ViSCA, Leyte, the Philippines. p. 84-85.

Tanafranca, D. E., L.B. Farre, L.C. Angeles and M.R. Soriano. 1985. Dehydration technologies of some Philippine fruits. *In* Proc. Workshop on Food Tech. Res. & Development. Bangkok, Thailand. September 1985. pp. 107- 116.

Truong Van Den. 1984. Dehydration of cassava and sweet potato for food. Paper presented at the Seminar on Recent Res. & Devt. in Rootcrops Processing and Utilization, Bureau of Plant Industry, Manila, 20 January 1984.

Truong Van Den and E.J. del Rosario. 1986. Processing of sweet potato for food and industrial uses. *In* Philippine Council for Agriculture and Resources Research and Development. State-of-the-Art of Sweet Potato Research. Los Baños, Laguna, the Philippines. p. 38-47.

Truong Van Den and G.B. Fementira. 1986. Process for the production of non-alcoholic beverage and concentrate from sweet potato. Patent Application, Philippine Invention Development Institute, No. 5521.

Truong Van Den, C.J. Biermann and J.A. Marlett. 1986a. Simple sugars, oligosaccharides and starch concentrations in raw and cooked sweet potato. J. Agric. Food Chem. 34:421-425.

Truong Van Den, L.S. de la Rosa, G.B. Fementira, and L.A. Baugbog. 1986b. Pilot production of Delicious S-P and sweet potato catsup. Terminal Report. Philippine Root Crop Research and Training Center Project, ViSCA, Leyte, the Philippines.

Truong Van Den, A.T. Sembrano and G.B. Fementira. 1986c. Process for preparing dried sweet potato product with a sweet and sour taste. Patent pending, Philippine Patent Office, Manila. No. 8128.

Truong Van Den, L.S. de la Rosa, R.C. Cuarte, I.J. Tabianan and P. F. Cerna. 1985. Dehydration of root crops for food and food products. Annual Report 1985. Philippine Root Crop Research and Training Center, ViSCA, Leyte, the Philippines. pp. 76-79; 83-84.

Tsou, S. C. S. and R.L. Villareal. 1982. Resistance to eating sweet potato. *In* Villareal, R.L. and T. D. Griggs (eds.). Sweet Potato. First International Symposium on Sweet Potato. AVRDC, Taiwan, R.O.C. pp. 37-44.

Walter, W. M., Jr. and M.W. Hoover. 1986. Preparation, evaluation and analysis of French-fry-type product from sweet potato. J. Food Sci. 51:969-970.

Winarno, F. G. 1982. Sweet potato processing and by-product utilization in the tropics. *In* Villareal, R.L. and T. D. Griggs (eds.). Proc. First Int. Symp. on Sweet Potato. AVRDC, Taiwan, R.O.C. p. 373-384.

Woodroof, J. G. 1975. Other methods in fruit processing. *In* Woodroof, J.G. and B. S. Luh (eds.). Commercial Fruit Processing. AVI Publishing Co., Westport, Connecticut. p. 447-496.

GENDER ROLES IN SWEET POTATO PRODUCTION, PROCESSING, AND UTILIZATION IN EASTERN VISAYAS, THE PHILIPPINES

Dolores I. Alcober and Leonila S. Parrilla*

INTRODUCTION

Women's participation in agricultural production is not new. Bauman (l928) reported that African women worked on the farm all year round producing food crops while men performed only preplanting tasks that occupied a small part of the agricultural year. Likewise, they were involved in cash crop production that was mainly market-oriented.

The Food and Agriculture Organization bared that women contribute about two-thirds of the total number of hours worked throughout the world (FAO, l973). Much of the work is done by women living in rural areas. They grow at least 50 percent of the world's food and up to 90 percent of the rural food supply in some parts in Africa. In return, they receive only l0 percent of the world income and own less than one percent of world property. Even in Islamic countries where religion discourages women's participation in activities outside the home, 50 percent of Pakistan rural women cultivate and harvest wheat, and 60 percent of the Jordanian women weed crops.

In the Philippines, particularly in the Eastern Visayas region, women also play a crucial role in agriculture and farming, and their participation, specifically in sweet potato farming, should be noted. It is imperative to identify and highlight some of the undertakings and contributions of women in sweet potato production, processing, and utilization. Information along this line could lead to optimal involvement of women in technology generation and utilization of sweet potato and other root crops grown in the region.

OBJECTIVES

This study was conducted to describe the general features of sweet potato production in the region, to identify specific sweet potato farming

*Associate Professor, Department of Agricultural Education and Extension, and Assistant Professor, Department of Agricultural Economics and Agribusiness, respectively, Visayas State College of Agriculture (ViSCA), Baybay, Leyte, the Philippines.

operations and related activities performed and decided by men and women, and to determine the reasons behind women's involvement in the different activities in sweet potato farming.

METHODOLOGY

Three of the six towns covered by the Farming Systems Development Project in Eastern Visayas (FSDP-EV) -- Matalom and Villaba in Leyte Province and Gandara in Samar Province -- were chosen as study areas. Ninety sweet potato growing households were randomly selected as subjects.

The case study method was used to collect the information needed. The research staff stayed in the sample villages to observe, participate, and monitor the activities of the members of the household respondents. Both informal and formal dialogues and personal interviews using a prepared checklist were also conducted.

The study is a descriptive one with minimum statistical analysis.

RESULTS

Educational Attainment of the Respondents

Generally, the level of education of the respondents was relatively low. The majority of sweet potato growers reached only the elementary level of education (Table 1). The average number of years spent by the husbands and wives in an educational institution was four, while their children spent an average of five years.

Involvement of Children and Helpers in Sweet Potato Production Production According to Age

Many male children and helpers were involved in weeding and planting. Majority of them belonged to the 15-19 and 20-24 age brackets (Table 2).

Comparatively, more male children and helpers assisted in sweet potato farming activities than the females (Table 3). No female was involved in land preparation but many assisted in weeding and planting.

Involvement and Decision-Making in Sweet Potato Farming Activities

Land preparation

A bolo or plow was used to prepare the areas to be planted to sweet potato. A bolo was used especially by those with limited areas to cultivate

Table 1. Educational attainment of household members involved in sweet potato production and processing.

Educational attainment	Household members (%)				
	Husband N = 87	Wife N = 88	Son N = 61	Daughter N = 32	Others N = 5
No formal schooling	22	15	7	–	–
Primary (Grade 1-4)					
Attended	29	25	23	31	20
Completed	13	23	26	–	40
Intermediate (Grade 5-6)					
Attended	9	10	7	16	20
Completed	16	11	23	28	20
Secondary (1st-4th year high school)					
Attended	9	9	8	19	–
Completed	1	1	–	–	–
Collegiate (1st-4th college)					
Attended	–	–	1	3	–
Completed	1	1	–	–	–

Table 2. Age distribution of male children and other household members and their work involvement in sweet potato production.

Farm activity	Age distribution (%)					
	Below 10	10-14	15-19	20-24	above 24	Total
Land preparation (N = 31)	–	–	45	45	10	100
Planting (N = 45)	–	11	39	39	11	100
Weeding (N = 42)	2	18	34	36	10	100
Harvesting (N = 10)	10	20	20	50	–	100
Transporting and carrying farm product (N = 18)	6	12	23	59	–	100
Marketing (N = 4)	–	25	25	50	–	100

Table 3. Age distribution of female children and other household members and their work involvement in sweet potato production.

Farm activity	Age distribution (%)					
	Below 10	10-14	15-19	20-24	above 24	Total
Planting (N = 19)	5	27	41	27	–	100
Weeding (N = 25)	12	28	36	24	–	100
Harvesting (N = 3)	33	–	33	33	–	99
Transporting and carrying farm produce (N = 5)	–	–	80	20	–	100
Marketing (N = 1)	–	–	–	100	–	100
Processing (N = 6)	–	33	17	33	17	100

and by those without working animals and no available primary tillage equipment.

In general, land preparation was done by the husbands (86 %) (Table 4). Others (48 %) were assisted by their sons and hired laborers. Those without carabaos were usually assisted by their wives in order to finish the work on time. Some wives said that their assistance was really needed because their children could not help on the farm. Besides, they could not afford to hire laborers.

Related decisions such as the sequence, timing in relation to rains, equipment used, and variation in method with seasonal condition of each operation were mostly made by the husbands (Table 5).

Planting

Sweet potato was normally planted on ridges. Vine cuttings obtained from the previous season were utilized. The number of vines/cuttings planted ranged from one to four cuttings per hill.

Planting was reportedly done by the majority of the husbands (82%) and male children (74%) (Table 4). However, wives, especially those with grown-up children, also helped because they felt bored and guilty if they stayed idle at home while the other members of the family were busy on the farm. Fifty-nine percent of the daughters were also involved in planting.

Table 4. Percent involvement of household members in sweet potato production.

Activity	Husband N = 86	Wife N = 88	Son N = 61	Daughter N = 32	Others N = 5
Land preparation	86	7	48	–	40
Planting	82	69	74	59	6
Weeding	84	70	79	78	80
Harvesting	37	90	16	9	–
Transporting and carrying of farm products	67	51	30	9	4
Marketing	20	31	7	3	–
Processing	5	95	–	19	–

Decisions related to planting, especially on the variety used (82%), time of planting in relation to rains (73%), and spread of planting dates (79%) were mostly done by husbands. Husbands also made decisions to intercrop and replant the field immediately after harvesting sweet potato.

Weeding

Hand weeding with the use of bolo was done by farmers. None of the respondents utilized herbicides to control weeds. As in planting, this activity used family labor, the husbands (84%) being mostly involved. Seventy-nine and 70 percent of the sons and wives, respectively, helped in weeding. Likewise, many of the daughters (78%) were involved in weeding than in any other sweet potato farming activity. Decisions on weeding rested on the husbands alone.

Harvesting

Because sweet potato is highly perishable and not normally stored, the farmers usually practiced staggered harvesting of the roots. They started harvesting only when the crop was expected to mature. The common implement used in harvesting was either a pointed wooden/iron stick or a pointed bolo.

Harvesting was mostly done by housewives (90%), sometimes with the assistance of the husbands (37%). Participation of children (male and female) in this task was low.

Each hill was dug with care during harvesting. This was the reason given by husbands as to why the women usually did this task. Besides, this task was considered "light and easy" by the men. Decisions related to harvesting were carried out by the housewives.

Table 5. Percent distribution of areas of decision-making in sweet potato farming activities.

Area	Husband	Wife	Son	Husband & wife	Husband, wife, children & others	Not practiced	Total
Land preparation (N = 90)							
Sequence of operation	93	2	1	4	–	–	100
Timing of each operation to rains	93	2	1	4	–	–	100
Equipment used in each operation	91	3	1	4	–	–	100
Variation on method with seasonal condition	92	3	1	4	–	–	100
Planting (N = 90)							
Varieties used	62	9	–	29	–	–	100
Density and spacing	59	5	–	30	6	–	100
Density and spacing of interplanted crop	24	6	–	8	–	62	100
Time of planting in relation to rains	73	5	10	12	–	–	100
Spread of planting date	79	3	10	8	–	–	100
Sequence of inter-planting crops	27	4	–	7	–	62	100
Method of planting (hills, broadcast, etc.)	47	2	–	32	19	–	100
Practice of replanting part or whole field	21	6	–	6	–	67	100

Table 5 (continued).

Weeding (N = 89)							
Number of weedings	75	9	–	13	3	–	100
Timing of each in relation to planting	78	10	–	12	–	–	100
Equipment used in weeding	75	9	–	14	2	–	100
Use of weeds	54	9	–	20	17	–	100
Harvesting (N = 90)							
Timing of harvest in relation to maturity	31	48	–	21	–	–	100
Method of harvesting	16	60	–	22	2	–	100
Use of leaves and tops for animals/man	36	51	–	13	–	–	100
Timing and method of picking leaves and tops	36	50	–	12	2	–	100
Storage	(Not practiced)						
Transporting and carrying of farm products (N = 90)							
Type of transport used	35	32	–	11	22	–	100
Method of transport	48	33	–	10	9	–	100

Table 5 (continued).

Marketing (N = 40)							
Method of selling	32	48	2	18	—	—	100
Type of buyers	30	50	2	18	—	—	100
Timing of selling	30	50	2	18	—	—	100
Transporting and carrying farm products	40	17	—	5	38	—	100
Method of transport when selling	33	17	—	5	45	—	100
Quantity to sale	33	42	—	22	3	—	100
Processing (N = 90)							
Method of processing	4	94	—	1	1	—	100
Type/kind of process product	4	94	—	1	1	—	100
Equipment/tools used	4	94	—	1	1	—	100

Transporting and carrying the produce

In some cases, transporting and carrying the produce to the house or market was done by the husbands (67%). Some of the sons helped. Housewives (51%) also usually carried the harvested crop to their houses after harvesting. This was usually the case if the sweet potato field was near their houses. Decisions related to this activity were made either by the husband or wife.

Processing and utilization

There are several ways of processing sweet potato. However, all respondents in the study area boiled the roots for their regular meals or snacks. Boiled roots were usually used as substitute for cereals. Other processed products were *baduya, maruya, bitsu-bitso,* candy, chips, camote cue, *sinaging,* and *ira-id.* The products were processed by the household members. The wives were mostly the processors, assisted by the children. Husbands seldom helped in processing. If they did, they helped in grating and in providing fuel for cooking. The wife and the children did the cooking and molding. If the processed products required wrapping, then this was done by the wife and the children.

Sweet potato was also processed for feeds. The roots were boiled and then fed to animals, mostly swine. The wives, assisted by their children or husbands, cooked the roots for feeds. Decisions related to processing were generally made by the housewives.

Marketing

Very few of the sweet potato household respondents marketed their produce except for some processed products. For fresh sweet potato roots, a few reportedly delivered their products to the town proper. Processed products, except boiled ones, were sold at school canteens during schooldays, cockpits during cockfights, town markets, local stores, and even in the processor's own place. Housewives, being in charge of money matters, were also in charge of marketing; they were assisted by the children. Decisions related to this activity were made by the wives.

SUMMARY AND IMPLICATIONS

The findings indicated that joint farming and decision-making were carried out by males and females in sweet potato production, processing, and utilization. There were also particular activities in which women were more involved and their decisions compared to those of the men carried more weight. Generally, women (housewives and daughters) tended to concentrate on certain farm practices such as planting, weeding, harvesting, marketing, and processing. The men were charged with land clearing, plowing, and transporting the produce. Except in processing, decisions related to sweet potato production were mostly made by the husbands. However, the wives, sons, and daughters were always supportive.

Apparently, the urgency to increase overall production and the very limited farm resources were the reasons for the housewives' and daughters' high level of involvement in sweet potato farming. Majority of the root crop farmers could not afford to finance farm activities, thus, most family members worked together in the various agricultural tasks to operate their small farms.

The general aim of conducting research on sweet potato was to assist farmers achieve adequate supply of the crop for food and increase their cash income to enable them to buy other necessities in life. Because the women, particularly the housewives, participated in decision-making and in crop production, it was essential that they should be involved in the sweet potato research program. In farmer-managed trials, the farmers revealed their reactions to the technologies, enabling the researcher to make necessary modifications and adjustments. Thus, farm trials and research would realize even better results if the farm women were actively involved from the beginning. Technologies and information related to planting, weeding, and harvesting of sweet potato should be designed from and disseminated to women because they did these tasks more than men. Furthermore, since women performed more of the processing and marketing functions, they were in a better position to provide reliable information on the size, shape, texture, color, taste, moisture content, shelf life, and other preferred characteristics of the crop. Such information would help the researcher in developing varieties and technologies that are acceptable to end-users.

REFERENCES

Alkuino, J.M. 1986. Comparative cost and return analysis of indigenous technologies in rural processing of sweet potato and cassava. IDRC-Funded Research Project. ViSCA, Baybay, Leyte, the Philippines.

Bauman, H. 1928. The division of work according to sex in Africa hoe-culture.

FAO. 1973. Participation of women in agricultural production.

FARMERS' RESPONSE TO VISCA SWEET POTATO VARIETIES

Monina M. Escalada and Ester L. Lopez*

ABSTRACT

Two technologies developed from root crop production and processing projects were evaluated in terms of farmers' responses to them. The results of the evaluation of one of the technologies are: l) VSP varieties/lines have been distributed nationwide in a relatively short span of time, 2) VSP's yield potential is appreciated by both small farmers and big growers, 3) VSP's short-maturing characteristic is most appreciated in typhoon-affected areas, 4) VSP varieties enable farmers to intensify land use, 5) government planners and private entrepreneurs now consider sweet potato as a possible viable intercrop, 6) excess supply of sweet potato generates processing activities, 7) increased supply of sweet potato also benefits the consumers in terms of lower price, 8) officially approved sweet potato varieties may not necessarily be the farmers' choice, 9) farmers make certain adjustments in the technology or environment to fit their specific needs and resources, l0) the positive attributes of VSP generally outweigh its negative qualities, and ll) farm size and farm resources are not critical factors in the acceptance of sweet potato varieties.

INTRODUCTION

Research significantly increases agricultural productivity among farmers by developing appropriate technologies for their adoption. This increased productivity results when a new product or process is introduced, product quality is enhanced, or the risk of crop failure of the farmer is reduced (Arndt and Ruttan, l977). Evidence shows that the rates of return of investment in agricultural research in Western countries have been two or three times higher than those in other agricultural investment.

While research literature is replete with quantitative cost-benefit analyses of the economic impact of research-generated technologies,

*Professor, Department of Development Communication, Visayas State College of Agriculture, Baybay, Leyte, the Philippines, and Senior Science Research Specialist, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Los Banos, Laguna, the Philippines, respectively.

some technologies have not been widely adopted because the social, economic, and political systems constrain their wider utilization.

An early assessment of the extent of a technology's diffusion and adoption and its socioeconomic impact is essential in order to provide some preliminary indications of the benefits that have been gained from the application of the technology as well as the problems encountered in its use.

In the case of the ViSCA sweet potato (VSP) varieties developed through an IDRC (International Development Research Centre)-PCARRD-ViSCA research program, an exploratory qualitative analysis of the returns of research investment would be useful to funding agencies in rationalizing the allocation of their research resources. This evaluation may convince policymakers and research managers to extend or limit support to these activities. Information on farmers' response to recommended varieties, however, is a significant input in any breeding program. Information on the process and extent of technology diffusion would guide research and extension managers in planning and managing technology diffusion activities.

This paper discusses the results of a follow-up study carried out in selected areas in the Philippines to determine the following:

- Extent of geographical distribution of the ViSCA-developed sweet potato lines and varieties and their performance in small farmers' fields and big sweet potato plantations under monoculture conditions.
- Impact of the sweet potato hybrids and varieties on multiple cropping.
- Extent of the use of sweet potato hybrids in emergency areas and situations such as typhoon-devastated places and economically depressed geographical regions such as coconut and sugarcane areas where depressed world prices of coconut products and sugar had taken their toll.
- Extent to which sweet potato is being used for animal feed and other commercial purposes.
- Extent of the use of village-level storage technology for fresh cassava and sweet potato roots.

METHODOLOGY

The evaluation was carried out by a social scientist and a biological (crop) scientist. It included a review of project documents and related literature; a series of interviews with project leaders, research administrators, local government officials, Department of Agriculture (DA) officials, and research assistants; visits to on-farm trial sites in Leyte and Southern Leyte; and interviews with farmer-cooperators and noncooperators.

In areas where there were cooperators, the approach was to contact and engage them in an informal discussion about their experience with either or both of the two root crop technologies they have tried: sweet potato varieties and village-level storage of fresh cassava and sweet potato roots. Later, noncooperators who had tried the technology were engaged in conversation to find out their impressions and sources of information. These informal talks enabled the researchers to obtain indications of adoption and changes in income, yield, and production systems brought about by the use of the root crop technologies. Since farmers harvested their root crops on a staggered basis, their lack of farm records complicated their recall of yield and production data. Hence, the evaluation's indicators of the technology's impact on income are merely qualitative effects of additional income (i.e., ability to buy rice, fish or meat; pay hired labor; and support children's schooling).

The use of a structured interview schedule or written questionnaire as a principal data collection instrument was ruled out early in anticipation of farmers' general reluctance to speak candidly in a formal question-and-answer session. Instead, these informal discussions with farmers and other key informants were guided by a short list of vital issues obtained from the proposal.

RESULTS AND DISCUSSION

A. VSP varieties/lines have been distributed nationwide in a short span of time.

VSP varieties developed by ViSCA-PRCRTC have been introduced in all regions of the Philippines through various channels. Foremost among these channels is a government-supported program of the Bureau of Animal Industry-Department of Agriculture (BAI-DA) called "Feed Root Crops ng Barangay Program." The program initiated the establishment of a number of seedbanks in various regions of the country. These seedbanks serve as sources of sweet potato planting materials for the region or area where they are located. The ultimate objective of the program is to encourage backyard livestock production. Planners of this program are convinced that with the high-yielding characteristic of VSP, the growers will produce sweet potato for feeds either in fresh form or chips.

A notable scheme observed in Leyte and Southern Leyte that could have contributed greatly to the distribution of cuttings and eventually in the dissemination of the technology is the farmer-to-farmer mode of distribution. Neighbors and relatives who were farming in the same or nearby barangays (villages) asked for cuttings from the farmer-cooperators. One farmer-coöperator gave cuttings to 30 farmers; another shared cuttings with more than 50 farmers. Noncooperators were encouraged by the yield that the farmer-cooperators were getting. Because of this, it is highly possible that another transfer is made from farmer-recipients to other farmers.

Several factors contributed to the speed of distribution, namely:

- Interest generated by the technology among public and private institutions and individuals.
- International and national economic situation (e.g., low price of sugar in the world market, which pushed sugarcane planters to look for viable alternative crops).
- High cost of inputs which made the farmers seek or concentrate on crops that do not need oil-based inputs or one that will give good yield even with animal inputs.
- The active stance taken by ViSCA-PRCRTC in promoting its technologies. While other research agencies stopped at technology generation or development, ViSCA-PRCRTC made vigorous efforts to "sell" the ViSCA-developed varieties through various media.
- Occurrence of natural calamities such as typhoons and volcanic eruptions in 1984 and early 1985 which left the farmers with no option except to plant crops with the shortest maturity period and which were readily available to them. VISCA's effort to have readily available planting materials for the users.

B. VSP'S yield potential is appreciated both by the small farmers and big growers.

Farmers who have successfully grown the new hybrids unanimously declared that ViSCA-developed sweet potato varieties yielded more than the native varieties. As a result, some entirely shifted to VSP varieties while others continued to plant both VSP and native varieties.

For small farmers, increased yield means more product to sell or barter and, consequently, more cash to pay for their children's school fees. Many farmers also indicated that because of the high yield of the VSPs, they were able to market some of their produce. Before the introduction of ViSCA sweet potato hybrids, the yield from their native varieties was just enough for their food needs.

For big growers, particularly the beleaguered sugarcane planters, the high-yielding attribute of VSPs encouraged them to venture into large-scale production of sweet potato. The advent of VSP also provided them with a viable alternative crop to sugarcane whose price plummeted in the world market.

Also, a former sugarcane planter narrated the timely presence of the high-yielding sweet potato varieties which came at a time when he was all set to dismiss many sugarcane workers because of poor income from sugarcane production. Sweet potato production made him decide to retain them, thus helping alleviate the unemployment problem in his province.

C. A short-maturing crop is most appreciated in typhoon affected areas.

In Padre Burgos, Southern Leyte, people from all walks of life were one in saying that VSPs have helped many people in their town, especially after a strong tropical typhoon (Nitang) with 220-km/hr winds battered the Eastern Visayas region in September 1984. Aside from their high yield, the people liked the short maturity period of the varieties which enabled them to avail themselves of a food source within 3 months.

D. VSP varieties contribute to land-use intensification.

Other farmers gained in a different manner from VSP's short maturing characteristic. A case in point is a farmer-cooperator who has planted sweet potato five times in two years since VSP matures within three and one-half months from planting. Another farmer who intercropped sweet potato with corn noted that because of intercropping, she needed a crop with a shorter growing season like VSP.

E. Excess supply of sweet potato generated processing activities.

The high yield of VSPs has encouraged some families to venture into processing and selling native delicacies. Village-level processing provided source of income and generated more employment opportunities.

Farmer-respondents pointed out that processing sweet potato into delicacies brought in more income than selling the roots fresh. This extra income enabled them to support their children's education and pay for other household needs.

F. Officially approved varieties may not necessarily be the farmer's choice.

Farmers have their own definite set of criteria on the technology that they will adopt. When farmers in Leyte and Southern Leyte were given the chance to select among Philippine Seed Board-approved sweet potato varieties and some advanced lines, a significant number of them chose the advanced lines, namely: V-11 and V2-42. The farmers based their selection on yield, eating quality, pest resistance, and drought tolerance.

Farmers recognized that ViSCA sweet potato hybrids were all high-yielding but there were characteristics other than yield that mattered to them. Farmers found that the tuberous roots of V-11 and V2-42 were flaky and less moist-fleshed; both characteristics were also found in their native varieties.

Some farmers also claimed that these advanced lines gave better yield than the Philippine Seed Board-approved lines. It should be noted that under the scheme set by the Philippine Seed Board, advanced lines are screened only under major agroclimatic areas in the Philippines and final recommendation is based on the overall performance of entries. Hence, it is likely that an entry that did very well in one region but performed poorly in another will not be selected for consideration as an officially approved variety. But, as the study shows, a farmer, if given the chance to do his own screening, will select what is best for his specific conditions and needs.

G. In most cases, the positive qualities of VSP outweigh its negative properties.

Farmer respondents were quite emphatic on their perception of the overall performance of VSPs. Generally, they would first talk about the better harvests that they got and the shorter waiting period between planting and harvesting. However, they would later mention one or two negative aspects of VSP based on their experiences. Frequently mentioned was the "wet-taste" of the cooked roots, especially of VSP-1. Many farmers also observed that VSPs were less tolerant to drought than the native varieties. Others complained that VSPs were more "prone to thieves" because the roots could easily be pulled. Owing to the VSPs' shallow root system, roots were also easily eaten by rats. In spite of these experiences, farmers continued planting VSPs. Majority of these farmers have expanded or were planning to expand their farm area planted to VSPs. This development shows that the farmers based their decision to adopt the technology on the overall performance of the new hybrids. Although they recognized certain negative qualities of VSPs, the benefits that they got out of planting them, such as higher yield and income, offset the undesirable qualities observed.

H. Farmers make certain adjustments in the technology or their environment to fit the technology according to their specific needs and resources.

In resource-poor conditions, farmers have to adopt the new technology to make it suitable to their situation. This is demonstrated in Villaba, Leyte, where upland farmers extensively grew VSP on plain or contoured hillsides. Since VSP does not form vines as much as native varieties, farmers who planted VSP on steep slopes discovered that during the rainy season, VSP does not produce fleshy roots because the soil around the main roots is washed down by run-off water. In contrast, the native varieties produce runners and thrive well on steep hillsides even on rainy months. Villaba farmers have learned to adjust to the bushy characteristic of VSP by planting it in lowlands or contoured areas and reserving native varieties for steep slopes. They did not reject the technology but made adjustments to accommodate it.

IMPLICATIONS AND RECOMMENDATIONS

While most small farmers interviewed appreciated the high-yielding quality of VSPs, they also emphasized eating quality and vegetative characteristics which were not compatible with high yield. In developing a variety for these farmers, the sweet potato breeding program should strive for a slight increase in yield and pest resistance and at the same time maintain the desirable characteristics (e.g., high dry matter content, creeping characteristics for hilly land, and sweet taste).

Care should be taken in choosing the cooperating stations for on-station trials to test the technology and eventually disseminate it. Commitment, capability of the researcher, and available resources of the station should be prerequisites. One cooperating station went out of its way to disseminate the technology. In contrast, some researchers in other stations were not fully aware of the features of VSPs. As a result, information about the VSPs was not disseminated.

There may be a need for the Philippine Seed Board to reconsider its criteria in selecting varieties and institute a varietal screening mechanism for regional rather than national recommendations.

Institutions responsible for the development of agricultural technology that generates initial planting materials should be ready to support the national extension service or the Department of Agriculture in its initial technology dissemination efforts. During the early stage of technology dissemination, it is important to involve the technology developers because they are in a better position to recommend technical modifications or solutions to users. Also, the feedback obtained from direct contact with users serves as input in subsequent development activities.

The VSPs have different levels of dry matter content. To adapt the VSPs to buyers' taste, growers of VSP-l and VSP-2 advise their buyers to cook the roots in little water or steam them on banana bracts. Others, however, have discontinued planting the moist-fleshed varieties because of the undesirable watery consistency. It is apparent that lack of information on which varieties are best for food and which are suited for animal feed has constrained the proper utilization of VSPs. At the technology dissemination stage, it is important to provide field technicians and the mass media complete information on the desirable characteristics and limitations of the varieties. A leaflet or bulletin that describes all features of VSPs would greatly help in teaching both farmers and technicians about the potentials of the varieties for specific use.

REFERENCE

Arndt, T. M. and V. W. Ruttan. 1977. Valuing the productivity of agricultural research: problems and issues. *In* Resource allocation and productivity in national and international agricultural research. University of Minnesota Press. Minneapolis, USA.

ECONOMIC TESTS FOR PROFITABILITY, MARKETABILITY, AND ALTERNATIVE USES OF SWEET POTATO IN THE PHILIPPINES

Nerelito P. Pascual*, Antonio P. Abamo**, and
Ma. Salome G. Binongo**

INTRODUCTION

The economic potential of sweet potato farming is now widely recognized. However, among the more important questions that farmers should answer before they engage in sweet potato farming are the following:

- Is it profitable?
- If profitable, how does its profitability compare with other crops/enterprises?
- What is the optimum input requirement for each sweet potato variety?
- How can we elevate the status of sweet potato from being a "commodity of the poor" to being a crop for everybody?
- What major characteristics of sweet potato varieties are most preferred by buyers and consumers?
- How acceptable and marketable are the new sweet potato varieties developed by ViSCA?
- To maximize return, under what market condition should the farmer:
  - sell sweet potato as fresh root?
  - process sweet potato and sell it as chip?
  - use sweet potato as ingredients for animal feeds?
  - use sweet potato as major material for flour mills?
  - use sweet potato as major material for processed products?

In an attempt to provide answers to the above questions, three related studies dealing with sweet potato profitability, marketability, and its alternative uses were undertaken.

*Professor and **Instructors, Department of Agricultural Economics and Agribusiness, Visayas State College of Agriculture, Baybay, Leyte, the Philippines.

PROFITABILITY STUDY

Cost-Return Analysis Under Experimental Conditions

Data pertaining to cropping seasons in 1982 and 1983 were gathered from the following stations: (1) ViSCA Baybay, Leyte; (2) Bohol Experiment Station, Ubay, Bohol; (3) Albay Experiment Station, Tabaco, Albay; and (4) Romualdez Experiment Station, Babatngon, Leyte.

The high-yielding varieties/cultivars included in the analyses were BNAS-51, Catanduanes 3, Daja, I_8 -328, I_8 - 498, Kabiti, Kadja, Kinabakab, Lo-323, Tinipay, VSP-1, VSP- 2, and VSP-3. VSP-1, a variety developed by ViSCA, yielded 19.7 t/ha, the highest among the 13 entries (Table 1). The other ViSCA varieties, VSP-2 and VSP-3, yielded 18.6 t/ha and 15.3 t/ha, respectively.

Table 2 presents the cost and computed net returns of the 13 entries. Three kinds of net returns are presented in the table. Net return A reflects the earnings of land, labor, capital, and management; net return B measures the earnings of land, labor, and management; and net return C indicates the return to land and management. Some farmers, especially the small ones, may use net return A as a measure of profit while the commercial farmers may adopt net return C. The data revealed that the entry with the highest net return was VSP-1, which gave P22,438/ha as its return to land and management.

Cost-Return Analysis Under Farmers' Field Conditions

The data covered the period from May 1984 to February 1987 and were gathered from farmer-cooperators in Ormoc, Matalom, and Julita, all in the province of Leyte.

Table 3 shows the yields of the five ViSCA sweet potato varieties, which ranged from 5.52 t/ha (VSP-3) to 8.78 t/ha (VSP-5). In 1984, VSP-4, although a new variety, was already tested in farmers' field as cultivar V-27. The other new variety, VSP-5, was tried in farmers' fields only in 1986.

Analysis of the cost and return of the five entries is presented in Table 4. Three kinds of net returns were also computed. Among the five ViSCA varieties, VSP-5 obtained the highest net return C of P7,927.18/ha. This was followed by VSP-4, VSP-1, VSP-2, and VSP-3, in descending order.

Profitability of Sweet Potato Compared With Other Major Crops

To compare the profitability of sweet potato farming with other crop enterprises, data on cost and return of selected crops were gathered. The analyses are summarized in Table 5. Comparison among Tables 2, 4, and 5 indicates that the high-yielding ViSCA sweet potato varieties yielded a

Table 1. Production (t/ha) of selected sweet potato varieties/cultivars grown in the different experiment stations, 1982-1983.

Variety/Cultivar	Dry season*		Wet season**		Average	
	Yield (t/ha)	Value*** (₱)	Yield (t/ha)	Value*** (₱)	Yield (t/ha)	Value (₱)
BNAS-51	8.83	16,518.33	10.83	14,730.47	9.83	15,624.40
Catanduanes 3	13.67	25,420.01	12.66	17,971.17	13.16	21,695.59
Daja	12.60	22,050.00	11.97	16,397.57	12.28	19,223.79
I8-328	15.47	28,613.34	17.09	25,125.30	16.28	26,869.32
I8-498	15.23	28,486.33	13.76	20,085.98	14.50	24,286.16
Kabiti	14.55	26,044.50	17.92	25,260.21	16.23	25,652.36
Kadja	9.35	16,549.50	14.54	20,209.74	11.94	18,379.62
Kinabakab	14.20	26,412.00	14.81	22,210.01	14.50	24,311.01
Lo-323	16.40	29,848.00	22.04	32,405.05	19.22	31,126.53
Tinipay	15.23	28,181.66	15.41	21,723.12	15.31	24,952.39
VSP-1	21.17	38,946.67	18.21	26,400.32	19.69	32,673.50
VSP-2	16.37	30,278.34	20.78	29,502.70	18.57	29,890.52
VSP-3	13.57	25,369.67	16.98	23,426.41	15.27	24,398.04

*Weighted average of 3 experiment stations: ViSCA, Bohol, and Albay.

**Weighted average of 4 experiment stations: ViSCA, Bohol, Albay, and Babatngon.

***Based on the prevailing market price in the area at the time of survey.

Table 2. Value of production and net return per hectare of selected sweet potato varieties/cultivars grown in the different experiment stations, 1982-1983 (average of dry and wet seasons).

Variety/ Cultivar	Value of production* (₱)	Expenses (₱)			Net return (₱)		
		Supplies & materials	Imputed Interest to Capital	Labor	A (return to land, labor mgt., & capital)	B (return to land, labor, & mgt.)	C (return to land & mgt.)
BNAS-51	15,624.40	3,620.31	344.92	5,577.47	12,004.10	11,659.18	6,081.72
Catanduanes 3	21,695.59	4,051.39	366.55	5,723,16	17,644.20	17,277.66	11,554.50
Daja	19,223.79	3,900.76	361.78	5,746.05	15,323.03	14,961.25	9,215.20
I8-328	26,869.32	4,145.54	370.06	5,723.16	22,723.78	22,353.73	16,630.57
I8-498	24,286.16	4,064.50	367.04	5,723.16	20,221.66	19,854.63	14,131.47
Kabiti	25,652.36	4,370.14	379.38	5,746.05	21,282.22	20,902.84	15,156.79
Kadja	18,379.62	3,884.91	361.19	5,746.05	14,494.72	14,133.53	8,387.48
Kinabakab	24,311.01	3,976.85	354.09	5,563.86	20,334.16	19,980.08	14,416.22
Lo-323	31,126.53	4,860.09	397.76	5,746.05	26,266.44	25,868.69	20,122.64
Tinipay	22,952.39	3,867.90	354.20	5,577.47	21,084.50	20,730.30	15,152.83
VSP-1	32,673.50	4,285.50	372.12	5,577.47	28,388.00	28,015.88	22,438.42
VSP-2	29,890.52	4,115.58	368.93	5,723.16	25,774.94	25,032.51	19,682.86
VSP-3	24,398.04	4,506.52	383.62	5,723.16	19,891.53	19,507.91	13,784.76

*Taken from the last column of Table 1.

Table 3. Production (in tons/ha) of ViSCA sweet potato varieties/cultivars grown in the different farmers field, 1984-1986.

Variety/ cultivar	1984 Yield*	1984-1985 Yield**	1986-1987 Yield***		Average	
			Ormoc	Matalom	Yield	Computed value****
VSP-1	3.28	7.90	6.57	6.09	5.96	8,942.73
VSP-2	5.48	8.88	5.26	3.52	5.78	8,673.13
VSP-3	3.26	7.58	6.68	4.56	5.52	8,281.98
VSP-4	7.13	8.32	11.76	7.74	8.74	13,104.93
VSP-5	–	–	13.45	4.12	8.78	13,177.18

*Average from 3 locations (Ormoc, Matalom, and Julita) during the May-October 1984 period.
**Average from 2 locations (Matalom and Julita) during the September 1984-March 1985 period.
***Data during the September 1986-February 1987 period.
****Based on a farm gate price of ₱1.50/kg.

Table 4. Value of production and net returns per hectare of ViSCA sweet potato varieties/cultivars grown in the different farmers fields, 1984-1986.

		Expenses (₱)			Net return (₱)		
Variety/ cultivar	Value of production* (₱)	Supplies and materials**	Imputed interest to capital***	Labor****	A (return to land, labor, management & capital)	B (return to land, labor & management)	C (return to land and management)
VSP-1	8,942.73	3,500.00	247.00	1,450.00	5,442.73	5,195.73	3,745.73
VSP-2	8,673.13	3,500.00	247.00	1,450.00	5,173.13	4,926.13	3,476.13
VSP-3	8,281.98	3,500.00	247.00	1,450.00	4,781.98	4,534.98	3,084.98
VSP-4	13,104.93	3,500.00	250.00	1,500.00	9,604.93	9,354.93	7,854.93
VSP-5	13,177.18	3,500.00	250.00	1,500.00	9,677.18	9,427.18	7,927.18

*Taken from the last column of Table 3.

**Based on 33,000 cuttings/ha at ₱10/cutting plus other supplies worth ₱200.00/ha.

***Total cash requirements multiplied by 15% per annum (or 5% for 4 months).

****Total man-days from land preparation to harvesting. multiplied by ₱25.00.

Table 5. Costs and returns of selected crops in the Philippines grown in various locations.

Crop	Gross income		Expenses (₱)*****			Net return (₱)		
	Yield (kg)	Value***** (₱)	Supplies and materials	Imputed interest to capital	Labor	A (return to land, labor management & capital)	B (return to land, labor, management & capital)	C (return to land, labor, & management)
Rice, lowland*	2,650	7,950	590	117	1,750	7,360	7,243	5,493
Rice, upland**	1,720	5,160	232	74	1,250	4,928	4,854	3,604
Corn, HYV**	1,230	3,690	240	75	1,250	3,450	3,375	2,125
Corn, traditional**	617	1,851	138	70	1,250	1,713	1,643	393
Mungo**	540	6,400	600	92	1,250	5,800	5,708	4,458
Mungo***	800	9,600	1,158	134	1,525	8,442	8,308	6,783
Peanut****	1,300	10,400	2,110	187	1,625	8,290	8,103	6,478

*Technical data were taken from rice farms in Gabas, Baybay, Leyte, as reported by Hermoso (1985).

**Technical data were taken from farms in San Isidro, Leyte, as cited in SIRSDP Annual Report (1984).

***Technical data were taken from "The Philippine Recommends for Mungo, 1977" (PCARR, 1977).

****Techical data were taken from "The Philippine Recommends for Peanut, 1978" (PCARR, 1978).

*****Based on 1986 prices.

return to land and management ranging from P13,785/ha to P22,438/ha when grown under experimental field conditions (Table 2). When grown under farmers' field conditions, these varieties yielded a net return ranging from P3,085/ha to P7,927/ha (Table 4). On the other hand, the return to land and management for the other major crops such as rice, corn, peanut, and mungo ranged from P393/ha to P6,783/ha.

Findings revealed that when VSP-1, VSP-2, and VSP-3 were grown in farmers' fields (with no commercial fertilizers), their net returns were very much lower than the average net returns obtained from mungo, peanut, and lowland rice. However, when these were planted in experimental stations (with fertilizers and other inputs), their net returns were more than twice those of other crops (rice, mungo, peanut).

Optimum Input Levels

To determine the optimum fertilizer input requirements of the ViSCA sweet potato varieties, farmer-cooperators were requested to plant each variety on various levels of fertilizer applications. Results during the period from September 1986 to March 1987 are summarized in Figure 1. The fertilizer levels used during this cropping season ranged from 0-0-0 (N-P-K) per hectare to 60-60-60 (N-P-K) per hectare.

Triple 14-14-14 complete fertilizer costing P186 per 50-kg bag (or P26.57/kg of N-P-K) was used. The average farm gate price of sweet potato in these locations was P1.50/kg. The optimum fertilizer level during this period would therefore mean that for every additional kilogram of fertilizer (costing P26.57) applied to the farmer's field, the additional yield of sweet potato must be at least 17.71 kg (valued at P26.57). But since the fertilizer study was at 15 kg intervals, the optimum input level would roughly mean that a 15-kg increase in fertilizer application (costing about P400) must be accompanied by at least 266 kg additional yield of sweet potato.

In the Ormoc area, the first trial results revealed that the application of 15-15-15 kg of N, P, and K per hectare was optimum for VSP-1, VSP-4, VSP-5, and Tongonan (native) varieties. The optimum fertilizer for VSP-2 and VSP-3 was the 45-45-45 level. In the case of the Matalom area, the 15-15-15 level was again optimum for VSP-1. The 30-30-30 kg of N, P, and K per hectare was optimum for VSP-3, VSP-5, and Siete Flores (native) while the 45-45-45 fertilizer level was optimum for VSP-2 and VSP-4.

On the other hand, in Maasin, Southern Leyte, the optimum yield for VSP-1 was on the 30-30-30 level, while the other ViSCA varieties (VSP-2, VSP-3, VSP-4, and VSP-5) responded favorably up to the 60-60-60 kg/ha of N, P, and K.

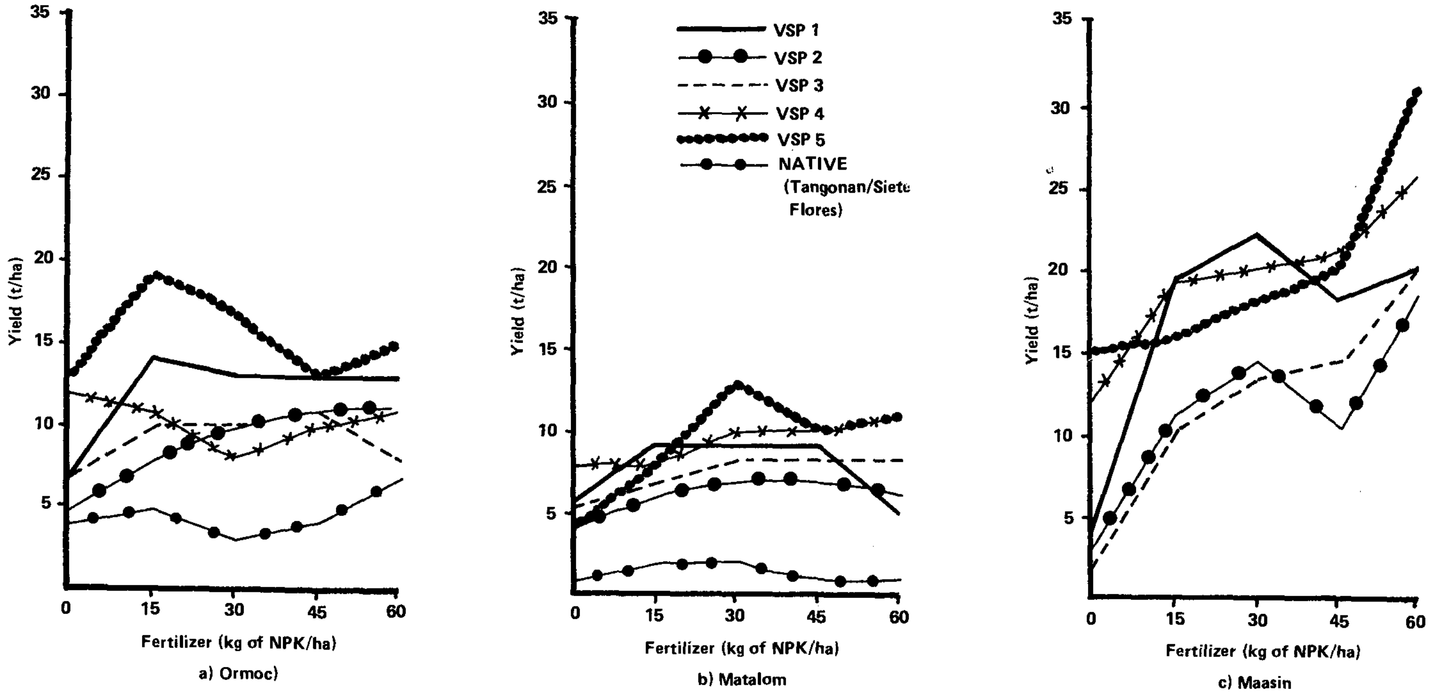


Figure 1. Yield of selected sweet potato varieties on various fertilizer levels in Ormoc, Matalom, and Maasin, September 1986 – March 1987.

MARKETABILITY STUDY

Marketing Practices*

Preselling operations

Harvesting. Sweet potatoes were usually harvested 3-4 months after planting. There were two common methods of harvesting: (1) digging or staggered method, and (2) plowing or all-out method. Digging was done by harvesting only the bigger roots, leaving the smaller ones to reach the desired size. The all-out method was done by plowing the entire field once the crop reached the expected maturity and the roots were picked up in the field. Findings revealed that the subsistence farmer adhered more to the staggered method of harvesting and plowing was more applicable to the market-oriented farmer. Staggered harvesting, which usually started before maturity, allowed the crop to stay longer in the field. The quantity harvested by the subsistence farmer at a given time depended on the consumption of the family, which sometimes included a certain quantity for the market. On the other hand, the market-oriented farmers harvested the entire crop at maturity and sold out to different outlets at the shortest possible period to minimize the problem of storage.

Harvesting methods did not necessarily vary in Leyte and in other places but differences observed were only in how a certain method was applicable to the farmer under a given situation.

Standardizing. In Leyte, it was observed that grading, sorting, and packaging in kerosene cans and even hauling were done by local buyers themselves. However, in other places (Region XII in Mindanao, Southern Philippines), the roots were chipped and dried by the farmers/producers since they were selling it to wholesaler-exporter (Year 1 report of Project 5, PCARRD/IDRC No. 3, 1985).

Transporting. Transport and delivery operations differed in various locations depending on the availability of transportation facilities. In Leyte, farmers transmitted sweet potatoes from the farm to the market with the use of carabao-drawn carts, jeepneys, motorcycles, and pedicabs. In some areas of Mindanao and other parts of Luzon, especially the Bicol region, the buyer-exporter absorbed the transport cost from the buying station (Farmer's Association) to the point of destination. The farmer, however, hauls the produce from the farm to the buying station using either a tricycle, carabao/horse-drawn bamboo sled, or jeepney. In Leyte, the greatest transport cost incurred was for jeepneys (Year III report of Project 5, PCARRD/IDRC No. 3, 1987).

---

*This section is based mainly on the reports of Villanueva (1980) and annual reports of PCARRD-IDRC No. 3 Project 5 (1985, 1986, and 1987).

Selling operation

In Leyte, it was noted that volume sold out was low in June and higher in January. This pattern was more or less the same in the Bicol region. In Mindanao (Region XII), they grew sweet potato the whole year round. Of the total volume of fresh roots recorded in Leyte, a large part was sold to wholesalers who channel the produce to retailers and consumers, leaving a very small portion of the volume sold for processing as food. In other places, the farmers/planters, through the assistance of the association, processed the sweet potato into chips to be sold to wholesalers-exporters (Year III report of Project 5, PCARRD/IDRC No. 3, 1987).

New Selling Strategies Tried Out*

To ascertain whether fresh roots of sweet potato can penetrate the supermarket, thus elevating its status as "a crop for the poor and the unsuccessful" to that of a commodity also of the affluent, new marketing strategies were tried out. The first innovation was used in 1984. In this method, net bags of three sizes (small, medium, and large) were prepared out of white nylon net screen to serve as packing materials for sweet potato. The prepacked sweet potato tubers with labels were advertised and sold at two big stores (City Fair at Ormoc City and ViSCA Cooperative Store).

Toward the end of 1985 and early part of 1986, another new marketing method was tried out. This time, instead of the net bag, a cellophane of 14" x 8" was used as packaging material. The l-kg capacity cellophane was punched with holes for ventilation and the prepacked sweet potato with labels was advertised and sold in the following department stores in Cebu City: Gaisano South, Gazini Plaza, Rustan's Superstores, Gaisano Metro, and Gaw Food Square.

The Ormoc and ViSCA experience

After six months of selling operation, the following observations were noted:

- All ViSCA sweet potato varieties brought to the stores (averaging 200 kg per delivery in Ormoc City and 50 kg in VISCA) were purchased within one to two days.
- Fifty-two percent of the buyers preferred to buy sweet potato in prepacked form for three reasons: convenience, less time spent, and sanitation. A 3-kg package was usually preferred by those who

*This section is based mainly on the annual reports of Study 2 of PCARRD-IDRC No. 3 Project 5 entitled Marketability and Market Channels of Various Sweet Potato (1985 and 1986).

bought the prepacked form. Volume- wise, however, 75 percent of the total volume sold was bought unpacked.

- VSP-1 was highly demanded by the Chinese customers because it was soft and sweet; VSP-2 by consumers who preferred to eat boiled sweet potato tubers because of its sweetness, fine texture, and dryness; and VSP-3 by the camote-cue* makers. In general, VSP-2 was the most preferred variety by the consumer-respondents.
- In general, the consumers were satisfied with the overall quality of VSP varieties.

The Cebu experience

There were more buyers in Cebu than in Ormoc. It was because there were five department stores that served as outlets of the ViSCA sweet potato.

Volume-wise, however, sales in the five outlets during the six-month period were very much lower (about 14,000 kg only) than those in Ormoc for the same length of time (about 24,000 kg). The reason was that, in general, buyers of sweet potato from Cebu department stores purchased the commodity in one-kg package only. Most of these small-quantity buyers used sweet potato as alternative source of snack items and they bought sweet potato only once a week.

It was noted that these small buyers included students but the majority were college graduates engaged in gainful occupations. Their family's annual income ranged from P8,400 to P230,000 and the majority had income above P30,000 per annum. Moreover, although they were generally satisfied with the ViSCA sweet potato they purchased, they were not very particular of the specific variety they liked most.

The characteristics that attracted most of the consumers included attractive color (both external and internal), sweetness, fine flesh texture, and manner of selling. On the other hand, some respondents, especially the nonrepeat buyers, said that the high moisture content and weevil-infestation of some tubers were the things they did not like.

While volume sold in Cebu department stores was very much lower than that in Ormoc, this did not mean that there were no big buyers of sweet potato in Cebu. Investigation revealed that large quantities of sweet potato were available in public markets, especially in the Carbon area. It was noted that large-quantity buyers preferred to buy sweet potato in public markets rather than in department stores.

---

*Local delicacy from fried fresh sweet potato mixed with sugar.

STUDIES ON ALTERNATIVE USES

Sweet Potato For Chips and Animal Feeds

In addition to being sold as raw tubers, sweet potato can be marketed as potato chip or processed further into sweet potato meal to be used as feed ingredients for animals. Previous experiments showed that at least 2 1/2 kg of raw sweet potato were needed to produce 1 kg of sweet potato chip. With processing cost considered, this means that a fresh sweet potato tuber costing P1.50/kg must be about P6.00/kg when sold as chip.

To determine the economic feasibility of utilizing sweet potato as feed, three price assumptions for the tuber, other feed ingredients, and various animal products were considered. The animals in focus in this study were fattening hogs, chicken broiler, and layer and broiler ducks.

The data used for the analysis were results of feeding experiments conducted by Milleza and Sanchez (1983), Gerona (1981), and Almoroto (l984). In these experiments, sweet potato in ground form substituted corn in the feed ration at 25 percent, 37.5 percent, and 50 percent levels in the case of hog; 20 percent level in chicken (broiler); 30 percent in layer duck; and 20 percent, 30 percent and 40 percent levels in broiler duck.

Results showed that although fattening hog and layer ducks performed better when fed with sweet potato-incorporated ration, the return obtained could not compensate for the cost of sweet potato meal used. Despite the improvement of the feed conversion ratio, the return per kilogram was still not sufficient to cover the cost of the feed ration. Results of the analysis showed that feed cost per kilogram increased as the level of sweet potato substitution to corn in the feed ration was increased, resulting in a negative profit. Cost of the feed increased when sweet potato was used as a substitute to corn owing to the increased requirement of the protein-rich feed ingredients. Also, the high price per kilo of sweet potato meal added much to the cost of the ration.

In the case of broiler, results disclosed that in terms of feed per liveweight conversion ratio, broilers fed with sweet potato at 20 percent level was far less efficient than those fed with corn alone. Although the cost of feed per kilogram was relatively cheaper when sweet potato was used, the farmer would still incur losses because of the poor performance of the animals. Broilers fed with sweet potato incorporated ration had only a feed conversion ratio of 4.87, which was only 57.7 percent of the conversion ratio obtained when using corn.

In the case of muscovy ducks, analysis showed that it was not economically feasible to substitute sweet potato for corn in the feed ration because feeds mixed with sweet potato was more expensive than that without sweet potato. Added to the increasing cost of the feeds was the declining conversion ration observed as the level of sweet potato in the ration was increased.

For mallard ducks, research findings disclosed that birds fed with sweet potato at 30 percent level were better converters of feed and were highly productive but the cost of feed per kilo was relatively expensive. Using sweet potato at 30 percent level, feed cost was P4.89/kg while at zero level, feed cost was only P3.38/kg.

Using return from aforementioned feed costs as bases, the analysis showed that on the farm level price of P16.00 per kg liveweight for hog and P5.57 for sweet potato chip, utilizing sweet potato as animal feed at 25 percent and 37.5 percent levels was more profitable than selling it as chip. Including sweet potato in feeds at the 50 percent level is still profitable if the price of hog per kg liveweight increases to P16.90 and the price per kg of sweet potato remains at P1.30/kg. Feeding sweet potato if its price is beyond P1.30/kg is not advisable because it is more profitable to sell it as fresh tuber after harvest. However, if the price of hog and broiler per kg liveweight and the price per dozen egg increase by 60 percent of their current farm level prices and the price of sweet potato remains at P1.30/kg or P1.50/kg, it pays to utilize sweet potato for animal feed.

Sweet Potato for Suman*

Data on the processing cost of *suman* utilizing sweet potato as a major ingredient were gathered in 1985 using a designed questionnaire from four sweet potato processor-respondents in two major sweet potato-producing towns in Leyte, namely: Dulag and Baybay. The return per kilogram when sweet potato was utilized as a main ingredient for *suman* was computed based on the data gathered. This was compared to the return obtained when sweet potato was sold directly as fresh tubers in the market.

Three price assumptions for sweet potato per kilo and *suman* per piece were made to speculate when to utilize sweet potato as a main ingredient for *suman* or sell it as tuber.

The findings revealed that compared with cassava, sweet potato when used as a major material for *suman* did not make any difference in the production process. The prime determinants in choosing the kind of root crop to be used for *suman* are the price of the root crop and the taste and preference of the consumers.

Findings also indicated that processing 9.12 kg of fresh sweet potato into *suman* would require P46.96 , which was 98.89 percent of total sales. Profit realized was P0.54 (Table 6). On a per kilogram basis, it was noted

---

*Suman is a local delicacy consisting of sweet potato, sugar, coconut milk, and anise.

that I kg of fresh sweet potato tubers plus other ingredients would produce 1.5 kg of *suman* or approximately 10 pieces at an average weight of 150 g/piece. The profit derived from processing one kilogram of sweet potato tuber was P0.06.

Table 6. Average production cost and income of sweet potato *suman* processors in Baybay and Dulag, Leyte.

Items		Amount
Gross income (95 pieces at ₱0.50/pc)		₱47.50
Less:		
Ingredients*	₱25.67	
Processing cost**	20.04	
Transport cost	1.25	46.96
Net income		₱ 0.54

*Consisted of 9.12 kg of sweet potato tuber; 1.25 kg sugar, 4 pieces of coconut, and anis.
**Labor cost at ₱2.20/man-hour.

To determine when it is advisable to utilize sweet potato for *suman* or sell it directly as fresh tuber after harvest, various price assumptions for sweet potato per kg and *suman* per piece were used. The price assumptions for *suman* were computed using the current selling price, and l0 percent and 20 percent inflationary rates.

For every kilogram of sweet potato, the price assumptions used were the current price, the yearly average price increase, and the current inflationary rate.

Results of the analysis indicated that processing sweet potato into *suman* was profitable on the part of the farmer/processor (Table 7). The analysis further disclosed that even if the price of sweet potato was increased from P1.35 to P1.60, provided that the *suman* price per 150 gram-piece was at least P0.55, processing sweet potato into *suman* was still favorable on the part of the farmer. This implies that farmer's decision to process his produce into *suman* is influenced to a large extent by the market price of sweet potato tuber and selling price of *suman*. Processing sweet potato into *suman* is advisable only if the price difference between fresh tuber and *suman* exceeds processing cost.

Sweet Potato for Soy Sauce Production

Information on the production cost per unit of soy sauce and processing cost of sweet potato flour was gathered from the Philippine Root Crop Research and Training Center (PRCRTC). The cost of sweet potato flour utilized in soy sauce production was computed based on the processing cost and the purchase price per kilogram of fresh sweet potato tuber. The price per kilogram of wheat flour was gathered and used as basis in computing the break-even price of sweet potato per kilogram. It was also assumed that the decision of the consumer to purchase was influenced largely by the price of the item rather than by his taste and preferences. Thus, if root soy sauce was relatively cheaper, it was assumed that more consumers would buy the product.

Table 7. Net income of processing a kilogram of sweet potato tuber into *suman* using three price assumptions of *suman* per piece and sweet potato per kilo.*

Price of sweet potato per kg (P)	Price of *suman* per piece (P)		
	0.50	0.55	0.60
		Net income	
1.35	0.66	0.56	1.56
1.50	–0.09	0.41	0.91
1.60	–0.19	0.31	0.81

*Production cost, excluding the cost of sweet potato tuber, was constant in this instance.

Researchers at PRCRTC reported that substituting wheat flour with sweet potato/cassava flour did not affect the process in soy sauce making. It was the price of root crop flour compared to that of wheat that determined substitution.

Assuming a 30 percent flour recovery, processing cost (under 1985-86 situations) per kilogram of sweet potato flour when solar dried and mechanically dried was P1.12 and P1.32, respectively. Using the purchase price of sweet potato tuber (P1.75/kg) in the experiment stations, a kilogram of sweet potato flour would cost P6.95 when solar dried and P7.15 when mechanically dried.

Results of the analysis revealed that a cost saving of P0.16 per liter would be realized if wheat flour would be substituted with sweet potato flour in soy sauce making. The price of sweet potato flour and wheat flour in this case was P6.95 and P8.00 per kg. The price of sweet potato tuber was assumed to be P1.75. Substituting wheat flour with sweet potato flour in soy sauce production would still be economically feasible if the price of sweet potato per kg was higher than P1.75 but it should not go beyond P2.07 (break-even price). The finding implies that it is the cost of sweet potato tuber per kilogram that determines the advisability of utilizing sweet potato flour in soy sauce production.

CONCLUSIONS AND RECOMMENDATIONS

- There is a bright prospect in sweet potato farming, especially if the farmers plant the ViSCA high-yielding varieties. If the recommended inputs are used, the profitability of these varieties is very much higher than that of other crops. If these are planted without additional inputs, however, lowland rice, mungo, and peanut give better returns.
- The fertilizer needed to optimize the production of the ViSCA sweet potato varieties is very minimal, that is, roughly between 15 and 45 kg/ha of N, P, and K. But data to determine the exact input level for each variety are still incomplete. Hence, it is recommended that study on various input combinations for each variety and in different locations be continued.
- Sweet potato, either packed or unpacked, can be sold to people in the higher income bracket in department stores. However, only a limited quantity is purchased in department stores, implying that bigger transactions are done either on the farm or at the public market.
- The acceptability of the first three ViSCA varieties (VSP-1, VSP-2, and VSP-3) was already documented but an acceptability study for the two new varieties (VSP-4 and VSP-5) has not been done yet. It is, therefore, recommended that this study be done very soon. The acceptability study shall include any additional varieties that will be developed by ViSCA plant breeders.
- Using past and current market situations, a farmer can get better returns if he sells his sweet potato as fresh tubers after harvest. Producing sweet potato solely for feeds to animals is less profitable on the part of the farmer. Utilizing it for animal feeds is, however, advisable for culls/nonmarketable or mechanically damaged tubers.
- Utilizing sweet potato for *suman* and for root soy sauce appears promising. However, there is no data yet that indicate whether there is a ready market for the root soy sauce and the *suman* if these food items are produced in large quantities.

ACKNOWLEDGMENT

The assistance of Edgardo A. Pañares, Magdalena S. Laguna, Hazel I. Bellezas, Jesus Clyde F. Colis, and Mario B. Tabinas is hereby acknowledged.

REFERENCES

Abamo, A. P., R. Felicilda, D. Sacro and M. Mercado. 1987. Marketability and Market Channels of Various Sweet Potato Products and Co-Products in the Philippines. ViSCA, Leyte, Baybay, Leyte, the Philippines.

Abella, A.P., H.I. Bellezar and S.G. Binongo. 1985. Feasibility Studies of Utilizing Sweet Potato for Animal Feeds. ViSCA, Baybay, Leyte, the Philippines.

Abella, A. P., H.I. Bellezar and S.G. Binongo. 1986. Feasibility Studies of Utilizing Sweet Potato as a Raw Material for Village-Level Feedmills and as a Major Material for Suman and Soysauce. ViSCA, Baybay, Leyte, the Philippines.

Almoroto, A.A. 1984. Suitability of Weevil-Infested Sweet Potato Tubers for Feed of Broilers. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Gerona, G.R. 1983. Studies on the Utilization of Root Crops as Energy Sources in Duck Rations. ViSCA, Baybay, Leyte, the Philippines.

Hermoso, R. P., Jr. 1985. Comparative Economic Analysis of Rice Farm Using *Azolla* and Inorganic Fertilizer in Gabas, Baybay, Leyte. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Milleza, T.O. and S.L. Sanchez. 1983. Verification/substitution of corn with root crops for swine ration. DASVM, ViSCA, Baybay, Leyte, the Philippines.

PCARR. 1977. The Philippine Recommends for Mungo. Philippine Council for Agriculture, Forestry and Natural Resource and Development (PCARRD), Los Baños, Laguna, the Philippines.

PCARRD. 1978. The Philippine Recommends for Peanut. PCARRD, Los Baños, Laguna, the Philippines.

PRCRTC. 1984. Annual Report. Philippine Root Crops Research and Training Center (PRCRTC), Baybay, Leyte, the Philippines.

PRCRTC. 1985. Annual Report. Philippine Root Crops Research and Training Center (PRCRTC), Baybay, Leyte, the Philippines.

COUNTRY REPORTS

Indigenous Technologies and Recent Advances in Sweet Potato Production, Processing, Utilization, and Marketing

STATUS OF SWEET POTATO (IPOMOEA BATATAS) CULTIVATION AND UTILIZATION IN MICRONESIA

Ruben S. Dayrit*

INTRODUCTION

The climate in Micronesia is typically tropical maritime with variations in seasonal and diurnal temperature means of less than 10°C and 15°C, respectively. The average daily temperature is 25°C and humidity is about 80 percent. Rainfall varies according to location, but it is generally high, ranging from 2000 mm in the eastern and western parts to 5000 mm in the central volcanic islands.

The islands in Micronesia are roughly classified into three types (Sproat,1967). These are the coral islands, which are atolls or raised reefs prominently found on the Marshalls and outer islands in the central states; volcanic islands of andesitic rock formation, which are located in parts of the Marianas; and continental islands of metamorphic rock formation in the Carolinian chains. The soils formed from these different parent materials are generally divided into volcanic soils and coral atoll soils.

SWEET POTATO IN MICRONESIA

Sweet potato is grown in all islands in Micronesia, except in the low coral islands where the soils are not suitable for the crop. The varieties that are commonly planted are holdovers from the Japanese period. There are two main groups of varieties: those producing dry, hard, often white-fleshed tubers sometimes referred to as "boiling" type; and those that have sweeter, softer, and more watery flesh when cooked, known as "baking" type (Migvar, 1968).

Sweet potato is planted in small patches either as a monocrop or as an intercrop with coconut or banana. Production methods, which were learned from the Japanese settlers, are similar to those practiced in Taiwan, the Philippines, and other Asian countries (Dayrit, 1975). Cuttings of approximately 30 cm long are planted in rows which are one meter apart; spacing between plants on the rows is about 30 cm.

*Associate Director, College of Tropical Agriculture and Sciences, College of Micronesia, Micronesia.

Sweet potato vines are hand-weeded two or three times until the spaces between the rows are completely covered. Sometimes, commercial fertilizer is applied before planting. No other production inputs are added until harvest, which usually takes place when the vines are four to five months old.

Even in small patches, harvesting is stretched several days or weeks. Farmers usually only dig out tubers that their families need or what they can sell in the markets or school cafeteria. Yields are generally low; 5-6 t/ha is considered outstanding with the varieties being planted. Leftover vines are either gathered and fed to pigs, or incorporated into the soil to serve as green manure.

Most of the sweet potato produced from farmers' fields is consumed by the farmers and their families. The tubers are baked in stone-lined underground ovens, together with bananas, breadfruits, yams, fish, chicken, and other food items that make up the traditional Micronesian table fare. Part of the production, especially those sold in schools, hospitals, and state prisons, is usually boiled and served whole as source of carbohydrate.

PROBLEMS IN SWEET POTATO PRODUCTION

One of the problems confronting Micronesian farmers growing sweet potatoes and other annual root crops is the low fertility of the soil. The prevailing humid climate, high temperature, and high rainfall speed up the process of laterization. As laterization proceeds, the base compounds tend to be leached out while aluminum and iron compounds accumulate. Commercial fertilizers, lime, and organic manures have to be regularly applied for sustained yields of sweet potato and other crops.

The scarcity of sweet potato varieties that are both responsive to fertilizer application and resistant to common sweet potato diseases is also a major production constraint. A number of the Japanese-introduced varieties that have shown response to added nitrogen, phosphorus, and potassium to the soil tend to be more susceptible to diseases (Soucie, 1978).

The prevalence of insect pests of sweet potato and some serious disease pathogens affecting the leaves and tubers of the plant presents another problem to farmers who want to expand their sweet potato plantings. Fleahopper (*Halticus tibialis*, Reuter), tortoise beetle (*Cassida circumdata* Herbst), and sweet potato hornworm (*Agrius convolvuli*, Linn) have been observed to considerably reduce sweet potato yield in Micronesia. Spot anthracnose *Elsinoe batatas* is widespread on the islands and could cause serious damage on the vines if left unchecked.

CURRENT RESEARCH ON SWEET POTATO

One of the main goals of the Land Grant Programs at the College of Micronesia is to promote the production and utilization of traditional staple crops. Sweet potato, being one of the more commonly grown root crops on the islands, has been receiving major attention in the research efforts.

The first trial was a comparative performance test using seven accessions and varieties from the Phonpei Department of Agriculture collection. Planting materials were treated with Malathion solution before these were planted 30 cm apart on raised beds spaced one meter apart. A blanket application of 100 kg/ha of N, P_2O_5, and K_2O was applied 30 days after planting. The vines were sprayed with Diazinon solution every month. Weeding was done twice with the use of garden hoes. The plants were harvested after 120 days.

The computed yields are shown in Table I. Highly significant differences between accession mean yields were found in this trial. The three top yielders were used in the NPK response experiment using similar plant spacing and methods of weed and pest control. The computed yields from the experimental plots taken l35 days after planting are shown in Table 2. Fertilizer treatment effects were highly significant with NPK and NK at 50 kg/ha elemental, superior to N alone, and N plus P. Nitrogen alone and N plus P did not show a mean yield difference from the control.

The rate of fertilizer application was doubled in the next NPK response test using the same accessions. Accession mean yield difference and rate of fertilizer treatment effects were observed in the trial (Table 3). Accession numbers 7 and 3 significantly produced mean yields higher than number 3. No mean yield difference between Accession numbers 3 and 7 was observed.

Test plants given l00 kg/ha of N,P_20_5 and K_20, and l00 kg/ha of N and K_20 yielded significantly higher than the control plants (i.e., those given only N at l00 kg/ha and N plus P_20_5 at l00 kg/ha).

A spacing experiment using the same accessions was conducted to determine the possibility of increasing yields by increasing plant population per unit area. No significant mean yield difference attributed to accessions or spacings was observed in the experiment.

Two experiments, one on chemical control of tortoise beetle on sweet potato and the other on fungicidal sprays for the control of spot anthracnose on sweet potato, are still in progress.

Table 1. Computed yields (in kg/ha) of marketable sweet potato tubers.

Accession	I	II	III	IV	Mean*
Acc. #7	23,240	21,640	20,000	23,860	22,185 a
Acc. #3	21,260	22,620	12,720	28,400	21,250ab
Acc. #5	19,140	11,880	18,840	17,100	16,740abc
Acc. #1	17,500	16,480	13,440	17,900	16,300bcd
Acc. #4	20,000	15,220	12,720	14,260	15,550bcd
Acc. #2	13,460	13,420	14,200	10,120	12,775cd
Acc. #6	9,520	8,300	14,540	10,280	10,660d
Mean	17,731	15,651	15,194	17,417	

*Means followed by a common letter are not significantly different at 5% level.

Table 2. Computed yields (in kg/ha) of marketable tubers at medium rate of NPK application.

Fertilizer treatment	Accession number			Mean
	Acc. #5	Acc. #3	Acc. #7	
0-0-0	10,348	8,959	11,007	10,105
50-0-0	8,299	10,278	12,431	10,336
50-50-0	10,973	10,695	12,049	11,239
50-0-50	13,091	12,847	12,986	12,975
50-50-50	14,688	16,389	18,653	16,577
Mean	11,480	11,834	13,425	

Fertilizer Treatment $LSD_{.05}$ = 2,192 kg

Table 3. Computed yields (in kg/ha) of marketable tubers at high rate of NPK application.

Fertilizer treatment	Accession number			Mean
	Acc. #5	Acc. #3	Acc. #7	
0-0-0	5,833	5,750	7,959	6,514
100-0-0	3,667	7,792	7,542	6,337
100-100-0	3,125	5,667	7,917	5,570
100-0-100	9,417	18,458	14,458	14,111
100-100-100	9,958	18,583	16,375	14,972
Mean	6,400	11,250	10,850	

Acc. $LSD_{.05}$ = 2,728
Fertilizer treatment $LSD_{.05}$ = 2,975 kg

REFERENCES

Dayrit, R.S. 1975. Sweet potato production training course. Terminal Internship Report. Asian Vegetable Research and Development Center, Taiwan, Republic of China.

Migvar, L. 1968. How to grow taros, yams, cassava, and sweet potatoes. Agriculture Extension Bulletin No. 7. Trust Territory of the Pacific Islands, Saipan, Marianas Islands.

Sproat, M. 1967. Subsistence agriculture in Micronesia. Trust Territory of the Pacific Islands, Saipan, Mariana Islands.

Soucie, E. 1978. Major subsistence crops in Micronesia. Tropical Agriculture for Secondary Schools. PATS Education Foundation of Micronesia. Phonpei, FSM.

INDIGENOUS TECHNOLOGIES AND RECENT ADVANCES IN SWEET POTATO PRODUCTION, PROCESSING, UTILIZATION, AND MARKETING IN PAPUA NEW GUINEA

M.B. Kanua and S.S. Rangat*

INTRODUCTION

The importance of sweet potato (*Ipomoea batatas* (L) Lam.) as a major food crop of Papua New Guinea (PNG), particularly in densely populated highlands, is well documented. The crop is cultivated on a wide range of soil types and agroecological zones, from sea level to over 2800 m, and climatic regimes of 1000 to over 8000 mm rainfall per year. Detailed information on PNG soils has been provided by Bleeker (1983). The climate, weather, rainfall, and seasonal variations of PNG have been described by McAlpine et al. (1975). Bourke (1982) attached a value of over K200 million (approximately US$200 million) on the production of sweet potato which further amplifies the crop's importance in this country.

Sweet potato cultivation can never be sufficiently described without going into the details of interrelated cropping systems. Other food crops such as taro (*Xanthosoma* and *Colocassia*), yam (*Dioscorea alata, D. bulbifera*), bananas, sugarcane, cassava, legumes, pandanus, and a wide range of vegetable species that supplement the diets are often integrated into the farming system. Cash cropping with perennial tree crops such as coffee, rubber, tea, and cocoa has assumed an important roie in these systems in recent years.

The land-use and cultivation practices in the highlands are not nearly the antithesis of those in the lowlands. The traditional form of shifting-bush fallow agriculture in both cases is similar to the common and widely used methods in the zone of intermediate elevations (500-1500 m) described by Powell (1976). Although the system of cultivation may vary slightly with altitude, the basic principle is the same. It is always based on a period of cropping that usually comprises a series of recultivations, followed by a fallow period of variable length. In general, the respective farming systems are highly specialized and unique in their own respect where the crops are planted with careful attention to their requirements, techniques are specific, and gardens are orderly in appearance.

*Food Crops Agronomist, Kuk Research Station, Mount Hagen, Western Highlands Province, and Food Crops Agronomist, Laloki Research Station, Central Province, respectively.

The farming systems are experiencing rapid changes because of some factors such as territorial conquest with intensive use of land owing to population pressure and accelerated socioeconomic developments. Intensive cultivation of land is common in many highland areas, often with up to four or five croppings on a single site and fertility being maintained by alternating cultivation with some fallow period of varying length of years. The fallows in the past, which often saw a selective woody regrowth of *Casuarina*, is now changing to one of unselective regrowth of shrubs, pitpit (*Miscanthus floridulus*), and kunai (*Imperata cylindrica*) grasslands. In the lowlands, the system is more relaxed with longer fallows of 10 to 15 years.

Indigenous technologies available for the production of sweet potato in the contrasting lowland and highland areas are very varied. The highland region alone represents a number of practices that also greatly vary between provinces. Indigenous soil conservation practices have wide recognition; soil maintenance techniques of mounding, compost-mounding, soil fertilization with ash, controlled use of pigs, and selective tree planting form the main basis of traditional technologies used in highland agriculture.

In the lowlands, the traditional bush fallow, slash-and-burn agriculture have been studied under various headings such as long forest fallows (Bourke, l978a), shifting cultivation (Newton, l960), and swidden farming. It is noteworthy that the lowlands are not that rich in traditional technologies as the highlands. The flat bed, zero soil tillage system, and mounding practices used in most lowland areas are similar to those in the highlands. There is no distinct cropping pattern for any specific group of people. For example, those people who are purely banana, taro, or sweet potato growers never hesitate to include numerous other food crop species in their gardening systems. Most often, as in other parts of the country, crops are mix-planted or intercropped and very rarely monocropped.

INDIGENOUS SOIL CONSERVATION TECHNIQUES

The'Giu' Technique

In many parts of the highlands, traditional soil conservation techniques have been well noted in the production of food crops (e.g., Wood and Humphreys, l982; Humphreys, l984). One is the 'Giu' technique used extensively by farmers in Eastern Highlands, Simbu, and parts of Western Highlands Provinces. The technique has been recognized as a significant development for soil conservation. It has been described by Paglau (l982) and Wood and Humphreys (l982). A summary of Paglau's description has also been given by Bleeker (l983). In brief, the Giu is a horizontal soil retention fence, and is constructed of small wooden stakes and rails that are built across contours on slopy gardens to counteract soil erosion. The Giu technique reduces effective slope length to prevent and decelerate runoff, soil and plant matter being washed down by rain or flood water. It is used effectively on gardens situated on greater than 30° slopes.

In the Bena-Bena area of the Eastern Highlands Province, downslope ditches are used to channel runoff water. Downslope of drainage systems is a familiar technique to avoid mass movement of the friable top soils in this area. However, precaution is necessary in the use of downslope drainage systems since gullies may develop from it.

The Mounding Technique

A characteristic feature of the traditional practices of PNG's central highlands and some areas of the lowlands is the cultivation of sweet potato on soil mounds. The practice of mounding creates an adequate environment for the growing crop and is often used where topsoils are shallow. The basic principle is to congregate and concentrate the comparatively nitrogen- and potassium-rich topsoil around the feeder roots as well as improving aeration for the plants. The mound shapes and sizes vary between provinces and between districts.

On the lowlands, most of the sweet potatoes are grown on flats in newly cleared gardens. On Bougainville Island where sweet potato has in recent years replaced taro as the staple, the crop is initially planted on flats in newly cleared gardens. The subsequent crop of sweet potato is planted on small mounds rather than on flats as in the case of first planting. These mounds are constructed by breaking the topsoil and heaping it into small round mounds where 2-3 sweet potato vines are planted.

The types of mounds used in the Simbu and Eastern Highland Provinces are similar to each other and were described as uncomposted earth mounds of average dimensions: 25-cm height and 50-cm diameter (Wohlt and Goie, l986). The method involves complete soil tillage prior to mounding and is restricted to slopes of l0°-30°. On steeper slope gardens (i.e., 30°-45° slopes), the soil is not completely tilled and no mounds are made. Instead small flat terrace-like stations are made by loosening the topsoil profile to provide an environment conducive to tuberous root growth. Here, digging sticks are used to minimize disturbances made to the soil. This practice conditions the soil physical properties to facilitate rapid filtration of rain water rather than surface flow. The Giu technique (horizontal soil retention fences) is effectively used in the latter type of gardens.

The people of Enga, some Western Highlanders (e.g., Tambul), and Southern Highlanders have evolved a universal usage of large mounds.

The practice of large mound construction in these cultures is nearly always done in association with compost. In the Enga Province, Wohlt (l980) recorded mounds containing 27 kg of fresh weeds, sweet potato vines, and other materials buried into mounds averaging 83 cm in height and 204 cm in diameter. Waddle (l972) recorded mound dimensions of 55 cm in height in 311-cm diameter in the Raiapu area of the Enga. Comparatively, in the Southern Highlands, mounds in established gardens were approximately 50 cm in height and 300 cm in diameter (Grittenden et al., l985).

The practice used in the central Western Highlands is the antithesis of the mounding system of the other highland groups. The central Western Highlands, which subsist on flat and fertile organic soils (histosols), cultivate sweet potato on flat beds. The villagers dig deep drains (20-50 cm in depth) into which the soil is thrown on top to form almost square flat beds where sweet potato is planted. This group of highlanders is famous for its drainage practice which is acknowledged as an effective water control technology to drain off excess water and facilitate adequate aeration for crop growth. The traditional winged bean/sweet potato rotation system is used in this system of agriculture.

INDIGENOUS SOIL FERTILITY MAINTENANCE TECHNIQUE

Composting on Volcanic Ash Soils

One of the dominant cultivated soil types is formed from volcanic ash material (hydrandepts), which occupies a total area of 25,000 km^2 in the Central and Western Highlands of PNG. Volcanic ash soils also occur in some parts of the lowlands: Oro Province, West and East New Britain, Bougainville, and the islands of Madang and Marobe Provinces.

The principal soil constraints to agricultural practices on volcanic ash soils were observed to be chemical rather than physical, namely: low availability of phosphorus (P), low available potassium (K), low effective cation exchange capacity, and possible deficiencies of secondary nutrients (Ca, Mg) and micronutrients (B, Zn, Mn) (RadCliffe, l983).

The large mounding system discussed earlier is almost always associated with composting and is a universal practice on volcanic ash soils cultivated by the Engans and Southern Highlanders. The practice of composting in sweet potato mounds is a technology foreign to any other group of highlanders or lowlanders. It is, therefore, highly recognized as a technology developed by this group of highlanders to offset inherent fertility problems of volcanic ash soils being dominant in this area.

Worth stressing is that volcanic ash soils have a very high phosphate fixation (90%), a potential problem for many other crops but not so for sweet potato, a crop known for its tolerance of very low levels of P (0.003 ppm) (Radcliffe, 1983). But the staple, like other tuber crops, heavily depends on potassium (low in hydrandepts) which is readily supplied by the composting technology in use and made accessible to the feeder roots by the mounding technique. Such highly striking feature of the agriculture of this group of highlanders explains why they have not only survived but also flourished on this soil type, which supports one of the highest rural population densities in PNG.

The practice of large mounding with incorporation of compost carries many advantages, four of which were cited by Wood (1984) in his study of Huli agriculture in the Southern Highlands and the fifth by Waddle (1972).

- It increases the depth of topsoil for cultivation, which is particularly important in areas with shallow topsoils.
- It provides some protection from soil erosion by channeling runoff water into the spaces between mounds.
- It provides drainage and aeration and, in swampy areas, raises sweet potato above the water table.
- It provides protection from floodwater in floodprone environments.
- In higher altitudes, the practice of mounding raises sweet potato plants above the level of the cold dense air which sinks on frosty nights, thus giving protection to plants against frost damages.

Sweet potato yields obtained in traditional Enga and Southern Highlands gardens differ with soil type but are comparably good. The recorded average yields range from 6.6 to 13.8 t/ha in Southern Highlands (Wood, 1984) and 17.4 to 20.9 t/ha in Enga Province (Waddle, 1972). The large compost mounding technique has received the highest appreciation in this area and the technique is appropriate for adoption by other highland groups and in parts of the country where soils are similar or where agricultural systems are under stress. This technique is at present being tested in Gumine district of Simbu Province.

Ash as Fertilizer

The practice of slashing and burning of shrubs and vegetative matter in the production of food crops is the same in the lowland and highland. In newly cleared areas, the vegetation is often burned. Ash from the burnt vegetation provides large amounts of K, Ca, and Mg to the soil, which is responsible for the large variety of crops that is grown in new gardens. Burning of bush fallow is probably done because of the resultant enrichment of the soil. Subsequent cultivations are often limited to sweet potato.

Though minor in terms of land area cultivated, gardens around houses contain a wide variety of food crops. Crop species grown around these gardens are sustained by the fertility of these soils being maintained by household wastes, animal manure, and burnt ash from the kitchen.

Long Forest Fallows

There is a distinct difference in time of fallow. The lowlands have longer fallow periods of up to 15 years, while in the highlands time is shortened to 5-7 years in some places and further reduced to 1-3 years in other areas. These differences have been attributed to land shortage and increased population pressure being felt more in the highlands than in the lowlands.

Subjecting land to the natural cycle to regenerate to a high secondary forest is the most significant method of replenishing the earth with plant nutrients. In the lowlands, the traditional practice of long forest fallows is the most prominent feature of the farming system in maintaining soil fertility. The long forest fallow system, however, is not efficient enough to meet the demands of cash cropping and increasing population.

Rotation

The central Western Highlanders who use the flat bed practice in cultivating their food crops are known for using the traditional rotation system of winged bean (*Psophocarpus tetragonolobus*)-sweet potato. In recent years, the traditional winged bean-sweet potato rotation has been nearly replaced by peanut-sweet potato rotations. One of the most significant changes in rotation has been the maize-peanut intercropping system used near urban areas. Prior to 1950, however, the traditional winged bean-sweet potato rotation system was thought to be a relatively minor technique for maintaining soil fertility. In Western Highlands where soils are very fertile and topsoils measure in tens to several hundred centimeters deep, there seems to be no problem for the villagers to develop significant soil fertility maintenance techniques.

Tree Planting

The highlanders plant many types of trees in their gardens. One of the most widely planted is *Casuarina* spp. Conversely, the lowlanders do not select any particular tree for planting – the fallow is left to nature to regenerate into a secondary forest. *Casuarina* is a prominent tree species in the highlands and is associated with human habitation and gardening. A typical highland village is nearly always marked by numerous stands of *Casuarina* trees. Fallowed gardens are recognized by *Casuarina* tree plantings, otherwise the bush or forest has never been cultivated before, except for a few cases where grasslands have been produced because of human interference.

The reasons for the highlanders' selective choice of *Casuarina* species over other trees are undoubtedly complex, an intricate socio-biological system of knowledge of the environment and cultivation practices acquired through experience and transmitted across generations. In the highlands, the tree has been found to be beneficial in fixing atmospheric nitrogen into the soil as well as having leaf litter that is high in nitrogen (Parfitt and Mavo, l975).

OTHER ASPECTS OF THE FARMING SYSTEMS

Mixed Cropping Systems

One of the prominent features of shifting agriculture is that a wide diversity of crop varieties and species is grown in gardens that are scattered in isolated locations. This practice is most advantageous in preventing major outbreak of pests and diseases. Mixed cropping coupled with the cultural isolation of growers accounts for the maintenance of diversity observed in many food crops in PNG, particularly sweet potato.

On the other hand, limited evidence suggests that the traditional system of mixed variety plantings has complicated the acclimatization process of newly bred or recommended sweet potato cultivars that are usually selected in monoculture plantings (AFTSEMU, unpublished). The local farmers often determine variety preference by taste, texture, or color and not necessarily by yield. This raises a number of problems for both the farmer and the researcher. First, it implies practical difficulties for future adoption by farmers of improved cultivars into their mixed variety planting system. Second, varieties selected for yielding ability in government research stations may not be acceptable to the farmers' taste. Furthermore, it complicates future researches in that variety screenings have to be carried out on mixed variety plots as opposed to the traditional monovariety plantings. Overall, to overcome these constraints, future genetic research must select for specific local needs such as improved protein quantity and quality, taste, and color preference combined with yield. However, this is not easy to achieve, particularly for a very highly variable crop like sweet potato.

The Role of Pigs in Agriculture

Pigs can be pests and become a burden or can be controlled to inject meaningful development into the land. A very common practice in the highlands is the tethering of pigs in aging gardens to remove the remaining leaves, vines, and tubers. In the lowlands, except for certain parts of Bougainville Island, the lowlanders rarely tether pigs. Pigs are less controlled and managed, and allowed to scavenge the wild. Tethered pigs forage for earthworms and in the process often dig up large areas of land. This practice has its advantages as well as disadvantages. The single most advantageous aspect of pig tethering is the lessening of work burden on the farmer. Pig droppings add fertility to the soil, particularly where pig population is high.

Conversely, the practice of pig tethering carries the disadvantage of breaking and exposing bare and broken ground directly to rainfall, thus endangering the topsoils to erosion risks. None of these features, however, has been studied in detail in PNG to quantify the magnitude of damage or benefit that domesticated pig tethering has on traditional agriculture.

Seasonality Problems

Traditional techniques of overcoming seasonality are well recognized in PNG (Siki, 1979). To avoid need for storage and to ensure a continuity of supply of fresh sweet potato all year round, the farmers, usually women, employ sequential or progressive harvesting whereby only few mature tubers are selected at any one time of harvest. The tubers are removed from the earth mounds with a digging stick. This technique serves to store tubers alive in the soil as well as allowing small tubers to bulk. Progressive harvesting of tubers may be continued for 3 or 4 months or even longer after a sweet potato garden is first harvested. A study to compare the single and progressive harvesting techniques indicated that one variety gave significantly higher total tuber yields for progressive harvesting than single harvesting (Rose, 1979).

RECENT ADVANCES IN SWEET POTATO PRODUCTION

Today, the traditional agricultural systems in PNG is experiencing drastic changes and, in general, it is fair to comment that farmers are advancing in sweet potato production. Major advancements have been made initially through the introduction of improved or high yielding, disease-resistant cultivars to replace traditional materials. Moreover, production constraints are being alleviated through the adoption of improved cultural practices and tools to boost production. Much of these has been achieved through the dedicated input of researchers and financial support from the national government. In this paper, a review of sweet potato research work is of necessity only as a summary.

The traditional approach to crops research in PNG is well defined by Crittenden (1985) as "one that involved an individual scientist with specialty in various aspects of the plant or its environment as well as particular crops, addressing specific problems on DPI research stations." By contrast, a multidisciplinary team approach was recently adopted on recommendations by the International Service for National Agricultural Research (ISNAR) based in the Netherlands and the United Nations Development Programme/Food and Agriculture Organization. The latter recognizes the necessity of multidisciplinary expertise input to research.

The Highlands Food Crops Research Team is one such multidisciplinary team which has been mandated to undertake sweet potato crop research in PNG. Its counterpart is the Lowlands Food Crops Research Team, which focuses research on taro and yam. Both teams address research from the Farming System approach.

In places identified as agricultural stress areas, multidisciplinary team research has concentrated on alleviating soil fertility and other major constraints deemed necessary for rectification. At other districts, research objectives have focused on cultivar improvement, pest and disease management, and, to a lesser extent, breeding and farming systems studies. Reported experiments have covered a wide range of investigations in which agronomic research received highest priority (Byrne, 1984).

Extensive use of organic material in sweet potato production has been tested in many highland areas. Most of these works have correlated well with sweet potato yield, type, and quantity of composting material used (Floyd et al., 1985; D'Souza and Bourke, 1982; D'Souza et al., undated).

The results suggest considerable scope for increasing the rate of compost used and, consequently, sweet potato yield. Cultivar evaluation trials have provided recommendations of suitable local and introduced cultivars for dissemination to the farming community (e.g., Akus, 1982; Kanua and Floyd, 1985). High priority has been set for the involvement of suitable leguminous food crops in rotation with sweet potato (Kimber, 1974). New food crops, leguminous and non-leguminous plants such as *Albizia, Casuarina oligodon, Crotolaria, Desmodium,* Pigeon pea, *Leucaena,* and many others have been suggested for incorporation into the normal cycles of fallow rather than an unselective bush and woody regrowth (Allen, 1984).

Results from some 50 inorganic fertilizer trials have indicated inconsistency. This inconsistency is attributed largely to the varying soil types and differences in cultivar responses. However, occasional meaningful responses to potassium and nitrogen have been reported (Kimber, 1980). It is known that potassium is an important element in sweet potato root enlargement or bulking.

While the future is uncertain, recent advances in cash cropping in PNG may allow more cash flow in the villages. Consequently, some farmers are familiar with inorganic fertilizer use in vegetable production but not so for sweet potato. If farmers perceive the value of long-term social and economic benefits attached to investing in inorganic fertilizers to produce sweet potato in preference to other laborious cultural techniques, this will be an important advancement. This expected change will have significant effects on the livelihood of the people when the very conservative subsistence-based economy is taken into account, in which the first priority is achieving a reliable food supply, while dietary variety seems of secondary importance.

Sweet Potato Breeding

The concept of sweet potato breeding, especially the role it plays in subsistence agriculture, has not been given the kind of recognition it deserves. Village farmers have recognized the potential of new cultivars developed from spontaneous germination of seeds and have evaluated and adopted them in what is normally a vegetatively propagated crop; hence a phenomenon which accounts for the large turnover of germplasm in PNG (Yen, l974; Powell et al., l975).

Preliminary breeding work has centered aroung germplasm collection and establishment of polycross nurseries (Anders, unpublished; Takagi, unpublished; Shrestha, unpublished) to cater to the collection of adequate seed numbers followed by characterization of these selections. Of the three, only Anders (unpublished) has advanced further to screen parent-progeny lines. Other researchers (Tumana, l986; Bang, l987) have contributed in a limited way, but in all cases there is convincing evidence that hybrid vigor in the progeny lines is more highly expressed than the selected parents. Other works have shown that recently bred or introduced varieties were not only higher yielding than the established local varieties but were more vigorous (Kanua and Floyd, l985). Furthermore, a possibility that vegetative propagation may select for vegetative growth rather than the tuber yield exists.

Bang (l987) observed yield increases of l0 hybrid sweet potato varieties in generation 2 but decreases in the third clonal generation. He attributed the cause of this reduction to differences in variety and their interaction with the environment.

SWEET POTATO UTILIZATION, PROCESSING, AND MARKETING

Utilization

Sweet potato is consumed locally as a new product by both man and domesticated livestock. In the highlands where pigs carry significant social and economic value, the quantity of sweet potato fed to pigs is quite substantial.

Processing

Sweet potato processing has the potential to cater to an industry of its own, but this has not been exploited. Only recently, on a trial project, dried and fried sweet potato chips were tested at Goroka (Thomas, 1982). Preliminary results indicated unfavorable consumer reaction and the product was unable to compete cost-wise with imported processed products. Furthermore, the industry could not find assurance of a consistent supply of suitable quality sweet potato tubers to keep industry running.

In l975 and l976, dried sweet potato chips were grounded into powder and mixed with wheat flour to make cakes for students at St. Pauls Lutheran High School in Wapenamanda. A particular promising result was that the sweet potato-wheat cake had an acceptable taste. Even though the future for such an industry is uncertain, institutions such as schools, hospitals, and jails have the opportunity to explore the economic benefits of sweet potato-wheat cake projects on the local level.

Marketing

Only limited information is available on the economics of sweet potato growing in PNG (Kimber, l976). Domestic market for this widely grown crop is limited to local urban food markets. Prices paid for sweet potato at urban food markets are high. However, marketing is time consuming and therefore expensive.

Marketing sweet potato is a big problem for growers in PNG. Institutional market demand is probably the only avenue for growers. However, schools, hospitals, and jails often require a guarantee of regularity or consistency of supply, which local growers often fail to meet. These heavily programmed institutions cannot accommodate risks and therefore resort to purchase of imported rice instead.

Sweet potato is occasionally in high demand. One such occasion is during *Taim Hangre*. *Taim Hangre* is a term used to described scarcity of food supply when natural disasters such as droughts or frost make it difficult for the normal cultivation of food crops to continue. *Taim Hangre* is not strictly attached to occasions of natural disasters, but also refers to periods of food supply shortage because of improper planning and inadequate planting. The latter is a more common event than the former. Occasionally, natural disasters in PNG such as droughts, floods, and frost occur and cut off food supplies. Even though assessment of these hazards is based on estimated frequency of occurrence and the extent of damage done, nature is not a respecter of persons. The assessments serve as a warning to plan and adopt frost- or drought-resistant varieties to offset unwanted catastrophic effects of future natural disasters.

ACKNOWLEDGMENTS

Acknowledgement is made to colleagues in the Department of Agriculture and Livestock who offered valued comments on this paper. In particular, we appreciate the kind assistance of Messrs. M. Gunther, J. Sherington, S. Bang, for commenting on the paper, and Ms. B. Silovo, for typing the document.

REFERENCES

Akus, W.L. 1982. Sweet potato releases from Aiyura. Harvest 8 (92) I: 63-66.

Allen, B.J. (ed.). 1984. Agricultural and nutritional studies on the Nembi Plateau, Southern Highlands. Occasional Paper 4 (new series), Department of Geography, University of Papua New Guinea and Southern Highlands Rural Development Project, Port Moresby.

Bang, S.K. 1987. Evaluation of polycross hybrids and compatibility studies on selected clones of sweet potato (*Ipomoea batatas*): Bach. Agriculture Honours Thesis, University of Papua New Guinea.

Bleeker, P. 1983. Soils of Papua New Guinea. The Commonwealth, Scientific and Industrial Research Organization, Australia, in association with the Australian National University Press, Canberra, Australia.

Bourke, R.M. 1978. Suggested farming systems for lowland areas where land is scarce. Harvest 4(3): 179.

Bourke, R.M. 1982. Sweet potato in Papua New Guinea. Proceedings of the First International Symposium on Sweet Potato. AVRDC, Taiwan.

Bridge, J. and S.L.J. Page. 1984. Plant Nematodes of Papua New Guinea: Their importance as crop pests. Commonwealth Institute of Parasitology, St. Albans, Herts, United Kingdom.

Byrne, P.N. (ed.). 1984. Department of Primary Industry Research Report for the period July 1969 to December 1982. Compiled for the World Bank/Papua New Guinea Agricultural Support Services Project, Port Moresby.

Crittenden, R. 1985. Farming systems, crops research or rural welfare: The case of the Nembi Plateau, Papua New Guinea. Department of Primary Industry, Konedobu, Papua New Guinea.

Crittenden, R., C.N. Floyd, R.D.B. Lefroy and R.A. Urben (eds.). 1985. A study of gardening activity and bodyweight in the Southern Highlands of Papua New Guinea. AFTSEMU Technical Report 4.

D'Souza, E. and R.M. Bourke. 1982. Compost increases sweet potato yields in the highlands. Harvest. 8(4):171-175.

D'Souza, E., R.M. Bourke and W.L. Akus. (undated). Intensification of subsistence agriculture, Nembi Plateau. 3. Sweet potato cultivar trials, crop rotation and fallow species trials, and crop introduction. Papua New Guinea Agricultural Journal.

Floyd, C.N., R.D.B. Lefroy and E.J. D'Souza. 1985. Composting and crop production on volcanic ash soils in the Southern Highlands of Papua New Guinea. AFTSEMU Technical Report No. 12. (*in press*).

Goie, A. 1986. Natural disasters surveys and studies: Frost Technical Bulletin No. 1. Division of Primary Industry Subsistence Unit, Department of Enga Province.

Golson, J. 1977. The Making of the New Guinea Highlands. *In* The Melanesian Environment. ANU Press. Canberra, Australia. pp. 45-56.

Golson, J. 1981. Agriculture in New Guinea: the long view. *In* Denoon, D. (ed.). History of Agriculture in Papua New Guinea. University of Papua New Guinea/Department of Primary Industry, Port Moresby. (*in press*).

Humphreys, G.S. 1984. The environment and soils of Simbu Province, Papua New Guinea with particular reference to soil erosion. Research Bulletin 35. Department of Primary Industry, Port Moresby.

Kang, B.T., G.F. Wilson and T.L. Lawson. 1986. Alley Cropping. A staple alternative to shifting cultivation. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Kanua, M.B. and C.N. Floyd. 1985. A study of site x variety interactions for sweet potato in the highlands of Papua New Guinea. Technical Report 13 AFTSEMU, Mendi, SHP, Papua New Guinea.

Kimber, A.J. 1974. Crop rotation, legumes and more productive arable farming in the highlands of Papua New Guinea. Science in New Guinea. 2(1):70-79.

Kimber, A.J. 1976. Costs and returns from growing sweet potato. *In* Willson, K. and R.M. Bourke (eds.). 1975. Papua New Guinea Food Crops Conference Proceedings. DPI, Port Moresby. pp. 313-316.

Kimber, A.J. 1980. Fertilizing sweet potato on mineral soils in the highlands. H.A.E.S. Technical Bulletin 14. Aiyura.

McAlpine, J.R., G. Keig and K. Short. 1975. Climatic tables for Papua New Guinea. Research Technical Paper No. 37. CSIRO, Division of Land Use, Australia.

Newton, K. 1960. Shifting cultivation and crop rotations in the tropics. The Papua New Guinea Agric. Journal. 13 (3):81-118

Paglau, M. 1982. Conservation of soil water and forest in upper Simbu Valley. (Transl: A. Goie). *In* Morauta, L., J. Pernatta and W. Heancy (eds.). Traditional Conservation in Papua New Guinea: Implications for Today. IASER. pp. 115-119.

Parfitt, R.L. and B. Mavo. 1975. Phosphate fixation in some Papua New Guinea soils. Science in New Guinea. 3 (3):179-190.

Powell, J.M. 1976. Ethnobotany. *In* Paijams, K. (ed.). New Guinea Vegetation. Australian National University Press, Canberra, Australia.

Powell, J.M., A. Kulunga, R. Moge, C. Pono, F. Zimke and J. Golson. 1975. Agricultural traditions of the Mount Hagen area. Occ. Paper 12. UPNG Department of Geography.

Radcliffe, D.J. 1983. The Management Properties of Andisols in the Southern Highlands Province, Papua New Guinea. AFTSEMU Technical Report No. 1.

Rose, C.J. 1979. Comparison of single and progressive harvesting of sweet potato (*Ipomoea batatas* (L) Lam). Papua New Guinea Agricultural Journal. 30(4):61-64.

Siki, B.F. 1979. Review of storage and processing of root crops in Papua New Guinea. *In* Plucknett, D.C. (ed.). Small Scale Processing and Storage of Tropical Root Crops. Westview Tropical Agricultural Series No. 1.

Thomas, G.C. 1982. Review of the prospect for food processing in Papua New Guinea. *In* Bourke, R.M. and V. Kesavan (eds.). Proc. Second Papua New Guinea Food Crop Conf. Department of Primary Industry, Port Moresby.

Tumana, W.C. 1986. Evaluation of ten selected parental clones of sweet potato, *Ipomoea batatas* (L) Lam, and their polycross hybrids. Bach. Agriculture Honours Thesis, University of Papua New Guinea.

Waddle, E. 1972. The Mound Builders: Agricultural Practices, Environment and Society in the Central Highlands of New Guinea. University of Washington Press, Seattle, USA. 253 p.

Waller, J.M. 1985. Diseases of small holder food crops in the Southern Highlands Province of Papua New Guinea. Commonwealth Mycological Institute, Ferry Lane, UK.

Wohlt, P.B. 1980. Ecology, agriculture and social organizations: The dynamics of group composition in the highlands of Papua New Guinea, PhD Thesis, University of Minnesota, Minneapolis, USA.

Wohlt, P.B. and A. Goie. 1986. North Simbu Land Use. Research report of the Simbu Land Use Project. Vol. 5.

Wood, A. W. 1984. Land for Tomorrow: Subsistence agriculture, soil fertility and ecosystem stability in the New Guinea Highlands. Unpublished PhD Thesis, University of Papua New Guinea, Waigani, NCD, Papua New Guinea. 530 p.

Wood, A. and G.S. Humphreys. 1982. Traditional soil conservation in Papua New Guinea. *In* Morauta, L., J. Pernetta and W. Heaney (eds.). Traditional conservation in Papua New Guinea: Implications for today. IASER Monograph 16: 93-114.

Yen, D.E. 1974. The Sweet Potato and Oceania. B.P. Bishop Museau Bull. 236.

INDIGENOUS TECHNOLOGIES AND RECENT ADVANCES IN SWEET POTATO PRODUCTION, PROCESSING, UTILIZATION, AND MARKETING IN BANGLADESH

M.M. Rashid*

INTRODUCTION

In Bangladesh sweet potato is regarded as a poor man's food. The educated urban people generally avoid it because it causes flatulence. For the poor rural population, however, sweet potato is a popular food item and often the only means of survival when there is scarcity of rice. Being a starchy food, it is consumed as a substitute for the two main staples -- rice and wheat. The real importance of sweet potato lies in the fact that it is available at a price cheaper than the cereals and as such is very attractive to low income people.

The desirable characters of sweet potato make it an ideal crop for small and marginal farmers. Firstly, it can be grown on any kind of soil with a minimum of inputs and still an acceptable yield is obtained. In Bangladesh, a sizable part of the crop is grown on 'char' lands (silted river beds developed because of sandy deposits) where other crops are difficult to raise. The plant's high degree of tolerance to water deficit makes this possible. On the other hand, it responds very favorably to the use of inputs such as fertilizers and irrigation. Secondly, it is relatively free from diseases and insects; thus its production does not require much cost for plant protection. Thirdly, the vines of the plant constitute a nutritious fodder and the young leaves are good for human consumption. Fourthly, some varieties of sweet potato are very good sources of carotene.

In Bangladesh, the deficiency of vitamin A in the diet of the poor people is very widespread and many children (statistics not available) are reported to lose their eyesight every year because of this deficiency. The significance of carotene-rich sweet potato for this country can be easily imagined. It may be mentioned that the local varieties of sweet potato are all white fleshed.

Though sweet potato ranks fourth in volume of production among the food crops after rice, wheat and potato, it somehow does not receive due attention as far as research and extension are concerned. This is because

*Coordinator, Root Crops Project, and Director, Potato Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

its contribution to the total food supply of the country is not properly appreciated and its production does not pose any problem serious enough to draw the attention of officials of the agriculture department. In recent years, however, the importance of the crop has become clear to all.

A survey on this crop yielded some very useful information which has been and will be helpful in designing future research programs in a more practical way. The major findings are provided in this paper.

SURVEY FINDINGS

Area and Production

The area under sweet potato and the annual production of the crop have been a matter of guess work for a long time. Although the Bangladesh Bureaux of Statistics compiles these figures every year, its data collection method is subject to criticism. In this survey, area and production figures were collected from agricultural extension agents working at the lowest administrative units (unions) of the country and, hence, are likely to be more accurate. According to the survey, the area planted to sweet potato in Bangladesh is 82,363 ha and production is 1.24 million tons, the average yield being 13.65 t/ha. The corresponding figures of the Bureaux of Statistics are 66,219 ha, 680,605 tons and 10.27 t/ha, respectively, for the year 1981-82 (Anon, 1985). It may be observed that sweet potato production is most concentrated along river banks and the lower deltaic islands.

Categories of Farmers Growing Sweet Potato

Bangladesh has a population of about 100 million and the total cropped area is only 13.2 million ha. The average size of the farm holdings is obviously very small. Hence, the acreage assigned to sweet potato by the majority of the farmers is also small (Table 1). There is no indication, however, that this crop is grown mostly by small farmers. A later study of three districts showed that among the sweet potato growers 27 percent are small, 30 percent medium, and 43 percent big farmers (Elias et al., 1984) . These farmers grow the crop on 10 percent of their cultivated land.

Growing Season

In Bangladesh sweet potato is grown during the *Rabi* season (October - March), which is characterized by a dry and cool climate. The survey revealed that the crop is planted mostly from mid-October to the end of November, but in some places planting is done as early as September and as late as January.

Table 1. Area planted to sweet potato by farmers in a season.

Area (ha)	No. of farmers	Percentage of farmers
Less than 0.10	217	43.75
More than 0.10 but less than 0.25	89	17.94
More than 0.25 but less than 0.50	100	20.16
More than 0.50 but less than 1.0	50	10.08
More than 1.0 but less than 2.0	34	6.86
More than 2.0	6	1.21

Variety

All the farmers interviewed reported that they have been growing the same old varieties inherited from their forefathers. They said, however, that they were interested in trying new varieties. When asked what desirable qualities they wished to have in a good variety, the majority of the respondents indicated high yield. Others sought after characters, including bigger size of roots, sweet flesh, slow sprouting in storage, resistance to diseases, and attractive roots.

Planting Method

Much variation was observed in the system of planting. In most places, cuttings were not planted in rows and spacing varied from l5 to 30 cm. Where row planting was practiced, the spacing between rows ranged from 45 to 75 cm and l5 to 45 cm between plants. Stem cutting was invariably used as planting material. In most places, cuttings were planted on flat soil but in a few areas planting was done on ridges.

Manuring

Out of the 496 farmers interviewed, l24 reported that they did not apply any fertilizer to sweet potato. Only l52 farmers applied complete fertilizer (i.e., N, P, and K). The rest applied only one or two kinds of fertilizers. Ninety-five farmers reported that they applied only cow dung. The quantities of the different fertilizers were also very variable. In many places, sweet potato was grown on freshly formed alluvial soils, which are naturally fertile. This explains why it is possible to raise a good crop without any fertilizer.

Irrigation

Only 40 of the farmers reported that they sometimes applied irrigation to sweet potato. Although it is a highly drought-tolerant crop, sweet potato has been found to respond very well to irrigation, even where water is available.

Insect and Disease Problem

A total of 203 farmers reported that they had problem with insects. From the given description of the insect and its nature of damage, it could be gathered that sweet potato weevil was involved. In some places, stem borer was observed in the field. The occurrence of weevil appeared to be quite widespread. Twenty farmers reported that they had applied insecticides but they could not remember the brand of the insecticides.

Incidence of diseases in sweet potato was also reported by 62 farmers, but from the given information, neither the disease could be identified nor the nature and degree of damage assessed. A few farmers reported that they applied fungicides.

A thorough survey of the farmers' fields by entomologists and pathologists is necessary to have a clear picture of the insect and disease problems of sweet potato.

Harvesting and Yield

Harvesting of sweet potato begins in February and continues up to the end of May, the peak period of harvest being the month of April. The reported yields varied from 5 to 36 t/ha, but generally it ranged from 10 to 15 t/ha. Regional differences in yields were noticeable.

Consumption

In Bangladesh, sweet potato is almost exclusively a human food, but a few farmers reported that they occasionally fed roots to cattle. Vines were invariably used as fodder in all places. Of 496 farmers, 408 reported that they consumed sweet potato as a substitute for rice at times and the rest took it only as snack food. Only 19 farmers indicated that they consumed sweet potato leaves as vegetable. The use of leaves as human food did not appear to be very common in Bangladesh. In some of the southern districts, roots were reported to be used as vegetable for making curry. As the major portion used for food, roots were either boiled or baked on fire. Chewing roots in a raw state was common.

Storage

Forty-nine of the farmers reported that they stored part of their sweet potato crop. The practice of storing was reported in only five out of 63 districts. Roots were stored in dwelling houses, on the floor or on *macha* (bench of bamboo/wood). Only two farmers reported that they stored sweet potato in *dool* (storing structure made of bamboo outside the dwelling house whose walls are plastered with mud).

The length of storing period varied from 25 to 200 days. No information as to the nature and degree of loss during storage was available from this survey. Further information on storage was given later.

Profitability

Most farmers grew sweet potato both for selling and family consumption; they sold the excess portion to earn petty cash. The percentage of the produce sold by farmers varied from 26 to 95 and the wholesale price received ranged from Tk. 571 to 1,822 per ton. The price level in some places appeared to be much higher than expected. The study of Elias et al. (1984) showed that when entirely sold, the profit per hectare was Tk. 6870 on cash cost basis (family labor not taken into consideration). All farmers agreed that sweet potato was a highly profitable crop and the main reason for this was the low cost of production. In sweet potato, there were considerable possibilities of keeping the price low by raising the yield through various available means. A major objective of the research project was to achieve that goal so that sweet potato remained a poor man's food.

VARIETY DEVELOPMENT

The germplasm collected was evaluated over the years through a series of varietal trials conducted at a number of research stations that represented the main agro-climatic regions of the country, as well as in the plots of the farmers. The average yields given by the promising exotic and local genotypes in research station trials conducted after 1980 are given in Tables 2 and 3, respectively. Results of yield trials carried out prior to 1980 were reported earlier by Rashid et al. (1982).

On the basis of yield, dry matter percentage, carotene content, attractiveness of tubers and other characteristics, two exotic genotypes, AIS-0122-2 and Tinirining, were selected in 1985 and released as improved varieties under the names 'Kamala sundari' (orange beauty) and 'Tripti' (satisfaction), respectively. The characteristics of the varieties are as follows:

	Kamala sundari	**Tripti**
Average root size (g)	200	225
Root shape	Elliptical	Thick elliptical
Skin color	Yellow	White

Flesh color	Orange	Creamy
Dry matter (%)	20.69	22.56
Carotene (microgram/g)	5,000	265
Protein (%)	1.12	1.08
Yield range (t/ha) in:		
Research stations	25-27	24-80
Farmers' field trials	15-47	20-58

Though these varieties are becoming rapidly popular as indicated by the demand for planting materials, farmers often complain that their flesh is moist and not as sweet as those of the local varieties. It may be mentioned that all local varieties are dry fleshed and people are not familiar with moist-fleshed varieties which thaw badly when overboiled. To meet the requirement of farmers who are not satisfied with the above varieties, it has been decided to recommend the best local variety. The evaluation of the local germplasm has been completed and arrangements are being made to release Acc. No. SP 108, a locally improved variety which is sweet as well as dry fleshed and nearly as good in yield as the other two. Proposal in this respect is being sent to the National Seed Board whose approval is needed for the release of crop varieties.

A program of hybridization to combine desirable qualities of superior genotypes has been initiated. Preliminary activities to standardize the techniques of flower induction and making crosses are going on.

AGRONOMICAL STUDIES

Experiments were carried out to standardize the method of production of sweet potato. The following are the results.

Date of Planting

Experiments showed that to obtain high yield of quality roots, sweet potato should be planted early in the *Rabi* season since climatic conditions permit land preparation. Results of one such experiment conducted by Mannan and Rashid (1984) in the central region of the country are given in Table 4. It shows that when planted at the proper time, the yield continues to increase up to 170 days. Harvesting before 130 day results in substantial reduction in yield.

Type of Planting Material

In Bangladesh, sweet potato is invariably propagated by stem cuttings. Studies showed that apical cuttings gave significantly higher yields than

Table 2. Yields (t/ha) of the top 20 exotic varieties/clones.*

Name of variety/clone	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
AIS 0122-2**	102.2(2)	38.2(6)	36.6(5)	41.8(1)	39.0(6)	–
AIS 209-3	18.6(1)	46.4(3)	33.9(5)	28.4(1)	–	–
AIS 243-2	19.6(2)	46.2(5)	35.7(5)	33.7(1)	–	–
AIS 243-2-1	–	38.8(5)	34.9(4)	39.9(1)	–	–
AIS 35-1	23.0(1)	49.2(3)	28.8(5)	28.4(1)	–	–
CI 548-3	–	34.3(1)	34.9(5)	27.4(1)	–	–
Okinawa	11.3(2)	81.7(1)	37.1(4)	31.4(1)	–	–
Norin	20.3(2)	62.7(1)	29.3(4)	27.5(1)	–	–
Kokeia 8	18.8(2)	34.9(5)	22.2(5)	–	–	–
Tinirining**	20.6(2)	45.6(5)	41.0(5)	32.8(1)	39.8(6)	36.0(5)
BNAS white	21.5(2)	42.2(6)	40.9(5)	31.9(1)	39.2(6)	–
Cinjhi	18.3(2)	48.5(6)	41.2(5)	31.4(1)	–	–
USA 1	11.0(2)	63.5(1)	49.7(4)	31.8(1)	–	–
TIS 3032	18.4(2)	37.7(6)	34.5(5)	35.6(1)	–	–
Acc. 6	16.9(2)	30.6(6)	24.4(4)	–	–	–
CN 1108-13	–	–	–	–	47.1(2)	37.6(5)
CN 1232-9	–	–	–	–	47.0(2)	36.3(5)
CN 941-32	–	–	–	–	42.6(2)	36.6(5)
CN 1219-1	–	–	–	–	47.9(2)	30.6(5)
CN 1280-3	–	–	–	–	46.8(2)	29.9(5)

*Figures within brackets indicate the number of trial locations.

**Released as improved varieties.

Table 3. Yields (t/ha) of the top 15 local varieties of sweet potato.

Name of variety	1981-82	1982-83	1983-84	1984-85	1985-86*
SP 078	45.2(1)	35.6	32.5	–	–
SP 079	45.4(1)	35.7	35.2	–	–
SP 081	52.2(1)	45.4	41.3	38.0	–
SP 082	42.5(1)	32.6	27.7	–	–
SP 083	–	49.2	42.3	41.8	–
SP 085	–	43.9	40.4	44.2	–
SP 092	–	42.8	44.8	49.5	34.5
SP 094	–	33.7	39.5	46.8	31.1
SP 097	–	44.5	32.2	–	–
SP 099	–	37.2	37.3	51.2	32.8
SP 100	–	32.8	41.7	45.3	28.2
SP 108**	–	38.5	39.0	50.0	32.0
SP 116	–	41.8	–	47.2	30.6
SP 117	–	39.8	40.6	31.5	–
SP 118	–	30.5	38.9	26.3	–

*Trial was conducted at 6 locations, all others at a single location.
**Proposed for release as a standard variety.

cuttings taken from the lower part of the vine. In one study, top cuttings yielded 34 t/ha against 24 t/ha by middle cuttings (Rashid and Choudhury, 1980). In another study, the yields were 62.51 and 57.55 t/ha, respectively (Hussain et al., 1982-83).

Spacing

Spacing trials gave varied results. In some cases, the highest yield was obtained from 30 x 30 cm spacing while in others, the highest yield came from 60 x 30 cm. In one case, spacing did not influence the yield. It was found that the effect of spacing depended on various factors such as variety, soil fertility, time of planting, and moisture condition of the soil. As a standard practice, a spacing of 60 cm from row to row and 30 cm from hill to hill has been recommended. Vines, however, should be planted closer if the soil is less fertile and planting was delayed.

Manuring

A number of trials have been conducted to determine the fertilizer requirements of sweet potato in different regions of the country, but the information gathered so far is not sufficient to formulate a generalized

Table 4. Effect of date of planting and duration of growing period on the production of vine and tuberous roots in sweet potato (t/ha).

Planting date	Duration of growing period (days)							
	30	50	70	90	110	130	150	170
				Vine weight				
15 Oct.	2.70	2.97	6.06	6.06	6.92	10.20	14.42	21.25
15 Nov.	0.94	2.27	4.81	4.96	5.40	16.05	23.22	28.50
15 Dec.	0.28	1.26	1.69	2.88	12.93	17.51	26.41	31.96
15 Jan.	0.27	1.27	5.17	10.59	16.04	26.84	30.30	35.77
				Root weight				
15 Oct.	0.00	2.10	8.62	15.33	22.23	36.43	41.58	53.73
15 Nov.	0.00	0.88	6.01	9.35	15.38	23.96	39.00	49.93
15 Dec.	0.00	0.22	1.57	4.22	12.72	21.27	22.16	28.14
15 Jan.	0.00	0.54	5.64	6.51	16.08	11.51	0.00*	0.00*

*Roots were completely damaged by insects.

fertilizer dose (Rashid et al., 1981-1986). Pending further studies, a provisional dose of 60 kg N, 40 kg P_2O_5, 90 kg K_2O, and 10 tons of organic manure (optional) is recommended.

Irrigation

Trials showed that best results were obtained when the crop was irrigated twice (Rashid et al., 1981-1986). Since the effect of irrigation depended on rainfall and soil factors, the results might not be applicable to all locations and season. In one experiment, the yield from the no-irrigation treatment was the same as with two and three irrigations. Hence, further studies are needed before making a recommendation on this aspect. General experience, however, indicates that sweet potato could be raised without irrigation in certain soil tracts of Bangladesh.

Plant Protection

As already mentioned, sweet potato weevil is the most serious pest in Bangladesh. A single experiment to test the effectiveness of different insecticides against it showed that Heptachlor 5%, Furadan 3G, Aldrin 5%, and Dotan applied to soil at the rate of 16.8 kg/ha were equally good (Annual Report 1981-82). More insecticides are being tested.

Storage

A survey conducted by Elias et al. (1984) in three districts where sweet potato was grown intensively showed that, on the average, 11 percent of the total production of sweet potato was stored by the farmers. Jenkins (1980) studied the problems of storage of sweet potato in Bangladesh with a view to exploring possibilities for improving storage methods used by farmers. Sweet potatoes were stored using three methods, the most common being piling the roots on the floor of dwelling houses (which have roof of either sun grass or corrugated iron sheets) in layers of varying thickness. The second method involved storing on *macha*. In the third method, which was not used frequently, roots in bundles were hung from the roof of houses with the help of jute ropes. Temperature within the houses ranged from 24^{o} to $35^{o}C$ with a relative humidity of 70-90 percent. Tubers in these conditions were kept for two to four months. It was estimated that loss during storage was 5-20 percent.

The causes of spoilage during storage were determined through interviews with farmers and experiments conducted at a research station simulating the conditions under which farmers stored roots. High rate of respiration and evaporation and sprouting of the roots, all accentuated by high temperature, were found to be mostly responsible for the spoilage of roots. Five species of fungi, namely: *Rhizopus oryzae, Botrydiplodia theobromae, Macrophomina phaseolina, Fusarium oxysporum,* and *Sclerotium rolfsii,* were isolated from rotten roots in storage, the first two being more common than the others. It was found, however, that infection occurred only when the roots were predisposed to the pathogens by any means. No bacterial rotting was observed. In some cases, sweet potato weevils were found to cause serious damage in storage.

On the basis of the findings of the experiments, it was concluded that under Bangladesh conditions, home storage of sweet potato is not possible for more than 2-3 months and loss during storage can be considerably reduced by storing only intact roots (free from damage caused by handling or attack of insects and diseases). Weight loss owing to desiccation can also be minimized by maintaining high humidity around the stored roots by covering these with sand, soil, or stubble.

Studies on the physiological behavior of roots from different genotypes of the collected germplasm revealed the existence of genetic variation in weight loss and sprouting during storage. This indicates that improvement in storability is possible through selection of appropriate genotypes. Storage behavior of some selected varieties and clones is shown in Table 5.

Table 5. Rate of weight loss and earliness of sprout development (dormancy period) in roots of selected local and exotic varieties/clones of sweet potato during storage.*

Variety/Clone	Percent weight loss after			Dormancy period (days)
	2 weeks	4 weeks	6 weeks	
AIS 0122-2	18.4	23.2	31.3	0
AIS 243-2	16.7	24.3	39.0	45
AIS 35-1	12.7	19.3	49.3	28
AIS 35-2	13.7	19.4	27.1	0
Tinirining	10.9	14.0	29.4	14
BNAS white	20.4	24.5	30.7	0
Cinjhi	9.6	14.5	22.7	0
Acc. 6	24.0	31.2	41.9	45
Kokeia	24.6	33.4	46.2	0
Norin	19.4	30.0	46.0	0
TIS 3032	26.2	32.2	37.8	0
TIB 8	20.7	36.0	57.2	30
SP 074	22.3	36.1	57.8	45
SP 092**	14.5	19.0	38.0	40
SP 094**	14.5	20.0	35.0	45
SP 108	18.5	25.0	57.0	30
SP 116**	14.0	17.0	32.5	35

*This is one of several experiments. Results vary widely from year to year depending on weather conditions. In this experiment, roots were kept in a shed with roof of sungrass and walls of bamboo mats. Temperature and humidity during storage ranged from 20.7° to 36.7°C and 69 to 99%, respectively.

**Data on these varieties were from a different experiment.

A search of literature showed that reliable methods of storing sweet potato in hot and humid climate could not yet be developed in any country. Intensive studies in this area are necessary. Where the average loss during storage is 20 to 25 percent, any simple technique for reducing loss even by a small degree will be of immense benefit to the farmers.

Processing

A few experiments on the processing aspect of sweet potato showed that the roots could be processed and preserved in the form of chips or flour. But the work was discontinued because the farmers did not have access to even the minimum facilities required to produce chips of durable quality. Production of chips through sundrying is not always possible since the rainy season will have set in by the time the sweet potato is ready for harvesting. Moreover, the acceptability of processed sweet potato is questionable even if it is possible to commercially produce chips or flour. There is, however, a good prospect for manufacturing starch from sweet potato in small- or medium-sized industries. Information on the economic feasibility of establishing such industries is being collected.

Marketing

Sweet potato is an important commercial commodity in Bangladesh, but its system of marketing and the problems associated with it have not been studied. Production of sweet potato is seasonally fixed in this country and the period of harvest is rather brief. These, plus the poor keeping quality and bulky nature of the roots, result in a market glut that seems to favor the poor buyers, though for a short period. But the sellers are happy about it because they can make a reasonably good profit as earlier reported. In this respect, sweet potato is a unique crop. For obvious reasons, its marketing is closely linked with its storage. An improvement in storage technology will prove beneficial to both the producers and the buyers.

REFERENCES

Anon. 1982. World Potato Facts. International Potato Center, Lima Peru, 53 p.

Anon. 1985. Yearbook (1983-84) of Agricultural Statistics. Bangladesh Bureaux of Statistics, Ministry of Planning, Bangladesh.

Elias et al. 1984. Sweet potato production in Bangladesh -- an agro-economic survey and constraints to its higher production at farm level. Agricultural Economics Division, BAR. 62 p.

Hussain M.M., M.A. Siddique and M.M. Rashid. 1982-83. Effect of production methods and planting materials on the growth and yield of sweet potato. Punjab Vegetable Grower. (17-18):25-29.

Jenkins, P.D. 1980. Storage of sweet potato in Bangladesh. 50 p.

Mannan, M.A. and M.M. Rashid. 1984. Seasonal effects on the pattern of growth, tuberization and root quality of sweet potato. Bangladesh J. Agric. Sci. 9(2). 89-96.

Rashid, M.M. and A.T.M.S. Choudhury. 1980. Effect of method of production type and source of cutting on the yield of sweet potato. *In* Final report, AVRDC project, BARC., Bangladesh. p 71-72.

Rashid, M.M., A.A. Mazumdar and M.S. Molla. 1982. Performance of exotic germplasm of sweet potato in Bangladesh. Proc. Ist Intl. Symp. on sweet potato, AVRDC. p.291-95.

Rashid, M.M. et al. 1981-1986. Annual Reports, Root Crops Project for the years 1980-81 to 1985-86. BARI, Joydebpur, Bangladesh.

APPENDIX 1. List of exotic and local varieties/clones evaluated for selection of superior genotypes and their origin.

Exotic

AVRDC

AIS 0122-2, AIS 209-2, AIS 209-3, AIS 230, AIS 243-2, AIS 243-2-1, AIS 272-9, AIS 35-1, AIS 35-2, CI 0017-25, CI 412-2, CI 428-3, CI 478-3, CI 478-9, CI 478-10, CI 489-1, CI 489-2, CI 548-3, CI 590-2, CI 590-33, I 0117-6, CN 941- 32, CN 1108-13, CN 1219-1, CN 1221-1, CN 1229-16, CN 1232-9, CN 1280-3, CN 1308-1, CN 1028-15.

IITA

TIS 2328, TIS 2330, TIS 2498, TIS 2532, TIS 3077, TIS 3030, TIS 3032, TGIS 3055, TIS 3247, TIS 5016, TIS 5081, TIB 8.

Taiwan Agricultural Research Institute

Tainung New 10, Tainung 57, Tainung 62, Tainung 64, Tainung 65, Tainan 15

Japan

Kokeia 8, Okinawa, Norin, Norin 5

Philippine Root Crop Research and Training Center

Acc.6, Acc.10 (B-NAS 51), Acc.13, Acc 87.

USA

Jewel, Pelicin, Cinjhi, Julian, Mount Diamond I, Mount Diamond 3, Mount Diamond 4, RS I, RS 2, USA-I, USA-2 (the last 2 are local selections from a seed population)

Sri Lanka

Wariyapola

Tropical Agricultural Research Station, Puerto Rico

Wart, Sunny, Papota, Macana, Ninety nine, Mojave, Margarita, Bugsbunny

Unknown origin (received from the Philippine outreach program of AVRDC)

DATA, GYY, HDK-12, Old yellow, Red Tuber Tail, Tinirining, B-NAS white.

Local

A total of 65 varieties were collected from within Bangladesh. The range of variability in sweet potato seems to be rather narrow in this country. The local varieties do not have cultivar names and are designated here by accession numbers prefixed with SP.

SWEET POTATO: INDIGENOUS TECHNOLOGIES AND RECENT ADVANCES OF PRODUCTION, PROCESSING, AND UTILIZATION IN INDIA

G.M. Nair, C.S. Ravindran, S.N. Moorthy, and S.P. Ghosh*

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is grown throughout the tropics and in warmer temperate countries. Its edible tubers are important sources of food. In India, it has been cultivated since ancient times. Hence, it is regarded by the Indians as indigenous. It is used in religious ceremonies as evident in Shradth where only native vegetables are cooked. However, there are more to find with the crop, being economically important in the northeastern part of India, in this report.

Selection of Planting Material

Sweet potato is propagated through vine cuttings obtained either from freshly harvested plants or from a nursery. To obtain vine cuttings, nurseries are raised either from healthy tubers or from selected vines. Vines obtained from a nursery are healthy and vigorous, resulting in maximum tuber production. Use of terminal vine cuttings has given the highest tuber yield at the Central Tuber Crops Research Institute (CTCRI) and Coimbatore (Anon, 1981; Shanmugavelu et al., 1972). Vine cuttings stored with intact leaves under shade for two days prior to planting also had better sprouting and higher tuber yield (Nair et al.,1984). A vine length of 20-40 cm was found to be optimum for tuber production in different parts of the country.

Land Preparation and Method of Planting

The field is generally plowed or dug to a depth of 10-20 cm and formed into ridges and furrows. Planting on mounds and flat beds is also practiced to a limited extent. In Bihar and Uttar Pradesh, planting on ridges is very popular. It is preferred to planting sweet potato on mounds in areas experiencing drainage problems. Among the different methods of land preparation, the highest yield in sweet potato was realized when planted

*Agronomist, Agronomist, Organic Chemist, and Director, respectively, Central Tuber Crops Research Institute, Trivandrum 695 017, India.

on mounds at CTCRI (Ravindran and Mohankumar, 1985) both under upland and lowland situations. Ridge and bed and furrow methods were also found to be suitable over the flat bed method of planting.

The cuttings are placed in the soil with both ends exposed and the middle portion buried in the soil. Vines are also planted in an inclined position with half of the length exposed. Planting of sweet potato vines at depths ranging from 2.5 to 10 cm when planted vertically did not have any significant influence on stand establishment and final tuber yield (Ravindran and Mohankumar, 1985).

Spacing and Plant Population

Close spacing is generally recommended for sweet potato to achieve maximum yield. The planting distance of 30-60 cm within rows and 15-20 cm between plants has given maximum yield in different parts of the country. Purewal and Dargan (1959) noted highest yields of sweet potato planted at 30x30 cm and 60x30 cm spacing in Punjab. Trials conducted at CTCRI showed that the highest yield in H-4l variety was realized when planted at 60x15 cm (Mandal et al., 197l) spacing. The other variety, H-42, gave optimum yield when spaced at 45x15 cm (CTCRI, 1970). Rajput et al. (1981) reported better yield from sweet potato when spaced at 30x15 cm in Maharashtra State. When sweet potato is planted on mounds, however, no specific spacings are followed and vines are planted on top of the mounds accommodating 3-6 slips/mound. CTCRI has recommended a general spacing of 60x20 cm for sweet potato planted on ridges.

In a technology recently developed by Rajendra Agricultural University, Bihar (Mishra and Mishra, 1984), on a system of two-tier cropping in sweet potato where shallow bulking cv. Cross-4 (produces tuber at shallow depth) and deep bulking cv. R. S-5 (produces tuber at deeper depth), are grown in alternate rows at a spacing of 30 x 15 cm. It is claimed that such planting could obtain 30-40 percent more tuber yield.

Organic Manuring

Preliminary studies conducted at CTCRI (1969) showed no significant yield advantage from the application of farm yard manure (FYM) at 5, 10, and 15 t/ha. In a recent trial at CTCRI on sweet potato with two levels of FYM and five levels of NPK, it was further confirmed that application of 5 t of FYM was as good as 10 t of FYM to achieve the desired yield of tubers (Anon, 1986). Sweet potato grown in fertile soils generally does not receive dressings of organic manures while soils low in organic matter content have to be supplied with organic manure at 5-l0 t/ha to ensure proper development of tubers.

NPK Fertilizers

Nitrogen

In one of the trials conducted at CTCRI (Mandal et al., 1977), significant yield increases were obtained with nitrogen application of up to 100 kg/ha. However, Nair and Sadanandan (1973) did not observe any significant yield increase over levels of nitrogen application at 50, 75, and 100 kg/ha in the red loam soils of Vellayani, Kerala State. Trials conducted at Coimbatore, Tamil Nadu, also showed that nitrogen application beyond 50 kg/ha did not improve the tuber yield of sweet potato (Muthuswamy et al., 1981). Rajput et al. (1981) observed highest yield from sweet potato when supplied with 50 kg N/ha in Parbhani district of Maharashtra State. Mishra et al. (1985a) concluded that the optimum dose of nitrogen for the highest yielding cultivar, Kalmegh, was 74.5 kg/ha at Dholi in Bihar State. Thus, the above observations clearly indicate that nitrogen supply should be moderate, ranging from 50 to 75 kg N/ha for optimum tuber production.

Trials conducted at Coimbatore, Tamil Nadu, indicated that application of 80 kg N, 50 percent as basal and 50 percent as foliar in the form of 2 percent urea at 30, 60, and 90 days after planting, regulated the foliage growth and increased the tuber yield over full basal dressing and 50 percent basal + 50 percent top dressing 30 days after planting (Shanmugavelu et al., 1973). Similar observations were made by Alexander et al. (1976) in the application of 75 kg N, 50 percent as basal and 50 percent as foliar 35 days after planting at Vellayani, Kerala.

Phosphorus

Very little work has been done on the response of sweet potato to phosphatic fertilizers in India. However, Rajput et al. (1981) observed significant yield increases owing to the application of 50 kg P_2O_5/ha, which is considered to be optimum for sweet potato.

Potassium

Differential response to applied potassium has been reported from various parts of the country. The response to added potassium, however, has not been as noticeable as that of nitrogen (Anon, 1979). Based on the results obtained at various coordinating centers in India, the recommended dose of potash for sweet potato varies from 30 to 60 kg K_2O/ha.

Soils high in available potassium status failed to show significant improvement in tuber yield to added levels of potash at Coimbatore (Muthuswamy et al., 1981). The most economic dose of potash was found to be 60 kg K_2O/ha at Trichur in Kerala (Ashokan et al., 1984).

Secondary and Micro Nutrients

With the use of more refined and complex forms of fertilizers, the deficiencies of secondary (Ca, Mg, and S) and micronutrients are bound to limit the yield of sweet potato. Although no specific reports are available to substantiate the actual response of sweet potato to secondary and micronutrients, it is commonly believed that sweet potato responds favorably to the application of zinc. In an earlier trial conducted at CTCRI, it was observed that application of boron, iron, and magnesium promoted flowering in sweet potato but did not contribute higher tuber yield (Maini et al., 1973). Crude protein content in tuber, however, was significantly increased by the application of boron and magnesium.

Weeding and Interculture

Sweet potato is so aggressive that it quickly covers the field and suppresses most of the weeds. Occasional weeding, however, may become necessary, particularly in the early stages of growth. Earthing up the soil also controls weeds, besides improving the physical condition of the soil. Field trials conducted at CTCRI (1981) showed that earthing up on day 30 after planting or weeding and earthing up on day 15 or 30 after planting recorded higher tuber yields than the control plants, which did not receive weeding and earthing up.

Irrigation

Hot weather planting needs irrigation on alternate days initially for the first 10 days and thereafter once in 7-10 days. Tuber yield and water use efficiency of sweet potato irrigated at 0.7 atmospheric tension were higher than when irrigated at 0.35 atmospheric tension or at an interval of one month or without irrigation (Biswas et al., 1980). Preliminary studies conducted at CTCRI indicated that it was not economical to irrigate sweet potato beyond 60 percent field capacity for achieving optimum yield. Imposing water stress during tuber initiation phase and tuber maturity phase adversely affected tuber development and yield of sweet potato as compared to the stress imposed during tuber development phase (CTCRI, 1985).

Maturity and Time of Harvest

In North India, sweet potato crops take 5-6 months to mature while those in the south mature within 4 months. Both crop variety and environment play a significant role in deciding the time of harvest. Tuber initiation in sweet potato, as revealed by starch deposition in cortical tissues, starts on the eighth day after planting and reaches a peak on day 14 (Indira and Kurian, 1977). Varieties that are sensitive to photoperiod, however, take more time for tuber initiation and development. Short-day treatment (8-hour photoperiod) delayed the starch deposition process until 24 days; the control (12-hour photoperiod) took 13 days only (Anon, 1983b). Field experiments on optimum time of harvest of sweet potato conducted at various coordinating centers in India revealed that the tuber yield increased up to the fourth month at Trivandrum and Coimbatore (South India), while under North Indian conditions, it took 150-180 days (Anon, 1979).

A trial on double harvesting done between 90 days and 150 days at intervals of 15-60 days resulted in significantly higher tuber yield when harvested at 90 and 150 days after planting as compared to single harvesting at 150 days under north Bihar conditions (Mishra et al., 1985b).

Effect of Growth Regulators

Sweet potato produces a lot of foliage under favorable conditions, often in excess of the optimum requirement for tuber production. A balanced partitioning of photosynthates toward root and shoot development is important in deciding the ultimate tuber yield of sweet potato. Both positive and negative results have been reported from various parts of India while improving this partitioning efficiency through the use of growth regulators.

Muthukrishanan et al. (1976) from Coimbatore reported a 49 percent increase in sweet potato tuber yield by the foliar application of ethephon at 250 ppm. Trials conducted at Kalyani (West Bengal) also resulted in increased tuber yield (Biswas et al., 1980) by the application of Kinetin (50 mg/l) and cycosel (1 ml/l). Abdul Vahab and Mohanakumaran (1980b) also noticed higher yields when ethrel (330 and 450 ppm) and cycocel (1000 ppm) were sprayed on sweet potato, the effect of ethrel being more pronounced. They also observed a significant increase in the starch and sugar content of the tubers while a decline in protein content was noted with the application of both chemicals. At CTCRI (1976), 500 ppm of cycocel and 250 and 500 ppm of ethrel were found to be effective in increasing tuber yield.

Khanna et al. (1980) reported increase in tuber yield with the application of 750 ppm of cycocel on an already high-yielding cultivar of sweet potato. Trials conducted at Trichur (Kerala State) indicated that cycocel at various concentrations could not influence the tuber yield; rather it tended to depress the yields at higher concentrations (Ashokan and Nair, 1983). Adverse effect on tuber yield with the use of growth regulators has been reported at Ullal in Karnataka State (Anon, 1983b).

Cropping System

Sweet potato is generally grown in sequence with cereals in many parts of the country. In the north, sweet potato is raised as a rabi season crop after Kharif cereals. In the south, particularly in Kerala which enjoys both the southwest and northeast monsoon rains, sweet potato is occasionally grown in the lowlands as a summer crop after rice.

Successful results have been reported from Dholi in Bihar State (Mishra and Mishra, 1981; and Anon, 1981) where sweet potato was grown in a four-crop sequence (maize-sweet potato-wheat-moong) and a three crop sequence (maize-sweet potato-onion).

In an intercropping trial with sweet potato in Dholi, it was observed that sweet potato and mustard (every four rows of sweet potato alternated with two rows of mustard) obtained the highest monetary returns (Anon, l98l). Growing sweet potato and turmeric alone or in combination as inter-crops in between young *Albizia* and *Moghania* plants (lac hosts) was found to be profitable (Purkayastha et al., 1981) at Ranchi, Bihar. However, the performance of sweet potato as an intercrop was poor in a 25-year coconut plantation (CTCRI, 1985).

Nutritive Value

The starch content in most varieties found in India varies from 15 to 35 percent, with an average value of 24-26 percent. The consumption of sweet potato in India varies widely among regions; there are no data on the per capita consumption of the tubers. Tubers are generally boiled, baked, roasted, or fried for home consumption.

The sugar content varies between l and 7 percent on fresh weight basis and it increases on storage and also on cooking and baking. The major sugars present in fresh tubers are sucrose, and smaller quantities of glucose, fructose, and maltose. When boiled or baked, however, the non-reducing sugar content is reduced and the amount of maltose increased substantially. The relatively large quantities of amylase present in the tubers break down the starch to maltose (CTCRI, 1984).

Sweet potato tubers that possess yellow or orange yellow flesh are excellent sources of pro-vitamin A (carotene), which is converted into vitamin A in the body. Although most of the varieties grown in India do not contain high quantities of carotene, CTCRI Trivandum has a collection of cultivars that have carotene contents of up to 10,000 IU and can be used extensively in the food of the people, since the diet of an average Indian lacks vitamin A.

Storage of Tubers

Storage of sweet potato tubers has not been given much attention in India, probably because its produce is usually consumed within a few days after harvest. Also, there are only few processing units producing sweet potato chips, flour, and others. The traditional method of storage involves spreading the roots under the sun for a week, providing suitable waterproof cover during the night, followed by storing in well-ventilated rooms, taking care to occasionally remove unhealthy roots (ICAR, 1956). In the Koraput District of Orissa State, the tribal people have developed an indigenous storage technique, where the tubers are heaped, covered with a thin layer of rice straw, and plastered with soil mixed with cow dung. The huts are completely dark even during daytime and are very cool. The area has a cold climate, especially from November to March, when the tubers are usually stored and the farmers claim storage life of 6 months (CTCRI, 1982).

Thomas (1965) compared tubers stored in ash, dry sand, and dry sawdust. Although he could not observe any difference in the storage life using the different media, any of them was superior to storage in the open. Storage after treatment with various chemicals, such as sodium hypochlorite, potassium metabisulfite, and ascorbic acid, was not effective. But mud coating considerably improved storage life (CTCRI, 1979).

The biochemical changes that take place during storage of the tubers have been studied in detail by various workers, including those at CTCRI. Changes mainly take place in the starch, sugar, and dry matter contents. The starch content is reduced with a corresponding increase in sugar content; this may be brought about by enzymatic degradation of starch, leading to increased sweetness of stored tubers. CTCRI has also observed significant differences in the conversion rate among different varieties. Initially, dry matter content has been found to decrease, then steadily increased later on because of dehydration of tubers. The phenol, pectin, and protein contents also showed variation on storage (CTCRI, 1979).

Processing and Utilization

The postharvest processing of sweet potato has not been practiced to a great extent in India, unlike in other countries like the United States, where canned sweet potato, sweet potato puree, and sweet potato flakes are common and popular. There is a very good scope for these products in India and also in flour-based products and in producing liquid glucose, high fructose syrup, and alcohol.

In addition, the vines can be fed to animals either as such or after ensiling. The excess tubers can be used as carbohydrate source in animal feeds.

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 fasts 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, and pudding. The flour has been used in producing chappathi (a handmade cake) along with wheat flour. The flour can be used as dough conditioner in break manufacture, as stabilizer in ice creams, and also consumed along with peanut cake. At CTCRI, some attempts have been made to produce bread and biscuits using sweet potato flour. It was found that up to 25 percent of wheat flour can be substituted with sweet potato flour without substantially affecting the quality of the products. They are sweeter, though slightly harder and darker than wheat bread.

CTCRI has done some work on pickling sweet potato chips. Tried as medium for pickling were brine (l%, 2%, and 5%) and sucrose syrups (25% and 50%). The chips, however, could be stored at ambient conditions for only 8 weeks in 50 percent sucrose syrup.

Sweet potato starch can be extracted like cassava starch, except that the pH is maintained at 8.6 by using lime water, which flocculates the impurities and dissolves the pigments. The tubers are ground with lime water and starch is separated by washing over a series of screens. It is bleached with sodium hypochlorite and centrifuged. The yield is around 20 percent.

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

Yeh (1982) discussed the possibility of using sweet potato chips in animal feeds. He observed that sun-dried chips could substitute up to 25 percent of corn in a pig ration and the carcass quality was better if 50 percent substitution of corn was substituted with sun-dried potato chips. Nutritive value could be further improved and the trypsin inhibitory activity was eliminated by heat treatments. Sweet potato chips supplemented with urea could also be used in cattle feed.

Sweet potato vines contain 12-l7 percent crude protein and can be used as animal feed. The silaging of sweet potato vines, the biochemical changes during the ensiling, and the results of feeding trials have been outlined (Ruiz, 1982). It is claimed that the use of sweet potato vines and wastes as cattle feed is economically feasible.

Presently the tops and nonmarketable tubers are hardly used in India. With increased demand for animal feed, sweet potato vines and wastes are incorporated profitably into animal feeds.

REFERENCES

Abdul Vahab, N. and N. Mohanakumaran. 1980a. Starch, sugar and protein contents of sweet potato tubers as influenced by ethrel and CCC. *In* Proceedings of the National Seminar on Tuber Crops Production Technology, 21-22 Nov. 1980, TNAU, Coimbatore, India.

Abdul Vahab, N. and N. Mohanakumaran. 1980b. Effect of ethrel and CCC on the yield, number and size of tubers of sweet potato. *In* Proceedings of the National Seminar on Tuber Crops Production Technology, 21-22 Nov. 1980, TNAU, Coimbatore, India.

Alexander, D., N. Sadanandan and R.V. Nair. 1976. Studies on the effect of methods of nitrogen application on mineral uptake of high yielding sweet potato varieties. Agric. Res. J. Kerala. 14(1):21-26.

Anonymous. 1979. Report of the 5th All India Workshop on Tuber Crops.

Anonymous. 1981. Annual progress report of All India Coordinated Project on Tuber Crops, Dholi, Bihar, India.

Anonymous. 1983a. Two Decades of Research. CTCRI, Trivandrum, India.

Anonymous. 1983b. Report of the 7th All India Workshop on Tuber Crops.

Anonymous. 1985. Handbook on cultivars. Ministry of Agriculture and Rural Development, New Delhi, India.

Anonymous. 1986. Agricultural situation in India. 41(5): 416-419.

Ashokan, P.K. and R.V. Nair. 1983. Effect of cycocel on the growth of sweet potato. J. Root Crops 9(1&2): 79-80.

Ashokan, P.K., R.V. Nair and Ku T.M. Kurian. 1984. Nitrogen and potassium requirements of rainfed sweet potato. J. Root Crops 10(1&2):55-57.

Biswas, J., H. Sen and T.K. Bose. 1980. Effect of growth substances on tuber development in sweet potato. *In* Proceedings of the National Seminar on Tuber Crops Production Technology, 21-22 Nov. 1980, TNAU, Coimbatore, India.

Biswas, D., H. Sen, M.G. Som and P.K. Jana. 1980. Effect of irrigation and nitrogen levels on the yield consumptive use and consumptive use efficiency of sweet potato. Vegetable Science. 7(1):1-5.

CTCRI (Central Tuber Crops Research Institute), Annual Progress Report. 1969. Trivandrum, India.

CTCRI. 1970 Annual Progress Report Trivandrum, India.

CTCRI. 1971. Annual Progress Report. Trivandrum, India.

CTCRI. 1976. Annual Progress Report. Trivandrum, India.

CTCRI. 1979. Annual Progress Report. Trivandrum, India.

CTCRI. 1981. Annual Progress Report. Trivandrum, India.

CTCRI. 1982. Annual Progress Report. Trivandrum, India.

CTCRI. 1984. Annual Progress Report. Trivandrum, India.

CTCRI. 1985. Annual Progress Report. Trivandrum, India.

Gupta, P.N. and Mathura Rai. 1979. Sweet potato for tilla lands of Tripura. Indian Farming.29(5):24.

ICAR (Indian Council of Agricultural Research). 1956. Harvesting and storage of sweet potato. Farm News Release No. 173. *In* Council of Scientific and Industrial Research. Dictionary of Indian Raw Materials. New Delhi, India. 5:244.

Indira, P. and T. Kurian. 1977. A study on the comparative anatomical changes undergoing tuberization in the roots of cassava and sweet potato. J. Root Crops. 3(1):29-32.

Indira, P. and T. Ramanujam. 1980. Intervarietal response of sweet potato to the months of planting in relation to tuberization. *In* Proceedings of the National Seminar on Tuber Crops Production Technology, 21-22 Nov. 1980, TNAU, Coimbatore, India.

Khanna, S., T.B. Dasaradhi and Abida Sultana. 1980. Effect of cycocel and ethrel on growth and yield of sweet potato. *In* Proceedings of the National Seminar on Tuber Crops Production Technology, 21-22 Nov. 1980, TNAU, Coimbatore, India.

Maini, S.B., P. Indira and R.C. Mandal. 1973. Effect of boron, magnesium and iron on flowering, yield and quality of sweet potato. Madras Agric. J. 60(8):1024-1025.

Mandal, R.C., K.D. Singh, S.B. Maini and M.L. Magoon. 1971. Response of sweet potato to plant spacing and nitrogen fertilization. Indian J. Agron. 16(1):85-87.

Mishra, S.S. and S. Mishra. 1981. Sweet potatoes in multiple cropping is paying. Indian Farmers' Digest. 14(12):13-16.

Mishra, S.S. and S. Mishra. 1984. Studies on two tier cropping system in sweet potato. South Indian Horticulture. 32(2):104-106.

Mishra, S., S.S. Mishra and U.R. Sinha. 1985a. Response function of sweet potato cultivars as affected by nitrogen fertilization. South Indian Horticulture. 33(2): 131-133.

Mishra, S., S.S. Mishra, P.K. Ray and S.J. Singh. 1985b. Comparison between single and double harvesting of sweet potato. *In* Proceedings of the National Symposium on Tropical Tuber Crops Production and Utilization. 27-28 Nov. 1985. CTCRI, Trivandrum, India.

Muthuswamy, P., M. Govindaswamy and G.V. Kothandraraman. 1981. Influence of sources and levels of potash in combination with nitrogen levels on sweet potato. Madras Agric. J. 68(6):351-354.

Nair, G.M. and N. Sadanandan. 1973. Performance of sweet potato varieties under varying levels of nitrogen and time of its application in red loam soils of Vellayani. Agric. Res. J. Kerala. 11(1):14-16.

Nair, G.M., C.S. Ravindran and Mangel Prasad. 1984. Cultural practices for tuber crops. Indian Farming. 33(12):29-33.

Nair, R.B., B. Vimala, G.G. Nayar and G. Padjama. 1986. H.80/168: A new high carotene, short duration hybrid in sweet potato. CTCRI Publication No. 488 (Accepted for publication in the J. Root Crops).

Nanda, S.K. 1984. Postharvest practices of tuber crops. Indian Farming. 33(12):64-66.

Nawala, R.N. and M.J. Salvi. 1983. Effect of season on yield of sweet potato. J. Root Crops.9(1-2):55-58.

Nayar, G.G., P. Kamalam and R.B. Nair. 1984. Two promising sweet potato selections for early harvest. J. Root Crops. 10(1-2):79-80.

Purewal, S.S. and K.S. Dargan. 1959. Effect of sowing dates, fertilizers and spacings on the development and yield of sweet potato. Indian J. Agron. 3(3):164-171.

Purkayastha, B.K. Singh and Motiram. 1981. Intercropping of tuber and rhizome crops within mixed plantation of young lac hosts, *Albizia lucida* and *Moghania macrophyla*. Indian J. Agric. Sci. 51(8):574-576.

Rajput, S.G., B.A. Kadam and V.K. Patil. 1981. Spacing cum nutritional requirement of sweet potato. J. Root Crops. 7(1-2):25-27.

Ravindran, C.S. and C.R. Mohankumar. 1985. Effect of method of land preparation and depth of planting on the yield of sweet potato. *In* Proceedings of the National Symposium on Tropical Tuber Crops Production and Utilization, 27-28 Nov. 1985, CTCRI, Trivandrum, India.

Ruiz, M.E. 1982. Sweet potato (*Ipomoea batatas* L.) for beef production. Agronomic and conservation aspects and animal responses. *In* Villareal, R.L. and T.D. Griggs (eds.). Sweet potato. Proceedings of the First International Symposium. AVRDC, Taiwan, R.O.C.

Shanmugavelu, K.G., S. Thanburaj and S. Shanmugam. 1973. Effect of soil and foliar application of nitrogen on the yield of sweet potato. Fertilizer News. 18(5):51-52.

Shanmugavelu, K.G., S. Thamburaj, S., A. Shanmugam and N. Gopalaswamy. 1972. Effect of time of planting and type of planting material on the yield of sweet potato. South Indian Horticulture. 20(1/4):55-58.

Singh, K.D. and R.C. Mandal. 1976. Performance of coleus and sweet potato in relation to seasonal variations (time of planting). J. Root Crops. 2(2):17-22.

Thomas, C.V. 1965. Studies on the response of certain varieties of sweet potato (*Ipomoea batatas* L.) to fertilizer application. MS Thesis. University of Kerala, India.

Vijaya Bai, K. and N. Hrishi. 1977. Synthesis of "pentaploid sweet potato." J. Root Crops. 3(2):53-54.

Yeh, T.P. 1982. Utilization of sweet potatoes for animal feed and industrial uses. Potential and problems. *In* Villareal, R.L. and T.D. Griggs (eds.). Proceedings of the First International Symposium on Sweet Potato. AVRDC, Taiwan.

INDIGENOUS TECHNOLOGIES AND RECENT ADVANCES IN SWEET POTATO PRODUCTION, PROCESSING, UTILIZATION, AND MARKETING IN INDONESIA

Roberto Soenarjo*

INTRODUCTION

Sweet potato is considered as a secondary crop ("palawija") or nonrice crop in Indonesia. It is mostly grown in monoculture or sole crop under upland condition or in lowland after rice during the dry season.

The sweet potato area is approximately 300,000 ha. Production is about 2.3 million tons annually but the hectarage has consistently decreased. There are two important factors responsible for the decline of the area planted to sweet potato. One is better irrigation facilities which make growing of rice in the lowland possible during the dry season. The other is that sweet potato cannot compete with higher-value crops such as soybean and vegetables.

There is a considerable gap between the research station yield of 25-30 t/ha and farm yield of 7-l0 t/ha. Research has shown that cultural practices could increase yield by 43 percent, improved varieties by 98 percent, and chemical fertilizer by 84 percent (Soenarjo, l979).

The major use of sweet potato is for food. Less than 5 percent is used for cattle feeding. In Irian Jaya, sweet potato is grown in approximately 50,000 ha and is a major staple food in the region.

Research and development work on sweet potato, as in other food crops, is done by the Research Institutes for Food Crops under the coordination of the Central Research Institute for Food Crops (CRIFC) in Bogor.

PRODUCTION

During the past decade, CRIFC released three sweet potato varieties and recommended five local varieties to farmers. The three varieties were

---

*Coordinator, Root and Tuber Crops Program, Central Research Institute for Food Crops (CRIFC), Bogor, Indonesia.

Daya, Prambanan, and Borobudur while the local varieties were Tumpuk, Citok, Mentik, Mongkrong, and Mantang.

Farmers generally do not apply fertilizer to their crop. Therefore, it is very important to show them that fertilizer application may increase the yield at least 32 percent under poor soil conditions and nearly double (83.93 percent) the yield under better soil conditions.

Time of fertilizer application is also an important factor to consider when aiming to increase sweet potato production. The split application of nitrogen and potassium increased both yield and fertilizer efficiency by 36.36 percent and ll.33 percent, respectively.

Sweet potato is mostly grown in the field during dry season after rice. Farmers generally take the rice straw away for their cattle or burn them to clear the field. Our research results showed that 2 t/ha of rice straw incorporated in the ridging could increase the yield by 2 t/ha of fresh roots.

Research indicates that sweet potato yield can be increased by 43 percent above the present national average through the application of improved cultural practices alone. When improved high-yielding varieties are included in the package, the increase reaches 98 percent. When appropriate plant nutrients are also added, yields can be increased up to 300 percent from the present average yield of 8.7 t/ha.

PROCESSING AND UTILIZATION

In Indonesia, farmers generally do not process their sweet potato. Most of their products are sold in the field to a collector or middleman. They save some amount they earned during harvest for their household needs.

CRIFC emphasizes table size and industrial use in the program. For table size or consumption use, sweet potato varieties should have good taste with dry flesh after cooking. Indonesians do not generally like wet flesh or sweet potatoes with watery flesh. For industrial use, however, it should have high starch content with low latex in the roots.

Sweet potato is prepared for consumption by means of frying, steaming, or boiling for evening tea. In Irian Jaya where sweet potato is used for food, the roots are roasted so that it can stand longer during the day. Fresh root, which is orange in color, is generally used for salad or *rujak*. White flesh roots are sometimes used as substitute for Irish potato in making frying cake.

There is no plant processing sweet potato in Indonesia; there are such facilities for cassava, however. This is because most roots are consumed by household and the demand for the product is reasonably good. Compared to cassava, sweet potato is a more seasonal crop. It is mostly grown during the dry season and the production center is more limited.

It is hoped that increasing demand for high fructose syrup in the country will attract investors to build sweet potato processing plants. Unstable raw materials for processing, however, will limit the activities.

REFERENCES

Achmad Affandi. 1986. Agriculture Development in Indonesia. Ministry of Agriculture, Jakarta, Republic of Indonesia. 53 p.

Soenarjo, R. 1979. Highlight Penelitian Ubi-ubian selama Pelita I dan II dan Program Pelita III. Lembaga Pusat Penelitian Pertanian, Bogor. 24 hal.

Soenarjo, R. 1983. Peranan Ubi-ubian sebagai Bahan Pangan dan Industri, Potensi dan Prospeknya. Lokakarya Perumusan Rencana Penelitian Tingkat Peneliti, Denpasar, Bali. 24-29 Nopember 1983. 35 hal.

SWEET POTATO IN IRIAN JAYA

Yan Pieter Karafir*

INTRODUCTION

While rice is the main traditional food crop in Java, Bali, Sulawesi, and other islands of Indonesia, tubers and sago are the traditional main food crops in some parts of Eastern Indonesia, particularly Irian Java and the Moluccas. In Irian Jaya, five tuber crop species have been traditionally grown as sources of carbohydrate of the local people's food supply. These are sweet potato (*Ipomoea batatas* (L) Poir), cassava (*Manihot utilissima* l), taro (*Colocasia* sp.), taro (*Xanthosoma* sp.), and yam (*Dioscorea* sp.). Of these crops, sweet potato is grown almost throughout the region both in the lowlands and in the highlands of up to 2,400 m altitude. From anthropological findings, it was established that this crop, which is native to tropical South America, might have been brought to New Guinea almost 400 years ago by Iberian travellers from Europe, through Africa and South and Southeast Asia (Yen, l982; Watson, l977).

ECONOMIC AND SOCIAL SIGNIFICANCE

Sweet potato in Irian Jaya is economically important only as a subsistence crop for the indigents in the villages. The Central Highlands -- Baliem and Paniai regions -- share more than 90 percent of the total provincial sweet potato production (Table l). In these regions, sweet potato has over the years gained social significance. It has been a familiar daily foodstuff in each household. It is also consumed in ritual ceremonies as well as in tribal feasts. The tubers are used not only by human beings but also for pigs. Sweet potato leaves were also consumed as vegetable.

Sunarto (l983) estimated that in the Baliem valley and Paniai, the average amount of sweet potato consumed by an adult person was 3 kg/day. Sumule, a socioeconomist of Tim Survey Faperta Uncen (l986), estimated that in the Kamu valley (Paniai), an adult man needed 2.89 kg/day, an adult woman l.27 kg/day, and children l.42 kg/day. In the Birds Head region, estimates for Anggi and Kebar are available. In Anggi, a family of three adults and two children consumed 7.5 kg/day of sweet potato (Karafir et al., l984). For Kebar, Buyney (l982) estimated that an adult consumed 0.406 kg/day, and the children consumed 0.27l kg/day.

*Faculty of Agriculture Cenderawasih University, P.O. Box 23 Manokwari, Irian Jaya, Indonesia.

Table 1. Distribution of sweet potato production in Irian Jaya, 1985.

Regency	Area harvested (ha)	Total production (t)	Ave. production (t/ha)
Merauke	97	991	10.22
Jayawijaya	21,587	210,111	9.73
Jayapura	525	5,366	10.22
Paniai	24,051	120,255	5.00
FakFak	480	2,201	4.59
Sorong	424	4,333	10.22
Manokwari	495	5,059	10.22
Yapen-Waropen	78	797	10.22
Biak-Numfor	68	695	10.22
Irian Jaya	47,805	349,808	7.32

Source: Bureau of Statistics, 1985.

Kebar is a case of a community with varied menu while Baliem, Paniai, and Anggi are communities with monotonous menu.

Using the individual consumption estimates and population data, aggregate consumption needs could be calculated. If compared with the production obtained, a phenomenon of food shortage seems to appear (Table 2). This phenomenon would have been concealed because within the communities a mechanism to overcome that problem has been developed. In Anggi, sweet potato shortage has appeared seasonally, especially after planting. The local people have tried to overcome this by first planting corn and pumpkin that could be harvested during the nursing stage of sweet potato (Karafir et al., 1984). Such a strategy might have been adopted also in Baliem and Paniai. In the case of sweet potato production itself, the prime cause of the shortage seemed to be the increasing shortage of land brought about by the rapid population growth and restrictions imposed by tribal rights. Another factor is the stagnant (in some) and decreasing land productivity in other parts of the region.

FARM AND CROPPING PRACTICES

Existing farming practices may be distinguished into those for lowlands and those for highlands. In lowland areas, sweet potato is normally grown in shifting cultivated gardens, whereas in the highland, sweet potato gardens are semipermanent to permanent, with well-developed mulching, irrigation, and drainage system.

Table 2. Sweet potato production and consumption need in Jayawijaya, 1985.

Subregencies	Estimated production (t)	Estimated consumption need (t)
Wamena	25,330	34,347
Kurulu	13,710	15,483
Asologaima	14,150	19,114
Makki	13,400	17,937
Kelila	15,300	21,277
Bokondini	9,120	11,514
Karubaga	27,650	40,973
Tiom	35,340	51,868
Kurima	58,320	101,902
Okbibab	4,896	18,939
Kiwirok	6,428	12,275
Oksibil	6,480	13,508
Jayawijaya	230,124	359,137

Source: Bureau of Statistics, Jayawijaya Regency, 1986.

The land area cultivated in one year by a farm family varies among regions. Most often, however, it is less than one hectare. In Kamu valley (Paniai), out of 0.433 ha, 0.295 ha is devoted to tuber crops; 0.037 ha to vegetable crops; and 0.093 ha to coffee (Tim Faperta Uncen, 1986). In Anggi, a family normally owns two gardens of about 0.21 and 0.35 ha each year. For example, on a piece of land owned by five families, the following crop combination was found (Karafir et al., 1984):

Corn + sweet potato	0.500 ha
Sweet potato + pumpkin	0.237 ha
Garlic	0.014 ha
Potato and Cabbage	0.001 ha
House + home yards	0.215 ha
Total	**0.967 ha**

In both the lowlands and the highlands, sweet potato gardens are usually fenced with pieces of wood cut during land clearing. As has been shown earlier, sweet potato may be grown as a single crop or in mixed cropping. In the highlands, single cropping is normally found; however, mixed cropping may also be found, particularly with maize. In the lowlands, mixed cropping is normally practiced. On a piece of land, sweet potato is usually mixed with other crops such as taro, banana, yam, and vegetables.

The soil is manually prepared before planting, consisting of soil tilling and bed preparation. Two types of planting beds are found (i.e., round heap, with a diameter of 50-60 cm and wide furrow beds). In Paniai, the beds are almost squared, about 2.5 x 2.5 m^2. From above, they look like a checker board. In the highlands, round heap and wide furrow are both practiced. In muddy areas, both types of beds are used in combination. Round heap beds are made on the wide furrow beds. Clay is used for the outer layer of the round heap beds. This method is used to protect the tubers from soil water and rainfall. The tubers are usually formed in the round heap beds. In places where podsolic soil dominates, wide furrow beds are usually preferred. Round heap beds are not suitable since rainfall may destroy the beds and leave the tubers uncovered and easily attacked by *Cylas formicarius*.

Women plant, nurse, and harvest the crop. Short cuttings of the stem are used in lowland plantings. In the highlands, long stem cuttings that are deepened several times in the ground are used. The harvest is not done all at once. Ground storage is performed and harvest is done on a daily, twice weekly, or weekly basis. The harvesting period may last up to three years. After that, the land is kept fallow until the next planting season. Usually, as practiced in Paniai and Anggi, before leaving fallow, pigs are released into the garden. In looking for overleft tubers, the pigs do the soil tilling activities. In Anggi, after the pigs have moved out, the land may be worked again and planted to peas, beans, and other vegetable crops and then abandoned for some time. The period of fallow depends on land availability of the clan and fertility restoration capacity of the land. The local people can determine whether the fertility has been restored by watching the development of vegetation on the abandoned piece of land.

In each region, more than one cultivar is usually found. The local people can easily distinguish the cultivars based on the known characteristics of the leaves, stem, and tubers. Local names have been given for each cultivar. No survey has ever been done to identify or to list the existing cultivars. From several social studies, however, relevant data might be available from the Baliem valley, Paniai, and the region around Manokwari. Heider, as quoted by Bourke (l982), reported that about 70 cultivars had been found in the Baliem valley. Soenarto (l983) stated that 22 cultivars had been found in the Baliem valley, more than 25 in Paniai, and about l5 around the Arfak mountains. Karafir et al. (l984) listed l0 cultivars in Anggi. Sawen (l985) likewise listed 2l cultivars found around Manokwari. Even though plant description and classification have been made by local farmers, these were not accompanied by variety selection. There seems to exist among the indigenous farmers a preference to cultivate all the available varieties in their gardens. The usually reported farm production figures were stated as the average of all cultivars grown.

Economic analysis of sweet potato production on local farms around Manokwari has been done by Dedaida (1986). He compared the economics of upland rice with sweet potato production in the indigenous and transmigrant farms. The average production costs per hectare of upland rice was calculated to be Rp 120,000, and of sweet potato about Rp 75,000. In one year, per hectare return-cost ratio of upland rice production was 3.5 and 7.5 for sweet potato. Based on these, it can be said that sweet potato production is more efficient than that of rice. This statement should, of course, be reconfirmed by doing economic analysis in other producing regions, particularly in the Baliem valley and Paniai. Other variables such as soil fertility level should also be considered in further tests, since tuber crops are generally known to degrade land fertility quicker than grain crops such as rice.

REFERENCES

Bourke, R.M. 1982. Sweet Potato in Papua New Guinea. *In* Sweet Potato: Proceedings of the First International Symposium. AVRDC, Shanhua, Taiwan.

Bureau of Statistics. 1978. Regional Income Dati I Irian Jaya 1971-1977. Development Planning Bureau and Bureau of Statistics, Irian Jaya, Indonesia.

Bureau of Statistics. 1985. Irian Jaya Dalam Angka (Statistics of Irian Jaya). Development Planning Bureau and Bureau of Statistics, Irian Jaya, Indonesia.

Buiney, D. 1982. Pola Makanan dan Nilai Gizi Makanan Petani Di Kampung Anjai, Desa Kebar Tengah, Kecamatan Kebar, Kabupaten Manokwari, Skripsi. Faperta Uncen Manokwari.

Dedaida, H.T. 1986. Pebandingan Effisiensi Produksi Padi Ladang dan Ubi Jalar di Warmare, Manokwari. Thesis. Faperta Uncen Manokwari.

Karafir, Y.P. et al. 1984. Laporan Pengembangan Usahatani Dataran Tinggi Di Kabupaten Manokwari. Facultas Pertanian Universitas Cenderawasih.

Lewarion, Y. et al. 1986. Laporan Praktek Usahatani Di Kampung Mokwam, S.P.V. Transmigrasi Lokal Prafi Manokwari. Laporan. Fakultas Pertanian Uncen Manokwari.

Marjudin. 1966. Pengaruh Pergiliran Tanaman Pada Hasil Ubi Jalar (*Ipomoea batatas* Poir). Edaran Dari Lembaga Penelitian Pertanian Manokwari Tahun 1966.

Murtono et al. 1986. Uji Daya Hasil Beberapa Kultivar Ubi Jalar Di Satuan Pemukiman Transmigrasi Prafi, Manokwari. Makalah Pada Seminar Akademis. Oktober 1986.

Oomen, H.A.P.C. et al. 1961. The sweet potato as the staff of life of the highland Papuan. Bulletin of the Agricultural Research Station Manokwari. Agricultural Series No. 5.

Ruinard, J. 1959. Report on an Experiment Concerning Different Cultural Methods with Sweet Potatoes at Kota Nica. Mededelingen van de Landbouwkundige Afdeling, Jaargang 1952.No. 2.

Saonng, 1961. Some remarks on the food value of sweet potato leaves and tubers. Circulars of the Agricultural Research Station Manokwari, Agricultural Series No.3.

Saonng. 1962. Selection of sweet potato. Circulars of the Agric. Research Station Manokwari, Agricultural Series No.5.

Sawen, H. 1985. Identificasi Kultivar Ubi Jalar Di Desa Yoom-Nuni Kecamatan Manokwari, Kabupaten Manokwari, Skripsi. Faperta Uncen Manokwari.

Soenarto. 1983. Beberapa Aspek Penelitian Ubi Jalar Di Irian Jaya. Makalah (Paper) pada Pertemuan Teknis dan Alih Teknologi Dinas Pertanian Tanaman Pangan Propinsi Daerah Tingkat I Irian Jaya tanggal 28-30 Juni 1983 di Jayapura.

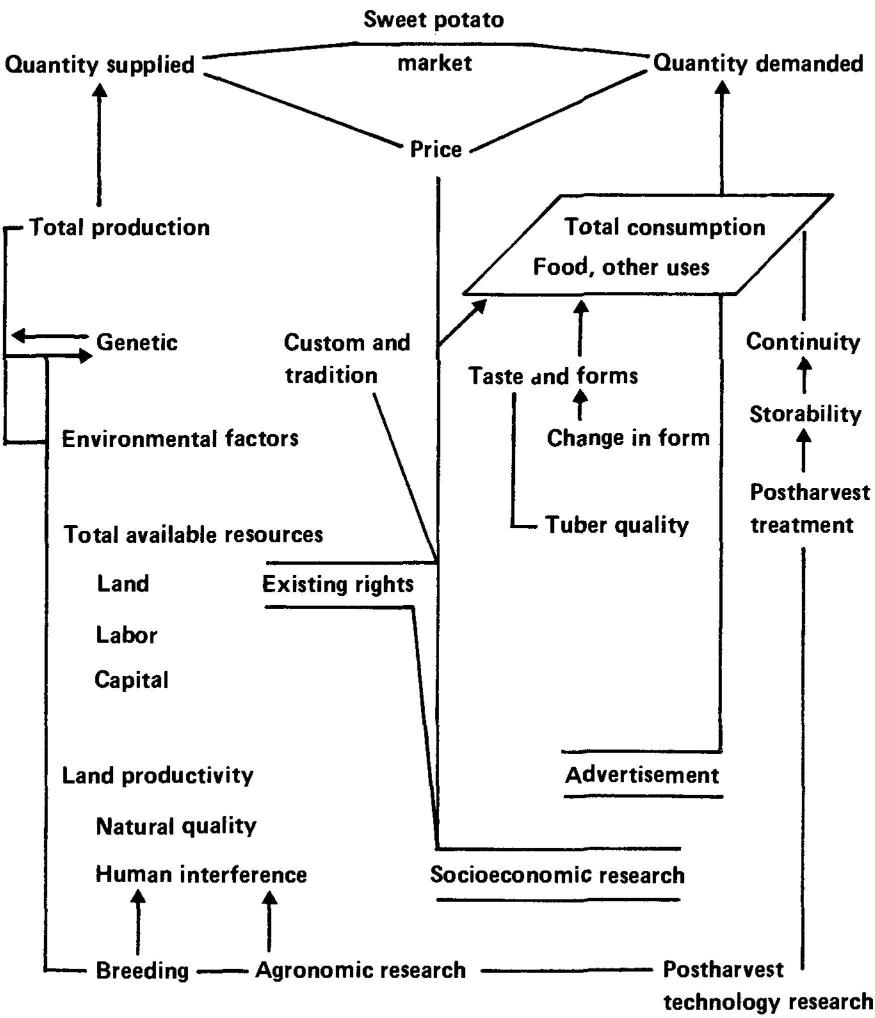
Tiblola, A.D. 1983. Produksi Ubi Jalar (*Ipomoea batatas* (L) Lamb) Jenis-Jenis Lokal Di Kampung Mupi Kecamatan Manokwari. Skripsi. Faperta Uncen Manokwari.

Tim Survey Fapert Uncen. 1986. Survey Potensi Sosial- Ekonomi Daerah Penyangga Di Kabupaten Daerah Tingkat II Fak-Fak. Bureau of Development Planning, Irian Jaya, and Cenderawasih University.

Tim Survey Faperta Uncen. 1986. Survey Potensi Sosial- Ekonomi Daerah Penyangga Di Kabupaten Daerah Tingkat II Paniai. Bureau of Development Planning Irian Jaya and Cenderawasih University.

Watson, J.B. 1977. Pigs, fodder and the Jones effect on Post Ipomoean New Guinea. Ethnology. 16: 57-70.

Yom, K. et al. 1985. Laporan Praktek Usahatani Di Kampung Sub-Say, Desa Dindey, Kecamatan Warmare, Kabupaten Manokwari. Laporan, Fakultas Pertanian Uncen Manokwari.



Appendix Figure 1. System approach to determine research programs for sweet potato development in Irian Jaya.

INDIGENOUS TECHNOLOGIES IN SWEET POTATO PRODUCTION AND UTILIZATION

F.G. Villamayor, Jr.*

INTRODUCTION

Filipinos are primarily a rice- and corn-eating people but in times of cereal scarcities and emergencies, root crops, particularly sweet potatoes, are often used as substitute for their carbohydrate needs. Moreover, there are some Filipinos, especially those living in the mountains whose staple is sweet potato (i.e., the Ifugao of Ifugao, the Ikalahan of Nueva Vizcaya, the Ibatan of Batanes, and the Mangyan of Mindoro).

According to the most recent available national production statistics (BAEcon, 1985), there were 164,300 ha devoted to sweet potato cultivation with a production of 777,176 metric tons, or an average yield of only 4.73 mt/ha. An agronomic survey in the province of Leyte revealed higher yields but the figures were still underestimated because the area sampled had already been harvested of big roots several times (Villamayor et al., 1987). Barker (1984) mentioned yield estimates of 32 and 16 t/ha/year for one- and three-year old *kaingin* (slash-and-burn agriculture) areas.

Most of the indigenous technologies in the Philippines apply to subsistence farming as only a small percentage of sweet potatoes is grown commercially, mostly in places near population centers like Metro Manila. Furthermore, researches on production are not really new since they mainly provide explanations for the current practices of farmers.

The presentation of topics will follow the cycle starting from production to utilization.

PRODUCTION

Land Preparation

For flat areas, the land is thoroughly prepared by plowing and harrowing. Ridges are then made about 1 meter apart. In Jones, Isabela, (Central Luzon), the land (alluvial soil) is so thoroughly prepared that no other operation was needed after planting. One farmer said he only spent for planting and harvesting. He got 300 sacks (about 70 kg each) from one hectare.

*Professor and Head, Production Technology Section, Philippine Root Crop Research and Traning Center, ViSCA, Baybay, Leyte, the Philippines.

In many cases, such as in *kaingin*, no land preparation is needed. Barker (l984) described *inum-an* as a typical system of shifting cultivation among the Ikalahan of Imugan, Nueva Vizcaya. The site is selected based on ease of clearing, anticipated crop yield, and proximity to home and other fields. Secondary forests are preferred when available. Clearing the *inum-an* is generally men's work, particularly in virgin and secondary forests. When grass and shrub fallows are cleared, women and older children often help. With the exception of fruit trees or other valuable trees, the area is cut clean. Small fields of less than one-fourth hectare are most common owing to rough topography which limits field size. Cleaning proceeds concentrically from the middle of a chosen site toward the outside. Felled trees are limbed with the tops left for burning. Cut vegetation is spread over the *inum-an* to insure even burning and a uniform layer of ash. Clearings are cut during dry periods so that the slash will dry thoroughly and burn well. The primary crop, sweet potato (*obi*), is planted days after the burning. Over 90 percent of the total *inum-an* area is planted to *obi*, which is the single most important dietary component for most families.

In Leyte, mounds of about 75-l00 cm in base diameter and 20–30 cm in height are made. This is true for slightly rolling areas and flat lands. There are several possible reasons for this type of land preparation. First, the rain is too much that mounding helps prevent waterlogging. Second, about 50 percent of soils grown to sweet potato is clayey in nature (Villamayor et al., l987) and mounding minimizes water saturation. Third, the soil is thin (rocky) so that mounding has to be resorted to to increase the volume of soil necessary for root development and expansion. Fourth, harvesting is done by selection of big roots and mounding minimizes injury to the remaining roots during harvesting.

In ViSCA, Labra and Forio (l982) found no yield differences between mound and ridge planting and the former required 25 to 30 more man-days per hectare than the latter. The soil used, however, was sandy loam and the rainfall was more or less evenly distributed during the growing period.

Selection of Varieties

Upland farmers prefer creeping varieties that suppress weeds, produce lateral storage roots, have short maturity period, and allow prolonged sequential harvesting (De Pedro et al., l986). Ken Turner (personal communication), a missionary working in Mindoro, observed a variety cultivated by the Mangyan that grows at about a foot a day. This kind of variety was probably selected unknowingly for erosion control. Among the Ikalahan, many varieties are grown in one field, with a variety occupying a certain portion of the field (Barker, l984). Two varieties, *motmot* and *kalbuoy,* are widely grown owing to their high yield when planted in fertile soils. They continue to yield better than other varieties even when soil fertility is low, and have a tendency to produce storage roots where a leaf node touches the ground (*pakad*). Once established, *motmot* and *kalbuoy* need not be replanted but are simply allowed to touch the ground. This characteristic (*pakad*) is both labor-saving and good for canopy maintenance. According to Rev. Delbert Rice (personal communication), a missionary working among the Ikalahan, many varieties are grown in one area as a form of insurance. Some varieties thrive well during the dry season while others make good during the rainy season. Some are early maturing while others are late maturing, thus assuring continuity of supply. Furthermore, these varieties have different responses to pests and diseases. Growing of different cultivars insures that some will survive and yield in cases of severe disease infection and insect infestation. Planting of several varieties in a field was also observed on Basco island.

On the other hand, there is a belief in Leyte that planting a mixture of varieties in one field is not good (Ponce et al., 1985). This mixed planting, however, is different from those previously mentioned where a particular variety occupies a specified block in the field.

Preparation of Planting Materials

The length of planting materials ranges from 25 to 40 cm. Normally, only the terminal shoots are used for planting, but when planting materials become scarce, cuttings may be taken from the middle of the vines. The people probably learned from experience that terminal shoots are better than any part of the vine. Research results showed that apical cuttings are better than those from the middle or the basal parts (Eronico et al., 1981). In Libertad, Echague, Isabela, sources of planting materials are the left-over roots that sprout at the onset of the rainy season (Domingo Laud, personal communication). In Paniqui, Tarlac, long cuttings (40 cm) are used because the surface soil is dry while the subsoil is wet. Cuttings are, therefore, long because they are planted deep in letter "L" form (Jeremias Rodriguez, personal communication).

Among the Ikalahan of Imugan, cuttings are gathered two to three days before planting and allowed to partially dry to prevent shock upon planting if the soil is not saturated (Barker, 1984). Under very moist conditions, planting immediately follows cutting. Cuttings are selected from healthy plants based on the color and thickness of the youngest leaves.

Some farmers in Leyte gather planting materials during full moon because they believe this will result in the production of full and large roots (Ponce et al., 1985).

Planting Method

. In Leyte, three to four cuttings are planted in mounds that are spaced about I meter apart. In hilly or sloping areas, planting is done at random 50-I00 cm apart, with two cuttings per hill. This method of planting probably minimizes erosion compared with row planting, which is oriented up and down the slopes. This method of planting is especially true among the Mangyan of Mindoro..

Barker (I984) described planting among the Ikalahan of Imugan as follows: first, a horizontal pit is opened along the contour about 5 cm wide, I5 cm long, and I5 cm deep; second, two cuttings are placed in the pit, each bent into an inverted "L" shape with 8 to I0 nodes positioned horizontally below the ground, and 9 to I0 nodes with leaves exposed and pointing down hill; third, the pit is covered with soil from uphill and mounded 2-3 cm higher than the original ground level.

In flat lands, planting is done along the furrows which are hilled-up later, or on the ridge when ridging has been previously done. A very fast method of planting was observed in Isabela. One man distributes the cuttings along the ridge 20-30 cm apart while another inserts the basal part into the ground using a flat wooden stick. It only takes 2 man-days to plant a hectare. The soil, however, is alluvial (light textured).

Planting Time and Planting Position

Planting is usually done at the onset of the rainy season. In areas with no distinct wet and dry season and rainfall is evenly distributed, however, planting is done anytime of the year.

There are certain beliefs associated with planting. Ponce et al. (I985) mentioned the following beliefs in relation to planting sweet potato. A full moon and low tide were believed to be the most appropriate time to plant to insure plentiful harvest. Planting when it is raining would result in bad harvest, and the first day of November and noon on the 29th of every month were believed to be lucky dates for planting.

There are many ways of planting sweet potato. Some plant vertically or slantwise, especially when the cuttings are short. Others plant in the bent or "L" position while still others plant in "V" or "U" position with both ends coming out of the ground. A few others plant in twisted position, or sometimes a knot is made in the middle of the cutting which is then buried in the ground. Tenebro (I935) compared the planting positions of two varieties and found the bent position to be the best, followed by the slanting position, and then by the twisted position.

Replanting

A survey of sweet potato farmers in Leyte showed that more than 50 percent of them practiced replanting usually within a week when planting materials are still available (Ponce et al., 1985). The report does not say the number of missing hills when farmers replanted and how these were located, whether contiguous or at random. Results of several experiments showed that replanting is not necessary if missing hills are not adjacent to each other and less than 30 percent (ViSCA, 1981) as long as there is adequate weed control. In addition, replanting should be done not more than a week after planting.

Fertilization/Maintenance of Soil Fertility

Majority of farmers do not fertilize sweet potato. In Leyte, 95 percent of household respondents said they did not apply fertilizers (Ponce et al., 1985; Villamayor et al., 1987). Even farmers in Tarlac who grew sweet potato mainly for the market did not apply fertilizers (Jeremias Rodriguez, personal communication). Reasons often given by farmers for not applying fertilizers were: it is not necessary and they have no funds to buy fertilizers.

Although farmers do not apply fertilizers, they have practices that contribute to the maintenance of soil fertility. Crop rotation, especially with legumes, is one of these practices. Barker (1984) mentioned several soil conservation measures practiced by the hillside Ikalahan farmers. First is the timing of production events (i.e., clearing, burning, and planting prior to peak rainfall months). By planting early, rapid growth response to early rains allows sweet potato to form a canopy before the onset of hard rains. Second is canopy maintenance, which is achieved by harvesting in blocks and selection of big roots. Third is staggered planting and harvesting. Working in small blocks prevents the formation of large, bare erosion-prone spots after initial clearing. Staggering helps maintain the canopy. Fourth is *gen-gen*, which combines terracing and composting when a block is replaced. *Obi* vines not required for replanting together with the weeds are placed in a shallow trench (*gen-gen*) dug on the contour. Leaves are piled and covered with soil. Not only is a miniature terrace formed but the composted leaves help to produce large roots. The *gen-gen* effectively breaks up runoff flow and traps eroding soil. Fifth is vegetative terracing, which includes intercropping rows of tiger grass, fruit trees, and nitrogen-fixing trees. These strip the break-up water runoff and the trap soil particles and debris. Sixth is intercropping, which helps conserve soil by forming vegetative terraces (described earlier) and by providing a layered canopy and a root zone. Seventh is known as *day-og,* in which drainage ditches are constructed around blocks of *obi* in relatively level areas near the bottom of slopes where excess runoff from above and where standing water may damage crops. Eighth is fallowing, which conserves the soil by covering the *inum-an* with a heavy canopy once cropping ceases.

Weeding and Cultivation

Weeding and cultivation are common practices of all farmers. In the flatlands, plows are used to control weeds through offbarring and hilling up. Hoes are also used, especially for mound planting.

In the hillsides and even in flatlands, as in the case of Basco Island, farmers use an iron bar or a handlebar to remove weeds. They do not use a bolo for weeding. The farmers said that using a handlebar might be slow but it is effective in uprooting obnoxious weeds such as cogon (*Imperata cylindrica*) and nut grass (*Cyperus rotundus*). The use of handlebar probably minimizes injury to the developing roots because of its narrow width (about 2 cm). At the same time, the soil is deeply cultivated, which is good for sweet potato. Results of studies have shown that tilled and weeded plots gave higher yields than untilled and unweeded plots (Remulta, 1983).

In Imugan, women weed their *inum-an* when not planting, harvesting, or attending to other activities. Weeds are pulled out, gathered in piles, and left to decompose for compost. Weeding is a continuous and monotonous job. It probably consumes the biggest portion of labor during a cropping cycle (Barker, 1984).

Insect and Disease Control

Farmers do not normally control pests by using chemicals. Survey results in Leyte showed that insects are controlled by handpicking, smudging, cutting of infested parts, and burning and keeping the farm free from weeds (Ponce et al., 1985). The Mangyan, Ibatan, and Ikalahan do not control pests and diseases. To them, these are just minor problems. The sweet potato weevil, however, is a common and serious problem, especially during the dry season. To avoid weevil infestation, the roots are usually harvested earlier when soil cracking is already observed. For farms where sweet potato stays the whole year round, weevil control is really a big problem.

Intercropping

Fifty-eight percent of the farmer respondents in Leyte practiced intercropping (Ponce et al., 1985). The intercrops used were cassava, peanut, and vegetables. Sweet potato was also being planted together with banana and coconuts but only where the latter two crops were not closely planted.

In Basco, Batanes, it was observed that sweet potato grew with corn, *gabi* (taro), and yam. As mentioned earlier, the Ikalahan practiced intercropping. Intercropping was one way of increasing canopy cover and providing additional income. Research results showed that intercropping or relay cropping could be profitable with corn (Evangelio, 1980; Antonio and Franco, 1981; Otivar, 1983) and legumes (Gorne, 1983; Olita, 1984; Mercado, 1983; Misa, 1985).

Harvesting

Harvesting differs between commercial growers and subsistence farmers. Commercial growers, who generally use flat to gently sloping lands, harvest at one time, depending on the market demand. The vines are cut first by a bolo or removed by a tooth harrow before passing a plow two to three times to expose the roots. At the Philippine Root Crops Research and Training Center (PRCRTC, Baybay, Leyte), a multipurpose plow was developed, one attachment of which is a sweet potato digger (Loreto, 1983).

In the case of subsistence farmers, harvesting is done daily and the amount of harvested roots depends on their needs. Farmers use a pointed metal or a wooden stick to harvest the big roots, leaving the small roots to develop further. In Leyte, 97 percent of the sampled farmers practice staggered harvesting by selecting big roots (Villamayor et al., 1987).

Farmers know when a crop is ready for harvest through signs such as bulging at the base of the plant, cracking of the soil, senescence of leaves, and by physical checking of the roots. There are two beliefs associated with harvesting (Ponce et al., 1985). One is that rubbing charcoal on roots prevents weevil infestation. The other is that rubbing sugar on the part where roots are harvested prevents rotting.

UTILIZATION

Food

Sweet potato is utilized mainly as human food. The most common preparation is plain boiling. About 80 percent of the household respondents in Leyte process sweet potato into native delicacies such as *lidgid, ginata-an, iraid,* and *tinabudlo*,(Ponce et al., 1985). Their preparations differ but they basically use the same ingredients -- sweet potato, sugar, coconut milk, and flavoring. Other products obtained from sweet potato are discussed by Truong (1987). Perhaps it should be mentioned that the leaves are used as vegetables.

Feed

Aside from being used as a staple and snack items, sweet potato is also fed to animals such as swine and poultry. About 90 percent of household respondents used the roots unfit for human consumption to feed their animals, some in raw forms but mostly in cooked form (Ponce et al., 1985). Even weevil-infested roots can be used as long as they are cooked and mixed with other ingredients. Research results showed that sweet potato could be used to replace all the corn in the rations of all classes of swine as long as the requirements for the various nutrients were met (Gerona, 1987). Even weevil-infested roots, when cooked, could be used at 20 percent level of incorporation for broilers (Almoroto, 1984). The vines could also be used as feed for swine and carabao.

Preservative

According to Perfecto Bartolini (personal communication) of PRCRTC, sweet potato can be used to preserve meat. Roots are boiled, mashed, mixed with the meat, and wrapped with cheesecloth or any suitable wrapping material and hung. The meat could last for several months.

REFERENCES

Almoroto, A.T. 1984. Suitability of weevil infested sweet potato tubers for feed of broilers. BS Thesis, ViSCA, Baybay, Leyte, the Philippines.

Antonio, J. G. and A.C. Franco. 1981. A study on relay cropping of sweet potato with corn under Paniqui conditions. TCA Res. J. 3(2):81-84.

BAEcon (Bureau of Agricultural Economics). 1985. Crop Production for 1985. BAEcon, Quezon City, the Philippines.

Barker, T.C. 1984. Shifting cultivation among the Ikahans. Working Paper, Series I. PESAM, UPLB, College, Laguna, the Philippines.

De Pedro, R., Jr., C. Lightfoot, D. Apura, M. Acaba and J. Cabiling. 1986. Screening of sweet potato varieties by subsistence farmers in Basey, Samar, Philippines. A case study of traditional experimentation in upland agriculture. Ann. Trop. Res. 8:201-207.

Eronico, C.A., R.G. Escalada and R.M. Trenuela. 1981. Effects of different portion and length of storage cuttings on the growth and yield of sweet potato. Ann. Trop. Res. 3(21):144-149.

Evangelio, L.A. 1980. Effects of different cropping systems on the growth and yield of sweet corn and sweet potato. MS Thesis. UPLB, College, Laguna, the Phillippines.

Gerona, G.R. 1987. Piloting of commercial formulation of root crop-based animal feeds in Eastern Visayas and the Bicol Region. Progress Report. ViSCA, Baybay, Leyte, the Philippines.

Gorne, N.D. 1983. Evaluation of intercropping methods using sweet potato and legumes in a hilly area. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Labra, J.S. and A.F. Forio. 1982. Economical seedbed preparation for sweet potato. The Radix. 4(l):6.

Loreto, A.B. 1983. A new versatile plow for root crop farmers. The Radix. 5(2):ll.

Mercado, H.B. 1983. Strip planting of ipil-ipil with varying population of sweet potato in marginal hilly area. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Misa, R.C. 1985. Performance of sweet potato at varying times of peanut intercrop. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Olita, L.L. 1984. Intercropping sweet potato with bushbean at different populations and timing of planting. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Otivar, N.P. 1983. Timing of relay cropping sweet corn and sweet potato under varying levels of organic guano fertilizer. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Ponce, L.B., E.I. Beray and J.V. Go. 1985. Field technology and beliefs in root crop production and processing in Northern and Southern Leyte. Terminal Report. ViSCA, Baybay, Leyte, the Philippines.

Remulta, F.N. 1983. Growth and yield of sweet potato as influenced by tillage, weed control and fertilizer application. BS Thesis. ViSCA, Baybay, Leyte, the Philippines.

Tenebro, M.T. 1935. The effect upon the yield of sweet potato of planting cuttings in three different positions. UPCA Bi-weekly Bull. 3(l5):l-2.

Truong Van Den. 1987. State-of-the-art: processing and utilization of cassava and sweet potato for food. Paper presented at the Symposium on State-of-the-Art of Root Crop Technologies. PRCRTC, ViSCA, Baybay, Leyte, the Philippines. 20 March 1987.

Villamayor, F.G., Jr., C.A. Eronico and N.B. Euldan. 1987. Agronomic survey of root crops in Leyte. Progress Report. ViSCA, Baybay, Leyte, the Philippines.

ViSCA (Visayas State College of Agriculture). 1981. Annual Report. ViSCA, Baybay, Leyte, the Philippines.

INDIGENOUS TECHNOLOGIES AND RECENT ADVANCES IN SWEET POTATO PRODUCTION, PROCESSING, UTILIZATION, AND MARKETING IN SRI LANKA

S.D.G. Jayawardena and K.P.U. de Silva*

INTRODUCTION

Though sweet potato is considered of tropical American origin, it could not be authenticated as to when and how it was introduced to Sri Lanka. There is no doubt, however, that sweet potato has been cultivated in Sri Lanka since the ancient times and is regarded by the people as indigenous. Since then, cultivation of sweet potato has traditionally been confined to peasant settlements. The crop has been an integral part of the people's diet and agriculture.

Sri Lanka is a country with a calorie-deficient, low income population strata and growing population pressure on land and available food. During the past 20 years, the population of Sri Lanka increased by 50 percent. The population growth has consequently reduced the per capita land availability by one-third. Furthermore, the main food crop has reached a point of saturation and it is becoming a costly item because of its dependence on energy-based inputs for intensive production. On the other hand, the potential of the highland for food crop cultivation remains unexploited. These situations provide strong justifications that root and tuber crops have a great potential in national agricultural development programs.

Sweet potato, among the tuber crops, is superior to rice in terms of dry matter production. It gives a high edible yield in a relatively short time and requires very little labor and care. In view of these, it has assumed a significant role in farming systems and in diversification programs. In spite of the importance of sweet potato as a food crop in Sri Lanka, little attention has been paid to improve it through research. The Research Project on Root and Tuber Crops was started only in 1978 with assistance from the International Development Research Centre (IDRC) of Canada.

*Head, Division of Botany and National Coordinator, and Research Officer and Principal Investigator, respectively, Root and Tuber Crops Project, Central Agricultural Research Institute, Department of Agriculture, Gannoruwa, Peradeniya, Sri Lanka.

Nevertheless, since sweet potato is an important traditional crop in Sri Lanka, some unique practices for its cultivation, crop management, marketing, and consumption can still be seen. Hence, the objective of this paper is to examine and review the indigenous and improved technologies on sweet potato production and utilization in Sri Lanka.

INDIGENOUS CULTIVATION PRACTICES

Methods of Culture

The growing of sweet potato on flat land is a common practice in home gardens and chena system where it is given scant attention. The grower simply harvests the roots while digging up the soil with a garden hoe. At the same time, the mass of vines is buried in one operation to produce another crop after a few months. However, yields of this remote culture are usually low.

To reduce the risk of water logging in the rooting zone of the crop, planting of sweet potato in dense population on raised flat beds (l.0 x 6.0 m dimension) is another common practice in the wet zone, where sweet potato is grown on *deniya* lands. One major advantage of this culture is its ability to smother and control weeds. Further, it provides better aeration and satisfactory tuberization, although marketable root yield decreases.

Sweet potato grown on flat lands in mixed culture with banana and vegetables without proper use of row cropping is another traditional setting. Furthermore, growing of sweet potato as border plants around vegetable blocks is frequently found in areas where vegetables have traditionally been cultivated. The major reason for including sweet potato in such cropping systems is to suppress weed growth along with optimizing land use.

Varieties and Selection of Planting Material

In almost indigenously evolved sweet potato production systems, traditonal sweet potato varieties still play a substantial role in the total output. These varieties could be the derivatives of the many early introductions and through a process of natural selection got adapted to the different agroecological conditions. Even though these varieties are poor yielders, the traditional growers are reluctant to avoid growing these varieties since they possess unique characters that are in favor of direct consumption as a food source rather than for selling.

Further, most of these cultivars are locally named according to their most well defined characters. For instance, Pol batala (elephant sweet potato) implies large tubers; Kaha batala (yellowish sweet potato) indicates high carotene content in the flesh; and Niyan batala (drought resistant sweet potato) implies ability to withstand drought. However, the traditional variety Wariyapola (name of the city where it is found) has been welcomed by most of the farmers since it possesses highly desirable characteristics such as yield, early maturity (3-3 1/2 months), compact plant type, and good cooking qualities.

Most of the traditional sweet potato growers give more emphasis on selection of planting material rather than on selection of variety. Usually, the use of vine cuttings from the harvested crop is done for the next planting up to the third and fourth generations. The source of cuttings is then renewed by planting a few medium- to large-size roots in nursery beds. Some interested growers make their own selection of high-yielding plants at harvest time and maintain high yields throughout without degeneration and rejuvenation of planting materials. The use of unmarketable size of roots for direct planting is sometimes practiced to take advantage of uncertainty in rainfall conditions during planting time.

The length and position of cuttings in vines, however, are not important for cultivation of sweet potato as a general practice in the traditional setting. It is interesting to note, though, that some growers remove spices of the vines in order to get the highest sprouting percentage.

Spacing and Seeding Rate

In traditional systems of cultivation, sweet potato is generally planted on the flat either in pure stands or mixed stands by adopting close and random spacings. Planting materials are placed in the soil by burying the middle portions as to expose 2-3 nodes each on both ends. When grown on raised flat beds in paddy and *deniya* lands, indefinite and closer spacings are adopted by dibbling the cuttings to an upright position. Although high seed rate is frequently necessary in this type of traditional production systems because of successive planting, this necessity is not a major problem because recycling of planting materials is absolutely free of cost.

After Cultivation Care

In native production systems, intercultural practices are usually shallow and often are only needed to control weeds. Under a dense population cultivation, however, the aggressive growth of sweet potato covers the soil very early and consequently weeding may become unnecessary.

The common inputs in most of the sweet potato farms are cattle manure, wood ash, or decomposed straw; inorganic fertilizers are seldom used.

Farmers believe that the root yields of sweet potato can be enhanced by controlling excessive vine growth. In traditional agriculture, it is a common practice among farmers to turn over vines to prevent excessive rooting and allow cattle to feed on the foliage. As a result of this, the nodal root tuber number is decreased and the marketable number and size of tubers is increased.

The root damage caused by the sweet potato weevil is presumed to be considerable in fields where the duration of standing crop is prolonged under dry condition. However, it is not of economic importance as much as rat menace is to farmers.

Yellowing of leaves is said to be a sign of maturity and harvesting in almost all native production systems of sweet potato.

RECENT ADVANCES IN PRODUCTION TECHNOLOGIES

Sweet potato research in Sri Lanka has not received a high priority compared with research support for other food crops. Research on this crop had not been given enough attention until the late 1970s. Thus, research progress and the outputs of technological advancements in sweet potato had been slow. The need for diversifying food supplies, however, has made clear the great potential of cassava and sweet potato in national agricultural development programs. Hence, in 1978, a Root and Tuber Crops Research Project was initiated with assistance from IDRC. Its activities have concentrated on improving the production technologies of cassava and sweet potato.

Research findings on coordinated varietal evaluation trials have demonstrated a significant production potential for sweet potato in many agro-climatic zones of the country, including some of the dry zone areas. During the first 8 years of this project, useful data on sweet potato production pertaining to planting systems, varieties, fertilizers, cropping systems, and many other management practices conducive to large-scale cultivation of sweet potato were obtained in different climatic conditions. Further findings of the project have created an awareness among policymakers, administrators, and agricultural research and extension workers on the promise of sweet potato as a main food crop as well as a raw material for industry and animal feed.

The most striking research findings of the project carried out so far may be summarized as follows:

- **Replacing the traditional stock of sweet potato with promising clones**

Two promising sweet potato varieties (CARI-9 and CARI-242) with excellent cooking qualities were evolved by intervarietal hybridization (De

Silva, et al., 1985). The crude protein content of these varieties ranged from 2.8 to 4.3 percent, while the presently cultivated traditional varieties record 0.9 to 1.44 percent on dry matter basis. The root yield of those varieties ranged from 18 to 35 t/ha at 3 1/2-4 months under varying agroecological conditions. This reflected a significant superiority over presently popular traditional varieties like Wariyapola (De Silva et al., 1986). In farmers' fields at different locations these new clones consistently outyielded Wariyapola.

- **Use of exotic genotypes in plant breeding**

With the objective of upgrading the native sweet potato genetic stock by adding exotic genes, a crop improvement program was initiated by using exotic (received from IITA, AVRDC, and ViSCA) and indigenous genotypes through the polycross breeding method.

Seedling progenies showed significant diversity and could hopefully result in the emergence of some outstanding plant types suited for different environmental conditions.

- **Studies on cultural and management systems for high root yield**

In land preparation studies, a marked increase in tuber yield was observed in raised ridges and mounds over flat lands and flat beds. Plant population studies indicated that interaction between planting density and root yield depended on plant type (bush, compact, or viny) of the variety.

Use of vine apices as planting material had the advantage of early plant vigor and showed superiority over those from the base cuttings in both the total and marketable root yields (Fonsoka, 1986). Tips sprouted from root tuber did not show significant yield advantage over vine tips obtained from the harvested crop.

- **Cropping system studies**

Investigations on the possibility of intensifying the utilization of land, solar radiation, and other resources in pure stands of sweet potato cultivations through mixed cropping of grain legumes have demonstrated a significant production potential. Although the yields of sweet potato varieties under monoculture were significantly different among themselves, there was a marked yield difference when these were subjected to mixed culture. Bush type of sweet potato (variety C-26) was better suited to mixed cropping system as it appeared to have less competitive effects on legume yield and tuber yield than the viny and semi-viny (compact) types (Prematilake and De Silva, 1984).

There is considerable land potential available in the coconut gardens because coconut trees use only 25 percent of available soil mass and intercept only about 45 percent of available sunlight. Hence, with the objective of promoting sweet potato cultivation in coconut plantations, varietal evaluation programs were carried out to identify suitable clones capable of giving high yields under partially shaded ecological conditions. Results indicated that the new CARI hybrids (CARI-242 and CARI-09) recorded high yields in both wet and intermediate zones by reflecting the zonal effects.

- **Crop protection studies**

Sweet potato weevil studies indicated that the use of ecologically adaptable varieties, early harvesting, and avoidance of dry weather during root maturity reduced weevil damage (De Silva and Prematilake, 1984). Results of another study showed that the use of tip cuttings for planting followed by earthing-up of the stem bases of vines is the best cultural method to reduce sweet potato weevil infestation (Mendis, 1986).

Investigation done on relative varietal resistance of sweet potato hybrid lines to weevil demonstrated that the degree of tuber damage was related to some of the morphological and biochemical characters of tubers. It suggested the use of skin thickness, neck length, latex, and sugar content of the tubers as criteria for selecting sweet potato varieties that are resistant to weevil infestation in a breeding program (Basnayake et al., 1984).

The importance of root knot nematodes as factors that affect the quality and marketable root yield of sweet potato has only been recognized recently. The considerable variation in the degree of susceptibility occurs among the cultivars and is known to react differently at varied locations indicating incidence of root knot nematodes (Ekanayake and Nugaliyadda, 1986). Hence, more detailed information on the pathogen and inheritance of resistance in sweet potato is urgently needed to tackle this problem, which is increasingly getting worse in most production areas of Sri Lanka.

RECOMMENDATIONS

Cultivation of sweet potato for direct human consumption as a fresh food is very profitable on the present yield levels and market prices. Higher yields could be obtained with adequate fertilizer application along with high levels of intercultural practices. However, such high levels of management practices should not be the technology for the farmer to increase yield per unit area. The main research objective should be to increase the farmers' income level and not the tuber yield per unit area. In this respect, more research on cost reducing technologies must be carried out to minimize the need for weeding, chemical inputs, and intensive culture methods.

Mixed cropping of sweet potato and legumes or vegetables could bring down the cost in most management practices and increase the farmers' income by optimizing the physical and socioeconomic resources. Hence, it is very appropriate that research should be directed toward cropping systems involving sweet potato. Nevertheless, evolving high-yielding varieties could be considered as the best method for reducing cost.

With the increase in prices of rice and wheat flour, the demand for sweet potato as a fresh food can increase faster than expected. In spite of the low current prices of sweet potato, demand is low because consumers are very selective. They prefer to purchase very fresh tubers -- usually a few days after their harvest and they still have acceptable eating and marketing qualities. Therefore, use of sweet potato as a source of food could be increased by developing marketing, storage, processing, and utilization technologies. In this connection, crop improvement programs should be directed toward developing varieties with specific characters that are needed to meet the demand for above technologies. High fresh tuber yield, high protein and dry matter content, mild or non-sweet flesh, acceptable weight loss in storage, and good keeping qualities are the major characters to be considered with respect to this.

However, shorter growth duration varieties with reasonably high yields and field tolerance to drought with resistance to weevil and nematodes could be used to exploit areas of low rainfall for sweet potato cultivation. In this context, a cheap source of starch is an urgent need for the dry zone *chena* farmer in Sri Lanka, whose calorie deficit level is much higher than the national level.

Furthermore, to promote sweet potato as a cheap source of food, low-energy consuming technologies to process sweet potato for human consumption should be developed. Programs to expand the cultivation should be undertaken simultaneously with projects to promote its utilization in industry and as a source of food.

REFERENCES

Basnayake, J.C.K., K.P.U. De Silva and S.D.G. Jayawardena. 1985. Relative varietal resistance of sweet potato hybrid lines to sweet potato weevil (*Cycla formicarus* Fab). Proceedings of the 41st Annual Session of the Sri Lanka Association for the Advancement of Sciences (SLAAS), Colombo, Sri Lanka.

Department of Agriculture. 1983. Cost of cultivation of Agricultural crops - *Yala* 1983. Department of Agriculture, Division of Agricultural Economics and Projects. Peradeniya, Sri Lanka.

Department of Census and Statistics. 1960 thro' 1982. Food balance sheets (Mimeo). Colombo, Sri Lanka.

De Silva, K.P.U., S.D.G. Jayawardena et al. 1985. Success in varietal improvement in sweet potato by hybridization. Proceedings of the 41st annual session of SLAAS, Colombo, Sri Lanka.

De Silva, K.P.U. and S.D.G. Jayawardena et al. 1986. Progress in breeding of cassava and sweet potato in Sri Lanka. Proceedings of the Annual Research Conference of the Department of Agriculture, Division of Research, 4-5 September 1986, Gannoruwa, Sri Lanka.

Ekanayake, H.M.R.K. and M.H. Nugaliyadde. 1986. Nematode problems of root and tuber crops in Sri Lanka. Proceedings of the Annual Research Conference of the Department of Agriculture, Division of Research, 4-5 September 1986, Gannoruwa, Sri Lanka.

Fonseka, H.D. et al. 1986. Yielding ability of vine cuttings of different physiological maturity in sweet potato. Proceedings of the Annual Research Conference of the Department of Agriculture, Division of Research, 4-5 September 1986, Gannoruwa Sri Lanka.

Mendis, V.M. 1986. Effect of cultural practices on sweet potato weevil (*Cylas fomicarus* Fab) damage on sweet potato. Proceedings of the Annual Research Conference of the Department of Agriculture, Division of Research, 4-5 September 1986, Ganoruwa, Sri Lanka.

Prematilaka, P.S.A.D. and K.P.U. de Silva. 1984. Effect of time of harvesting and growing seasons on weevil infestation in sweet potato. Proceedings of the 40th Annual Session of SLASS, Colombo, Sri Lanka.

Prematilake, P.S.A.D. and K.P.U. de Silva. Mixed cropping of sweet potato (*Ipomoea batatas* L) with grain legumes. Proceedings of the 40th Annual Session of SLAAS, Colombo, Sri Lanka.

Samaratunge, P. A. 1984. A review of economic potentials for promoting root and tuber crops in Sri Lanka. IDRC/SLAAS-sponsored Workshop on Root Crops. 29 June 1984, Gannoruwa, Sri Lanka (unpublished).

SWEET POTATO DEVELOPMENT, SELECTION, AND CREATION FROM SEEDS IN VIETNAM

Mai Thach Hoanh*

INTRODUCTION

Sweet potato was first cultivated in Vietnam 2,000 years ago. This crop is a popular food among farmers. It ranks third, after rice and maize, among the food crops being produced in the country (Table I).

Table 1. Main food crop production in Vietnam, 1980.

Crop	Area (1000 ha)	Yield (t/ha)
Rice	5600	2.07
Maize	390	1.00
Sweet potato	450	5.37
Manioc	360	7.50
Potato	50	9.29
Banana	15	12.00

The distribution of sweet potato varies according to Vietnam's geographical regions (Table 2). The crop is cultivated throughout the country from north to south, as indicated in the I980 figure.

Table 2. Distribution of sweet potato according to geographical regions in Vietnam.

Region	People using (in millions)	Area (ha)	Yield (t/ha)
Northern mountainous area	3.33	20.16	3.49
Northern Midland	4.72	34.4	5.53
Red River plain	11.86	89.9	6.10
Middle of North Vietnam	77.55	52.1	4.53
Middle of South Vietnam	5.76	72.8	4.67
Southern mountainous	1.49	21.4	6.39
Southeast of South Vietnam	1.49	18.2	4.87
Mekong Delta	18.09	38.8	8.92

*Food Crop Research Institute, Agriculture and Foodstuffs Industry Ministry, Vietnam.

As far as custom is concerned, sweet potato is used most in the Red River plain (north) and Mekong plain (south). The Red River plain and Central South Vietnam are the largest areas planted to sweet potato. The average yield of sweet potato ranges from 4 to 6 t/ha. Mekong Delta registered the highest yield (8.92 t/ha) followed by the Red River plain and the mountainous areas in the South (6t/ha) and then the mountainous areas in the North (3.49 t/ha).

SWEET POTATO VARIETIES IN VIETNAM

Most of the varieties cultivated in Vietnam per 1980 data are of domestic genes such as Chiemdau, Lim, and Dongdieu.

Besides, there are some varieties imported from China such as Batluanxuan, Hongguang, and Hoanglong. Until now, there has not been any variety selected from seeds. They are distributed according to geographical region (Table 3).

Table 3. The main sweet potato varieties cultivated in different regions of Vietnam.

Region	Sweet potato variety
North Vietnam	Lim – Chiemdau – Dongdieu – Hoanglong
Central Vietnam	Tradoa – Chiemdau – Quangtri
South Vietnam	Duong ngoc – Quangtri

Sweet potato is grown throughout Vietnam, taking part in the continuous cultivation system in each region of the country (Table 4). It is grown mainly between two rice crops in the plain and river beach where water is abundant. After that, it is planted together with maize and bean in the highland or sandy soil regions.

SWEET POTATO VARIETY SELECTION

Area and Yield of Sweet Potato

Since 1976, Vietnam has intensified sweet potato cultivation to solve the food problem of the country. The area planted to this crop has been increased year after year. The largest sweet potato fields are in the Red River plain -- middle of the north and middle of the south. In 1980, the total area doubled that of 1976; in 1983, the total area increased twice that of 1980 (Table 5).

The average yield in the whole country is 5 t/ha. Owing to the increase in area planted to sweet potato and stable yield, the food problem of the

Table 4. Sweet potato varieties grown by continuous cultivation formula.

Region	Continuous cultivation formula
Northern mountainous area	Maize + sweet potato
Northern Midland	Sweet potato + bean, sweet potato + rice
Red River Delta	Rice + sweet potato + rice, sweet potato + rice
Central area of North Vietnam	Sweet potato + rice, rice + sweet potato + rice
Central area of South Vietnam	Maize + sweet potato, sweet potato + bean
Mountainous area of the South	Maize + sweet potato
Southeast	Sweet potato + bean
Mekong Delta	Rice + potato

Table 5. Sweet potato production in Vietnam from 1976 to 1983.

Year	Area (1000 ha)	Yield (t/ha)
1976	249	5.9
1977	325	4.7
1978	355	5.3
1979	396	5.5
1980	450	5.4
1981	414	5.9
1982	404	5.9
1983	550	5.2

people as well as the animal population has been effectively tackled in the 1980s.

Sweet Potato Selection

Selection of sweet potato variety is very important and helps a great deal in making stable yields and in increasing the area for production (Table 5). Prof. Dr. Vu Tuyen Hoang, Director of the Research Institute of Food and Food Crop, has made a great contribution to this activity.

The variety selection results can be divided into two parts as follows:

1. Mass collection, selection, and restoration of Chiemdau variety in time for production.

Mass collection. From 1974 to 1980, the RIFC collected existing varieties in the country (Table 6). From 1979 to 1980, more than 100 local varieties were collected.

Selection and confirmation of Chiemdau and Hoanglong varieties for winter crop. RIFC, together with other provinces, correlated and selected the best varieties now existing in Vietnam such as Chiemdau, Dongdieu, Mam, Bi Dongnai, and Hoanglong (imported from China). Three provinces (Thaibinh, Hanamninh, Haiphong) have encouraging results (Table 7). Also, the Chiemdau and Hoanglong varieties with 120-day long growing duration were selected because of their high adaptability to cold weather.

Restoration of Chiemdau variety for winter crop. Because Chiemdau is a very old variety, living strength is reduced to meet the demand of production. RIFC began restoring this variety in 1979 and satisfactory results have been obtained (Table 8). The round tuber type of Chiemdau yields two times higher than non-restored Chiemdau, which increased the average yield by as much as 1.5-2 times. This increase in yield contributes to the increase in the area planted to sweet potato and stabilized the sweet potato yield from 1979 to 1983 (Table 5).

2. Results of crossing and selection of short growing duration and cold resistant sweet potato varieties for planting in late winter in Vietnam.

Practical demand. After obtaining the sweet potato varieties, RIFC subsequently selected two varieties -- Chiemdau and Hoanglong. These, however, were later found to have two weaknesses: long growing duration (more than 120 days) and low cold resistance. Therefore, they greatly hamper the increase of the cultivation area and yield in Vietnam. The yield of Chiemdau and Hoanglong varieties in 1979 and 1981 are shown in Figure 1.

Thus, the old varieties must be planted in early September to avoid the cold weather and to provide ample time for growth (four months or longer). The yields of these varieties depend on the weather and planting time.

Aims of the selective crossing method

From the weaknesses of the old varieties and the demand of the production, we must create a hybrid variety that has a short developing duration (90-100 days), cold resistance capacity, can develop quickly in low temperature (15°-20°C), and can be planted later in October and November, making the winter crop the main crop between two rice crops. Under the supervision of Prof. Dr. Vu Tuyen-Hoang, we conducted a crossing method and after that, the experimental selection and production, according to the following system: group - crossing garden - variety garden -- selection of asexual generation -- localization- seed production.

Crossed varieties

The results of selected crossed varieties 59, 8, and 251 have been ap-

Table 6. Number of collected sweet potato varieties in Vietnam from 1974 to 1980.

	1974	1975	1977	1978	1979	1980
Number of sweet potato variety in various localities	2 South 4 China 1 Thanhhoa	1 Haihung	5 South 1 Thaibinh 5 Haihung	4 Habac	24 Institute 4 Dalat 1 Danang 2 Thaibinh 3 Thanhhoa	12 South 8 Hue 1 Hanam-ninh 2 Thaibinh 2 Kyson 1 Institute 5 University 6 Haiphong 3 Haihung
Total	7	1	11	4	34	40

Table 7. Results of local variety selection for winter crop in Vietnam (1979-1980).

Province	Variety				
	Hoanglong	Chiemdau	Dongdieu	Mam	Dongnai
Thaibinh	26.6	30.8	15.6	23.3	25.0
Hanamninh	12.1	14.0	12.7	8.3	7.8
Haiphong	17.5	18.0	16.0	14.0	18.3

Table 8. Classification and restoration of two types of Chiemdau variety (winter crop, 1979-1980).

Tuber type	No. of tuber/ root	Wt. of tuber/ root (g)	Tuber type (%)			Bio-yield (t/ha)	Economic yield (t/ha)	% increase (controlled)
			Big	Middle	Small			
Restored	4.7	145	30	28	42	27.7	18.9	201
Long and round tuber	4.3	129	25	26	49	29.0	14.6	155
Non-restored variety	3.7	94	2.5	16.8	80.7	23	9.5	100

plied for production in Vietnam.

Cold resistant capacity of the crossed varieties

To confirm these experiments, we at the same time study closely the crossed varieties in a temperature-controlled room (Table 9).

Crop and growing duration and yield of the crossed varieties

Throughout the country, from Lamdong province to the north, the crossed varieties no. 59, 8, and 251 have been introduced for mass production. The results for 1985 are shown in Table 10.

The crossed varieties are planted late, from October to November, mainly between two rice crops. Their planting time was one month later than the old varieties (Hoanglong and Chiemdau). They have a short growing duration (90-100 days) while Chiemdau and Hoanglong are grown for more than 120 days. These crossed varieties have an average yield of 7-13 t/ha in winter (lower than 20°C) while Chiemdau reaches only 3-7 t/ha. The maximum average yield of the crossed varieties in the north ranges from 14 to 20 t/ha while that of Chiemdau is only from 6 to 12 t/ha.

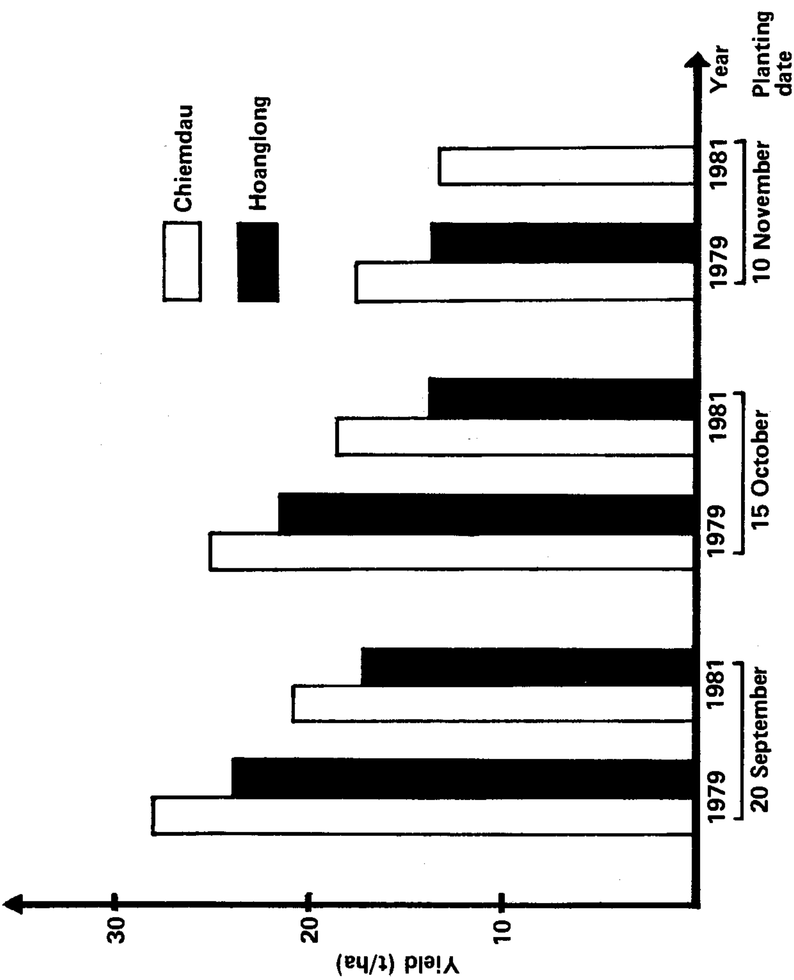


Figure 1. **Yields of the two varieties, Hoanglong and Chiemdau, in the two cropping years, 1979-1981.**

Table 9. Development of leaf and stell and color of the crossed varieties at 10°C for 4 continuous days.

	Variety				
	59 Atmat 7 x Biclongnai	8 1B x Batluan xuan	25 1 Naturally crossed Atmat 8	Chiemdau (controlled)	Hoanglong (controlled)
Leaf: No. before treatment	11,00	7,33	8,00	7,67	8,33
No. after treatment	11,00	8,33	9,33	7,67	8,33
After/before (%)	109,00	113,64	116,63	100,00	100,00
Color	Green	Green	Yellowish green	Green yellow	Withered yellow
Stell before treatment	23,40	19,50	13,33	21,83	24,00
Stell after treatment	25,00	20,83	15,17	22,50	24,67
After/before (%)	106,84	106,02	106,31	103,07	102,80
Color	Nice Green	Green	Yellowish green	Withered yellow	Withered yellow

Table 10. Growing duration and yield of crossed varieties bred in Vietnam, 1985.

Region	Variety	Cropping month	Growth duration (days)	Average yield (t/ha)	Maximum yield (t/ha)
Red River Delta	Chiemdau	Sept	120-150	7,40	12,3
	59,8,251	Oct, Nov	90-110	12,3	18,5
Central of the North	Chiemdau	Sept	120-150	5,65	10,8
	59,8,251	Oct, Nov	90-110	13,10	20,5
Midland of the North	Chiemdau	Sept	120-150	5,55	8,1
	59,8,251	Oct, Nov	90-110	11,50	15,5
Mountainous of the North	Chiemdau	Sept	120-150	3,50	6,5
	59,8,251	Oct, Nov	90-110	7,50	14,10

Economic efficiency and quality of the crossed varieties in comparison with Chiemdau and Hoanglong.

In the 650 ha of Thaithuy District, Thaibinh province, general economic efficiency of crossed varieties 59, 8, and 25l has been calculated for the whole district as follows:

- The cost of one ton of the crossed varieties: Reduced by l00 dongs.
- Profit: More than l,385 dongs in comparison with the old varieties (as l7 dolor/ha).
- Quality: The inside part of the tuber is yellow, so it must be sweeter than Hoanglong and Chiemdau. Variety no. 8 is ivory-colored and can be as sweet as Chiemdau, while variety no. 25l has a loose and ivory-colored flesh, is sweeter than Chiemdau and Hoanglong, and has a specially nice flavor.

PROBLEMS IN SWEET POTATO VARIETY SELECTION

After a long and continuous war, Vietnam has just started developing its agriculture to solve the problem of food shortage. Because of poor infrastructures and materials necessary for research, most of the plant material resources have been lost. The remaining crossing materials are too little; the valuable materials have totally disappeared.

There is also an acute lack of necessary research facility and equipment. Moreover, documents, books, and materials concerning sweet potato are too few. There is no regular exchange system for these documents with foreign countries and international organizations.

RECOMMENDATIONS

A cooperative exchange program on materials and research managements with other countries, specially those in Southeast Asia, is proposed. There should also be an exchange of valuable materials such as sweet potato varieties that contain protein oil in the tuber, have excellent resistance capacity, and short-growing duration.

A network of cooperation and frequent exchanges of documents, materials, and methods of study among Southeast Asian countries should likewise be established.

OPEN FORUMS

SESSION I

DISCUSSION

Batugal: Dr. Saladaga mentioned that the objective of ViSCA's breeding program is the small farmers. I wonder if there was any attention directed toward low-income consumers since not all sweet potato eaters are farmers; there are low-income consumers.

Escalada: As observed, the price of sweet potato per can has decreased because of the extra supply of tubers in the market caused by the farmers' growing of high-yielding varieties. This, in a way, answers Dr. Batugal's concern about looking into the concerns of low-income consumers.

Batugal: Yes, that is well and good but that is just accidentally favoring low-income consumers. I would like to suggest that a directed effort should be focused on how the low-income people in the rural as well as in the urban areas could also benefit as part of the total objective.

MacKay: In her paper, Dr. Escalada recommended that the Philippine Seed Board should reconsider its criteria in selecting varieties and institute mechanism for screening varieties for regional rather than national recommendation. What is the status of her recommendation?

Gapasin: Up to this time, the only commodity group that has regional recommendation is rice. For other crops, the releases made by the Philippine Seed Board have all been national releases. But I think efforts are now being exerted to come up with regional or even provincial recommendations. For example, the Regional Integrated Agricultural Research Systems or RIARS of the Department of Agriculture has been conducting provincial testing for a few years now. Also, the root crops group has started instituting a mechanism for obtaining the needed data that would serve as basis for regional or provincial recommendations.

SESSION II A - BREEDING

DISCUSSION

Paper presented: Evaluation of breeding value of interspecific hybrids of Ipomoea

Pillai: As a scientist who has been working on the entomological aspect of sweet potato, particularly sweet potato weevil, for the past 10 to 15 years, I could not locate any factor governing resistance. You said that the most important factor is the dry matter content. We have analyzed the dry matter content of hundreds of varieties and we have not found any correlation between dry matter or starch or sugar content and resistance to sweet potato weevil. Is it a confirmatory result or is it a preliminary observation that dry matter content is related to weevil resistance?

Iwanaga: I mentioned that there are some reports indicating a positive correlation between dry matter content and resistance to weevil. I am not saying, however, that dry matter content is a mechanism of resistance. Actually, I suspect antibiosis in my materials. As shown in one of my slides, we have observed surface damage only and that means the weevils can reach the tubers but they do not stay there. With this, we suspect some antibiosis; however, before we could make any conclusion, we would like to see more data.

Paper presented: Biochemical studies in sweet potato for better utilization at AVRDC

Tsou: I requested my chemist friends to define starch quality. They told me that there is no fixed definition of starch quality; rather, it depends on how the starch is used. In Taiwan, sweet potato starch is the most expensive starch, costing 24 percent higher than cassava starch because there are few traditional Chinese foods that can be made from sweet potato starch. Generally speaking, however, cassava starch is preferred to sweet potato starch because of two reasons. First, the polyphenol compound of cassava starch is usually lower than that of sweet potato starch so that if you use the same processing procedures, cassava starch is whiter than sweet potato. Second, the gelatinizing temperature of sweet potato starch is not as high as that of cassava starch so that when we talk about high fructose syrup or glucose type of enzyme actions, the sweet potato starch is more difficult to process than cassava starch.

Baniqued: I am from the Bureau of Plant Industry here in the Philippines. Our agency is one of your collaborators as far as your sweet potato lines are concerned. We have some advance lines coming from AVRDC and we found out that in terms of yield they are highly comparable with those of the ViSCA and UPLB-developed varieties. Their dry matter content, however, does not go beyond 30 percent. Using these lines and with the standard set by the Philippine Seedboard, we tried but failed to come up with a variety that can compete with the varieties developed by ViSCA and UPLB. Do you have any program that aims to increase the dry matter content of the lines you are producing?

Tsou: As mentioned by Dr. Takagi, the dry matter content improvement program of AVRDC was initiated a few years ago. Actually, we have a problem similar to yours when we submit our lines to the Seedboard for release. The dry mater content is the weak point of our lines. That is why we have been concentrating on the dry matter improvement for a few years now. We already have new lines with acceptable levels of dry matter content but the virus indexing activity becomes a block to the distribution of our new lines. As announced by Dr. Takagi, virus-free materials can be distributed at the end of this year.

Paper presented: Virus indexing and pathogen testing of germplasm

Palomar: Reduction in yield owing to viruses generally ranges from l0 to 20 percent. The symposium we are having now is addressed to the small farmers, Asian perspective, and the low yield obtained by most farmers is not really due to diseases but to the lack of fertilizer. If they apply fertilizer they can get l00 percent increase in yield, whereas if they reduce their problem on diseases they can only get l0 to 20 percent increase in yield. I would like to be a devil's advocate and ask you this question. Is disease indexing really worth pursuing when there are more pressing problems that confront the small farmers?

Mason: Yes, I think it is because disease indexing is an important factor in the exchange of germplasm. Based on existing quarantine regulations, we cannot transport germplasm materials to other places unless they have been tested for pathogen.

Dodds: I would like to comment on what Dr. Palomar said. I think we need to have bases when we say that yield reduction in sweet potato owing to diseases ranges only from l0 to 20 percent. In the case of potato, yield reduction caused by leaf roll virus reached 80 percent. Dr. Mason, as well as we at CIP, have started comparing the yield performance of healthy and infested cuttings but we have not analyzed our data yet so we cannot say that yield reduction is l0 percent or 20 percent. My other comment is in support of what Dr. Mason said. Indeed, it is important to pursue virus indexing to make sure that the germplasm materials we are distributing to other places are clean. We do not want to be held responsible for introducing new pathogens into other countries -- pathogens that may not affect sweet potato but may affect other crops found in the place.

Paper presented: In vitro sweet potato germplasm management

Chujoy: I would like to ask Dr. Dodds when the CIP headquarters will be able to distribute the tissue-cultured sweet potato in the regions. Also, I would like to ask the representative of ACIAR and AVRDC about their virus indexing activity. What are the procedures or standards you have adopted for exporting your tissue-cultured sweet potato to other countries?

Tsou: I have a similar question here. For your information, I have been working on the tissue culture business of AVRDC for two months now and I have logical difficulties in somatic mutations, virus indexing, and meristem culture. I am hoping that the tissue culturists and the virologists can come up with a certain consensus to slightly reduce the time gap between line introduction and utilization. Anyway, are we really sure that the indexed materials are virus-free? Can we use a more civic approach to identifying the varieties existing in certain regions and their limitations?

Dodds: I'll try to clarify first some of the logical problems expressed by Dr. Tsou before I'll answer the question on the distribution of tissue cultured sweet potato from CIP. In terms of somatic mutation, CIP is now getting into sweet potato. Eventually, we will be following the same basic methodology that we use with potatoes because in the case of this crop, there is already a much more detailed analysis carried out to determine the progress of somatic mutations and variations. When a clone is brought for cleaning or for pathogen elimination, we take first an electrophoretic pattern of the protein quality/quantity of the original clone. In the case of potato, we are already one step ahead because aside from protein patterning, we are also looking into restriction fragments. After this, the material goes into thermotherapy meristem culture. Any material that forms a callus during this stage is discarded. So we have to do a direct regeneration. After regeneration, the material goes to the virologist for virus testing. The testing is very expensive because we have to undergo serological tests, electron microscopy, and the use of indicator plants. Then we produce tubers that go through electrophoretic analysis to check if the protein pattern of this cleaned material is the same as that of the original clone. But then, this doesn't solve all your problems yet because there can be some changes. A classic one would be changes in skin color. You might be cleaning a pink clone but it comes out white or vice versa. To overcome this problem, we morphologically and biochemically characterize the original as well as the cleaned-up clone and then compare. We keep the original clone either in the field or in screenhouses and the in vitro culture in clouting.

In the case of sweet potato, there has been a lot of concern by many national programs and international centers about the cleaning up methods. The major problem is not on the tissue culture component but on the virus testing. Part of the problem is the enormous ignorance about sweet potato viruses. We know the basic tissue culture methods involved and how to carry out serological tests and electron microscopy and how to use indicator plants but there are several problems concerning the changes and distribution of the virus throughout the plants both in vitro and in vivo. We had a long discussion about this with the representatives from AVRDC, IITA, and Australia at the planning conference held at CIP last February. It was agreed that it would be good if there is an internationally accepted standard for virus indexing of sweet potatoes. We requested Dr. Jim Moore, a North Carolinian who is known to have research links with many institutions, to draw up a detailed position paper about this. Perhaps, in a couple of weeks from now, we can have the information from him.

With regards to the assurance of the pathogen-tested materials to be virus-free, I can say nobody is l00 percent sure about it. There may be pathogens that we do not know and thus we cannot get rid of. We can never classify a material as virus-free, rather we can classify it as pathogen-tested.

Going back to the question of our regional representative about the distribution of tissue cultured material, I think the other CIP regions have more or less similar questions: When and where can they get tissue cultured materials? AVRDC, CIP, and IITA have a good working relationship and it is possible that we will be able to get a unified system so that we can distribute germplasm materials not just from our center but from the other centers, too. So I think in a short term, CIP will probably be distributing materials in collaboration with the other centers. Regarding the distribution of our own materials, it will depend on when our breeders will submit to us materials for cleaning. About a year after their submission, we can distribute pathogen-tested materials.

SESSION II B - SOCIOECONOMICS

DISCUSSION

Papers presented: Commercial scale processing and utilization of sweet potatoes

Dayrit: May I know the percentage of sweet potato vines we can use as supplement in commercial feeds?

Hsu: The maximum safe percentage we can use is 5 percent. Using a lot of vines can cause diarrhea because vines have a high potassium content.

Bradbury: The results of the test you conducted on the digestibility of the sweet potato-based feeds showed that 20 percent remained undigested. Why is the figure so large?

Hsu: Sweet potato contains a lot of indigestible polysaccharides and raffinose. That is why we need to cook it in order to increase its digestibility.

Paper presented: New development in processing of sweet potato for food

Dodds: I have two questions. First, what is the cost of the dryer you have developed? Second, have you conducted any study concerning the cost effectiveness of your root crop food products? If so, do these products have commercial potentials?

Truong: The cost of the dryer is P3,600.00 (US$180). On the feasibility study of the food products, we have started conducting such kind of study and we already have some data about the sweet-sour sweet potato or what we call the Delicious SP. It is interesting to note that commercial production of Delicious SP was found to be economically feasible. Based on the result of our study, the return on investment of the product is 62 percent. The technology has been transferred to a private company that produces Delicious SP on a commercial scale.

Batugal: Is there any patent of the products you have developed?

Truong: Yes, we have applied for patent in the Philippine Patent Office but I understand that this patent is good only in the Philippines, not in other countries.

Batugal: I asked this question because I was thinking that other countries might be interested in your root crop food products. Will there be any objection if other countries duplicate such products?

Truong: There is none.

MacKay: What do you think are the major constraints to the commercial processing of sweet potato?

Truong: In the case of the small farmers, the major constraint to sweet potato processing is the marketing of the processed products. With the farmer's resources, the product they can most likely process is the chips. The immediate product of chips is flour. We should take note that sweet potato flour is used only as a substitute for wheat flour in the preparation of selected baked products. Most of the bakery owners revealed that they would only buy root crop flour if its price would not exceed 50 percent of the price of the wheat flour. In 1983-84, we had the chance to promote sweet potato flour because at that time the Philippines was in crisis and it was difficult to import wheat flour. Later, however, the government policy changed, allowing the full importation of wheat flour. The price of wheat flour went down to as low as P7.80/kg. This means that the maximum price we could set for sweet potato flour so that it would be bought by bakery owners was only P3.90/kg. The computed processing cost of sweet potato flour ranges from P6.00 to 8.00. This means that with the above condition, flour production is not a profitable venture. This explains why farmers do not usually process sweet potato.

The second major constraint to processing sweet potato, which concerns not only small farmers but also processors, is lack of capital. Considering this problem, we organized farmers associations in some places in Leyte and Samar and then helped them set up a root crop processing project. Now, each farmers association can market six to seven sacks of flour per week.

Paper presented: Postharvest handling and storage of sweet potato

Escalada: At what scale of operation will root crop storage be needed?

Data: Root crop storage is needed in small-, medium-, and large-scale operations. This practice is very useful for farmers who process sweet potato into candies. This is also important for medium- and commercial-scale farmers who practice one-time harvesting.

Batugal: Which of the storage methods you have presented is better, the use of storage structures or the underground storage?

Data: As of this time, I cannot specifically say which is better because both storage methods have advantages and disadvantages. One disadvantage of the underground storage is that when the storage area is exposed to changing conditions, the stored roots develop sprouts. Another disadvantage is that the roots stored underground are usually attacked by termites. In the case of hut storage, its disadvantage is the additional cost incurred in constructing the hut. We want to make it clear that farmers do not necessarily need to build another hut. The conditions inside our storage structures are more or less the same as those inside their houses. Thus, they can store the roots in their own houses instead of inside special storage huts.

Paper presented: Gender roles in sweet potato production, processing, and utilization

MacKay: With your methodology, how did you recheck the conflicting estimates on labor involvement made by the husband and the wife? Do you have any data that indicate the husband's or the wife's involvement in sweet potato production, processing, and utilization? I am also interested in the decision-making aspect. Was there any case where the husband and the wife made joint decision?

Alcober: The method that we used was basically a case study. This was done through personal interviews, both formal and informal, and also through participant observation. We did not have a workable statistical analysis that specifies how much labor women contribute to a certain sweet potato farm activity. However, we based our report on the interview results and the actual field observations we made. With regards to the time spent by the husband or the wife, we did not have an in-depth study on it. Concerning decision-making, we found out that whoever does a particular activity makes the decision on it. There were cases, however, when husband and wife made joint decisions.

Batugal: In what specific area do husband and wife make joint decisions?

Alcober: It depends on the family. There are some families where husband and wife make joint decisions in all areas.

Batugal: How about in the investment aspect? For example, who usually decides whether to buy fertilizer or not?

Alcober: Based on our observations, it's always the wife who has the final say because she keeps the money.

MacKay: With your report, I think the researchers here are beginning to see the benefits of looking at the gender roles.

GENERAL DISCUSSION

D. Gapasin: I am wondering why PRCRTC promotes only the VSP varieties when in fact there are other varieties approved by the Philippine Seedboard for recommendation.

Villamayor: Actually, we are propagating all the recommended varieties and when farmers come, we give them the variety they want. We do not limit our distribution to the VSPs only. The reason why we are not making general promotion of all the seedboard varieties is that at present we still lack data concerning their adaptability to different locations. We are still conducting trials in our cooperating stations. We are planning to prepare a brochure containing information on all the seed board-recommended varieties, their specific uses, and the conditions where they perform best.

Truong: From the processing point of view, we cannot help but recommend specific varieties. In selecting varieties suited for processing purposes, we included all those recommended by the Philippine Seedboard and we found out that VSP-l and VSP-2 were the best. In other words, we are not working on the VSPs alone but it just came out that the two varieties from ViSCA were found to be the best for processing purposes.

SESSION III A -BREEDING

DISCUSSION

Paper presented: Screening of sweet potato cultivars by subsistence farmers

Ganga: Dr. Lightfoot mentioned about yield, resistance, and other agronomic traits as bases for screening, but did not elaborate on the eating preference or eating quality. In the highlands, the first thing that farmers ask when we introduce new varieties is the eating quality of the varieties.

Lightfoot: In our encounter with the farmers, we do discuss this issue of taste. It is just a matter of distinction between cooking and eating qualities. In our study, we pooled together all the information on cooking and eating qualities and we called them taste. Taste then becomes a distinction between sweet and not sweet varieties and between dry and wet varieties. For their snacks, farmers prefer the sweet varieties but for their staple, they prefer the very dry and not-so-sweet.

Paper presented: Breeding early maturing sweet potato varieties

Mariscal: In screening for early maturing lines, have you identified indicators for early maturity at seedling stage? Is there any correlation between yield at seedling stage and that obtained after several generations of testing?

Ye Yan-Fu: We have discovered that there is a close correlation between early tuberization and early maturity in F_1 seedlings. To determine whether a line is early maturing or not, we consider the weight of the tubers at 50 to 60 days after planting as an index. On correlation among yields, we have observed that there was quite a close correlation between the tuber weights at 50 and 60 days after planting. Tuber weight at 50 days, however, was negatively correlated with that at 140 to 150 days after planting. Though the identified early maturing lines developed tubers early, their yields were not consistently high as observed from the several generations of testing.

Paper presented:The theoretical basis and practice of the polycross breeding technique

Pillai: In the Philippines, what is the extent of yield loss in sweet potato owing to weevil infestation?

Saladaga: We do not have scientifically collected data in yield loss caused by weevil in the farmers' fields. Observations, however, show that during wet season, when the soil remained moist from tuber formation period up to harvest, 0 to l0 percent weevil damage was obtained. On the other hand, during dry season when soil cracks are formed sometime between the tuber formation period and harvest, 20 to l00 percent weevil damage was noted.

Pillai: Are the varieties released by ViSCA resistant to weevil?

Saladaga: The sweet potato varieties released by ViSCA, such as VSP-l, VSP-2, VSP-3, VSP-4, and VSP-5, have undergone trials for sweet potato weevil resistance. However, these varieties still do not have a stable resistance to this particular pest.

Pillai: Do you recommend control measures against sweet potato weevil? If so, do the farmers adopt these control measures?

Saladaga: Dr. E.N. Bernardo has recommended some agronomic management practices that may reduce weevil damage. Among these practices are sanitation in the field such as removal of alternate hosts, hilling-up to cover soil cracks, and mulching to maintain soil moisture at field capacity. Many farmers are employing these cultural management practices.

SESSION III B - PEST AND DISEASES

DISCUSSION

Paper presented: Control of sweet potato weevil in India

Tsuo: Do you have data on the minimum survival temperature of the insect?

Pillai: We have not obtained such data from our experiment but it was reported that the weevil could not survive below l7°C.

Kanua: In the highlands of Papua New Guinea, we do not have much problem on weevil and we think one reason is that PNG is cooler than other places. Also, there is a relatively high rainfall in that particular region. I wonder if irrigation has any effect on the activity of weevils?

Pillai: Soil moisture is one of the important limiting factors for the control of sweet potato weevil. If there is sufficient soil moisture, the soil is relatively compact, thus weevil infestation is less. If you irrigate, you are providing enough moisture to the soil and in a way you are preventing the entry of weevil into the tubers.

Paper presented: Screening sweet potato cultivars for pests and diseases resistance

Dayrit: What is in the chicken manure that makes it effective in controlling root knot nematode?

Gapasin: Dr. Davide and Dr. Villas have identified nematophagus fungi in chicken manure. These fungi are responsible for the colonization or death of the nematodes.

Baniqued: What is the rate of chicken manure application that can effectively control nematodes?

Gapasin: Based on our experiment, it is 20 t/ha.

Baniqued: Do you think it is economical to use that amount of manure considering the economic value of the crop?

Gapasin: Considering that sweet potato has low value, it may not be economical to use 20 t/ha of chicken manure to control sweet potato nematodes if the manure is bought. However, we have observed that in Leyte, farmers grow sweet potato and at the same time grow chickens in their backyards. In this case, chicken manure can be used to control nematodes without additional expense to the farmers.

Batugal: How long do the nematophagus fungi stay in the soil from the time the chicken manure is applied? If it can last for two or three seasons, then the problem of high cost of the manure would be solved.

Gapasin: We do not know how long the nematophagus fungi can stay in the soil. Probably, as long as we have the chicken manure, we have the nematophagus fungi.

Kanua: In PNG, we have conducted a study on the effect of scab on the yield of sweet potato. We found out that some varieties that had been badly infested with scab gave high yields. In your experiment, however, you observed yield reduction owing to scab.

Baniqued: The possible reason why you got high yield despite heavy scab infestation is that the infestation may have come at the later stage of plant growth when yield is no longer affected by the incidence of the disease.

SESSION IV - COUNTRY REPORTS

DISCUSSION

Paper presented: Malaysia

Pillai: Your report recommended Gramoxin 26 and Heptachlor for the control of sweet potato weevil. I believe that Gramexin or Benzene Hexachloride (BHC) is not recommended for tuber crops and Heptachlor is a banned insecticide in most countries at present. How come you are still recommending these chemicals?

Hussain: Actually, I am presenting a research conducted in the I960s when insecticides were freely used.

Pillai: In that case, I suggest that you withdraw your recommendation of BHC and Heptachlor because these chemicals cause problems in tuber crop production.

Hussain: We are not using the chemicals anymore. At present we are using Furadan.

Paper presented:Papua New Guinea

Bradbury: You mentioned that progressive or sequential harvesting yielded higher than single or one-time harvesting. Do you have quantitative data on yield? Also, can you tell us the other advantages and disadvantages of sequential harvesting? I think this particular method needs to be given enough attention because it is commonly used in subsistence agriculture.

Kanua: I have quoted some works done by Cris Rose in Tariaria in the Southern Islands. He had some yield data and from his works it was found that the yield difference between sequential and single harvesting was significant. Aside from higher yield, the other advantages of sequential harvesting are related to root bulking and root storage. In sequential harvesting, only the needed amount of roots and usually the big ones are harvested. Thus, there is no problem in terms of storage because the harvested roots are used immediately. Also, the small roots left in the ground have the chance to grow further over a period of time. So in the long run, higher total yield can be obtained when sequential harvesting is employed. On the other hand, if sweet potato roots are harvested all at one time, a problem on storage and marketing of the roots may arise. The quantity of roots harvested may be large but the demand may not be too high.

Paper presented: Micronesia

Batanes: Have the people in your place encountered a problem on flatulence caused by eating sweet potato cooked under a mound of rocks with fire on top?

Dayrit: I think they have not because they still cook their sweet potato using that method. There are people who had told me that our students eat fresh sweet potato tubers yet they do not encounter problem on flatulence.

Bradbury: The classic study on flatulence was done on black beans. Black beans contain a considerable percentage of sugars that are longer than disaccharides. These are trisaccharides, tetrasaccharides, or pentasaccharides which have 3, 4, or 5 residues. These are easily digested in the small intestine because of the particular structure of the sugar. Thus, they go through the large intestine or the colon or the large bowel and they are attacked by bacteria. The bacteria produce gases such as hydrogen and methane which give rise to flatulence. In sweet potato, only a small amount of raffinose has been identified as one of the above mentioned sugars. AVRDC cultivars have trace amounts of raffinose while the South Pacific cultivars have none. It seems that sugars are not the cause of flatulence. There may be some other causes and one of these is that some people might have the enzyme in their intestines that could break down the sugars taken in, causing flatulence. Maybe the reason why Asians do not have so much problem on flatulence, while the Papua New Guinean people have, is that the former might have the mentioned enzyme while the latter do not. Another possible reason is related to varietal differences. The yellow sweet potato, in general, has more sugar and B carotene than the white sweet potato. Thus, it is possible that they differ in starch content. It is better if their starches are tested chemically but this has not been done yet.

GENERAL DISCUSSION

Batugal: My question is directed to the country representatives. Do you have a problem on flatulence caused by any sweet potato variety grown in your country?

Nair: I have heard some complaints from farmers that if they eat sweet potato, they sometimes experience gas trouble.

Hussain: Malaysians have encountered the problem of flatulence but we have not done much study about it.

Jayawardena: Generally, farmers in Sri Lanka consume sweet potato for breakfast then they go to work. So far, there has not been much complaints about flatulence problem.

Kanua: In the selection of varieties and the subsequent recommendation of these varieties for use by farmers, do breeders take into account the particular preference of the farmers other than high yield, resistance, and others?

Hussain: After we have identified a particular variety as high-yielding, we conduct sensory evaluation where we study the sweetness, color, fiber content, texture, and overall acceptability of the variety.

Nair: We take into account the farmers' preference. We do not release our varieties unless we are sure that they are acceptable to the farmers.

Jayawardena: When we breed varieties and when we identify objectives, we always keep in mind what happens to our rice. We cannot make a big jump in the sense that the farmers still have indigenous practices and they have lots of things attached to the characteristics of indigenous varieties. In our breeding program, we do not have much manpower so we have to come up with simple criteria for our selection. These criteria are based on what the farmers want in a certain variety. The characteristics commonly considered are taste, dryness, color, and storage quality.

Xue: In China, the farmers' requirements for a variety change with time. Before, they wanted high-yielding varieties but in recent years, they wanted early-maturing varieties with high starch content. This happens because farmers in the rural areas have changed from subsistence to commercial. Inasmuch as the people's needs change, we also have to change our breeding objectives to conform with their needs.

Kanua: Our breeders in PNG have come up with varieties that are really high yielding. But when we introduced these varieties to the farmers, they did not accept them.

Batugal: It seems that there is a need for a twin objective in sweet potato breeding. If we are going to breed sweet potato for food, it appears that we have to consider taste preferences even if the yield is not too high. On the other hand, if we have to breed sweet potato for processing, we have to go for yield and other characteristics. I do not know if this objective for breeding suits the breeders well.

Chujoy: Are you paying attention to the development of sweet potato varieties that need little fertilizer?

Soenarjo: One of our programs is the development of sweet potato varieties that give high yield at minimum inputs. We are doing this to help our farmers who have very low income.

Jayawardena: If we are looking for varieties that produce high yield at low input, we should not think of breeding. Rather we must properly evaluate the available germplasm and select from them the variety that we desire. If we change the gene pool just to increase yield, it does not strictly justify the output because in breeding we are increasing our inputs. Going back to Dr. Batugal's earlier comment about breeding sweet potato for processing, particularly into animal feed, I would like to point out that we have a similar objective with the cassava group. We are even competing in this area. Thus, I would like to suggest that before going into the development of sweet potato for processing purposes, we should find out first the cost of production and the land available for sweet potato. We have to identify objectives within the total framework and our objectives must conform with the food, nutrition, and industrial policies of our respective countries.

Levett: I have noticed that the representatives from India and the Philippines showed a planting method wherein both ends of cutting stick out from the ground. In PNG, we have observed that farmers insist on planting sweet potato in a particular way, either by removing the leaves then burying three nodes or not removing the leaves and burying the cuttings horizontally. Does anybody here conduct a research on the different ways of planting sweet potato and their effect on yield? Does anybody share the farmers' view that we must plant in a particular way to increase yield or promote early maturity?

Estioko: At present, we are studying seven planting techniques, namely: one cutting per hill, two cuttings per hill, the traditional three cuttings per hill which has been used in the Bicol region and the Visayas, slant method with two ends out, circle method and two others. So far we have not found any significant difference in yield when we use the planting density of 30,000 plants/ha.

Karifir: We noticed that the people in the highlands of Irian Jaya use very long cuttings as planting materials. So, we conducted a research on the effect of the different lengths of cuttings on the yield of sweet potato. We found that the 45-cm cutting which is measured from the tip of the vine gave better yield than other lengths of cuttings.

Levett: What countries practice vine turning? Is it beneficial? If it is, how is it done?

Hussain: I did a trial on vine turning using three varieties of different leaf types. I found out that there was no difference in yield among the varieties. No yield increase was obtained even if the vines were turned. There was no interaction among the varieties as well. Despite this, however, Malaysian farmers still do vine turning.

Villamayor: There is a report on vine lifting published by the Central Mindanao University in Southern Philippines. The researchers used BNAS-5I as test variety. This is a creeping variety and storage roots are usually produced not only in the main vine but also in lateral vines. The report said that there was a significant increase in yield when the vines were lifted. I think it happens because when the vines are lifted, there is no chance for the lateral roots to become storage roots, so the photosynthates can go directly to the main hill. I think the effect of vine lifting on yield depends on the variety. If the variety is bushy and its vines do not root, vine lifting has no effect. On the other hand, if the variety is creeping and there is a lot of lateral root formation, then vine lifting may have a positive effect on yield.

Levett: I think Dr. Villamayor is right in saying that yield increases when vines are turned because the lateral roots are prevented from growing, thus photosynthates go directly to the roots of the main vines. However, I wonder what might be the effect of vine turning when sequential harvesting is employed. I am afraid it will result in lower yield in the long run.

Kanua: I have the same apprehension. In PNG, the farmers do not harvest sweet potato all at one time. Instead, they start harvesting from the main vines and leave the lateral vines to develop roots. When the lateral roots are big enough, they harvest them. Such practice gives the farmers more sweet potato roots. If vine turning is practiced, there's no chance for the lateral roots to bulk.

Levett: The Malaysian representative talked about mountain location trial, the correlation between yield and planting locations, and the conclusion that we can test one variety just at one site. I would like to ask if your sites included a range of altitudes. In PNG, we found that our 5,000 cultivars were highly adapted to certain environmental conditions. But we cannot transpose one cultivar to just even l00 or 200 km away and expect it to perform well. I would like also to ask the other country representatives if they have done any work on mountain location testing. If so, what are your conclusions?

Nallana: I have met a group who worked on root crops in the highlands. The group found that the varieties that performed best in the highlands of Leyte did not perform well in other locations. I think the elevation and the differences in climatic factors such as temperature and rainfall pattern had something to do with the result. However, I do not know if there are already formal research findings on this.

Ganga: I am one of the cooperators in the National Cooperative Testing Trial. We have been testing location effects on sweet potato for almost three years now. We found that the best varieties under lowland conditions did not perform well under highland conditions. When planted in the highlands, they produced high yields but their dry matter contents and the shape of their tubers were really bad. Similarly, the best performers in the highlands were bad performers in the lowlands.

Saladaga: Mrs. Nallana is wondering if there are studies on the effects of location on the yield of sweet potato. Many studies on location effects have been conducted but most of these studies deal on crops other than sweet potato. The few studies on sweet potato deal on the interaction between variety genotypes and environment and the stability of the crop's characteristics. There are a number of problems regarding the approaches used in the study of stability. Four methods have been developed but these have a number of limitations. In my opinion, the method of choosing a variety suited to certain locations should be refined first.

Tamani: Has anyone encountered the problem of rat damage in sweet potato?

Pillai: Rats damage almost all tuber crops and it does not spare sweet potato. They are found in many localities and their number depends on the elevation and topography of the area. We can expect more rats in fields near a small jungle or in areas with some ridges, or on farms where sweet potato is raised as a rotation crop. Rat damage is a common problem in almost all the Asian countries and it is a particularly serious problem in India.

Levett: We have a significant problem on rat damage in PNG. We have noticed, however, that rat occurrence is seasonal and rat damage is pronounced during the dry season. During the wet season, the river grows sufficiently to flood all the rat holes along the riverside, thus rat is not much of a problem. We have done trials on river terraces and we found that this practice seemed to control the rats until the next dry season comes.

WORKSHOP OUTPUTS

WORKSHOP OUTPUTS

Workshop sessions were conducted to identify research priority areas on sweet potato and to plan strategies for an effective collaboration and networking among the Asian countries and research centers. There were three session groups, namely: the Crop Improvement group chaired by Dr. Kenneth MacKay of IDRC-Singapore; the Crop Management group headed by Dr. Ponciano A. Batugal of PCARRD-CIP, the Philippines; and the Processing, Utilization and Marketing group chaired by Dr. John Howard Bradbury of ANU.

CROP IMPROVEMENT

Identification of Needs

Problem areas related to sweet potato varietal improvement include breeding objectives, development of varieties suited to certain conditions (e.g., highlands or lowlands) and purpose (e.g., subsistence farming or commercial production/processing purposes), breeding for pest and disease resistance, development of varieties with good storage characteristics, establishment of a wider germplasm base, germplasm collection/characterization, information exchange, and improvement of breeding techniques. A matrix containing the different areas of concern was drawn and the country representatives were asked to indicate the degree of importance of such areas in their respective places. Five areas came out to be commonly important among the participating countries. These are information exchange, establishment of a wider germplasm base, germplasm collection/characterization, improvement of breeding techniques, and development of weevil-resistant varieties. The other areas were country specific (Table I).

Germplasm Exchange

To satisfy the need for a wider germplasm base, a mutual germplasm exchange is necessary. The following exchange mechanisms were suggested: (l) germplasm from countries to international centers, (2) germplasm from international centers to individual countries, and (3) country-to-country exchange.

A question of what materials to exchange was raised. It was agreed that the materials should be characterized first before these are sent to other countries or research centers. The group felt that the IBPGR method of characterization should be simplified and the breeders should be more involved in the discussion of the characters. Also, AVRDC is conducting

Table 1. Areas of concern in sweet potato varietal improvement and the degree of importance given to them by each country.*

Country	Breeding objectives	Subsistence	Cash prog. (Animal)	Pest/Diseases: Weevil	Scab	Nem.	Virus	Others	Rots	Storage	Wider germplasm	Germplasm collection characterization	Information	Breeding
China	3	2	3	1	1	1	1	0	0	1	3	2	3	3
Japan	3	2	2	1	0	2	2	0	0	0	3	3	3	3
S. Pacific: Micronesia	0	3	1	0	2	2	1	0	1	0	3	2	3	0
Tonga	0	2	1	3	3	2	2	3 yield	0	0	3	0	3	3
Papua New Guinea	0	3	1	3	1	2	2	High DM 2	2	0	3	3	3	2
Indonesia	0	2	3	3	3	0	1	0	0	2	3	3	3	3
Thailand	0	2	3	3	3	0	0	0	0	2	3	3	3	3
The Philippines	0	3	3	3	3	3	2	0	2	3	3	3	3	3
Malaysia	0	2	3	3	2	1	2	0	0	3	2	2	3	3
Vietnam	3	2	3	3	3	1	1	Cold tolerance	0	2	3	3	3	3
India	0	2	2	3	0	0	0	0	0	3	3	3	3	3
Sri Lanka	0	3	1	3	0	3	0	0	0	3	3	3	3	3
Bangladesh	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*3 — Highest priority 2 — Medium 1 — Low 0 — None trainings in germplasm evaluation and characterization, and its catalogue would be available shortly.

A major problem which the group believed to affect the effectiveness of the germplasm exchange is the presence of viruses. Viruses cause major diseases and consequently great losses in sweet potato. The group recognized the importance of ensuring that germplasm materials received or sent out to other places are virus-free. The problems related to the first two mechanisms of germplasm exchange previously mentioned are minimal. Germplasm exchange via the first mechanism is not so dangerous because most of the international centers have established their own quarantine regulations. A material that cannot pass their standard is not accepted, thus, one is quite assured that the germplasm materials they are taking in are clean. In the same manner, the second mechanism of exchange does not entail much risk. The international centers, which are handling germplasm materials from around the world, are certainly concerned that the materials they receive and will be sharing with other countries are clean. The third mechanism of exchange, country-to-country, seems to be more difficult than the other two mechanisms inasmuch as each country has its own quarantine regulations to be met. Some countries do not even have strong quarantine regulations. Considering this difficulty, it was suggested again that a third party should be involved in the germplasm exchange.

The group also recommended the intensification of efforts on virus indexing and cleaning of germplasm materials.

Networking

Two types of networking -- in-country and regional -- were proposed. In regional networking, one focal point for networking per country is necessary to avoid unnecessary duplication or networking with individual institutions. The country representatives favored this point and identified network centers in some countries. PCARRD was mentioned for the Philippines, the Food Crops Center for Indonesia, and the China Agricultural Academy of Sciences for China.

It was agreed that the networking would cover the exchange of germplasm and any information on sweet potato through publications and trainings. The group cited technologies that a particular country could share to others (Table 2).

CROP MANAGEMENT

Identification of Needs

The group designed a process of identifying the areas of concern,

Table 2. Sweet potato information/technologies ready for dissemination in various countries.

Country	Information/Technologies
Japan	Basic research information on breeding, physiology, and utilization of sweet potato (mostly in Japanese)
China	Production and breeding technologies, distribution of different sweet potato cultivars, trainings, translation of information materials
Vietnam	Breeding for cold tolerance
The Philippines	Breeding, processing and utilization technologies, publications, assistance in trainings
Malaysia	Germplasm materials
Indonesia	Cropping system approach, scab resistance program, germplasm materials
Thailand	Trainings (AVRDC-Thailand Outreach Project, Root Crop Symposium in 1978)
Sri Lanka	Subsistence cropping systems, intercropping

available information and gaps, and activities that need to be undertaken in relation to sweet potato management (Table 3). First, three broad areas of concern, which include soil fertility, insect pests, and diseases, were identified. The group then determined specific problem areas under each area of concern.

After listing down all the activities that need to be undertaken, the group identified high priority studies that would be recommended for implementation (Table 4). The activity considered of general importance is documentation and exchange of information on practices that are already working well in various countries.

CROP PROCESSING, UTILIZATION, AND MARKETING

Identification of Needs

The needs were identified from two points of view: subsistence level and commercial level of sweet potato procesing, utilization, and marketing.

For subsistence level of sweet potato processing, utilization, and marketing, the four areas of concern are nutrient content, storability, potential use as animal feed, and development of new food products (Table 5). Of these four areas, improvement of nutrient content, especially the protein content, was regarded as the most important area. To solve this problem, three possible solutions were suggested: (l) improving the

Table 3. Areas of concern, available information, gaps, and activities that need to be undertaken in relation to sweet potato management.

Areas of concern	Available information	Gaps	Activities/projects to be undertaken
A. Soil Fertility			
1) Varieties for highland and lowland conditions	• limited number of cultivars for highlands	• need to identify/evaluate cultivars suitable for highlands	• improve germplasm collection and evaluation under low fertility level
	• good native cultivars available in some countries (Papua New Guinea, Indonesia, South Pacific, Phil.)	• need to develop and evaluate these cultivars in different locations/countries • need to evaluate farmers' needs • need to collaborate	• recommend to sweet potato breeders to develop cultivars that are suitable to lowland and highland conditions; responsive to low, medium, and high fertility levels and low pH in Micronesia. It is recommended that in developing the said cultivars, breeders should consider farmers' needs and preference and their participation in the evaluation process.
2) Soil pH	• low soil pH in Micronesia		
3) Shorter fallow period	• cultural practices available to maintain soil fertility with short fallow period (Papua New Guinea)	• documentation of practices that improve soil fertility • cropping systems information	• verification/piloting of known practices • development of cropping systems for soil fertility improvement
4) Moisture stress	• moisture effects	• increasing moisture holding capacity of the soil	• information exchange • verification or piloting of known practices
5) Cropping system in marginal/hilly areas	• hedge row planting	• identification and management of hedgerow species	

Table 3 (continued)

6) Soil fertility improvement	• mounding • intercropping/rotation • nitrogen fixing plants • use slow release fertilizer	• mycorrhiza studies • use of crops and animal wastes	
7) Soil conservation	• hedge row planting, mounding, green manuring, mixed cropping		
B. Pest			
1) Loss assessment (weevil, beetle, mites, rats, thrips)	• general information available in most countries	• need to quantify damage particularly in fields	• study on method of loss assessment, perception of loss by farmers • loss assessment study (the Philippines and University of South Pacific)
2) Pest bioecology	• bioecology on weevil	• need to study bioecology of weevil (Papua New Guinea) and beetle (Micronesia)	• study on the bioecology of the said pests
3) Control strategies			
a) Chemical	• chemical control information available except on residue and new chemical products	• need to incorporate residue analysis • study effective doses with cost reduction as objective	• toxicity studies, including secondary hazards • screening of new chemicals

Table 3 (continued)

		• need to identify pest species specific to areas	
b) Cultural	• crop rotation, tillage	• need to verify known practices	• documentation and verification of existing practices
		• need to develop crop rotation scheme for the control of pests	• exchange of information
c) Biological	• not much is known	• need to identify varieties, natural enemies, residues, pheromones, and botanicals for control	• study on biological agents for the control of pests • verification of different control methods
		• need to document, verify, and exchange available information	
d) Mechanical	• not much is known	• need to study the use of detergents and other repellents against thrips, mites, and rats	• documentation and exchange of information
4) Insect vectors	• limited information, not much is done in some countries	• identification of viruses and vectors	• work on viruses and vector identification (all countries)
C. Diseases			
1) Loss assessment	• limited information	• standardization of method of loss assessment	• study on the methods loss assessment and perception of loss by farmers • loss assessment study (the Philippines and University of South Pacific)

Table 3 (continued).

2) Epidemiology	• limited information	• epidemiology and life cycle of disease-causing organisms	• study on the life cycle, method of spread, mode of action, alternate hosts
3) Control strategies			
a) Quarantine policies		• need to study quarantine policies for effective exchange	• workshop and training in each policy documentation of existing policies • development of safe and efficient quarantine systems for germplasm exchange
b) Chemical	• Chemical control information available except on residue analysis and new chemical products	• need to incorporate residue analysis • study effective doses with cost reduction as objective • need to identify pest species specific to areas	• toxicity studies, including secondary hazards • screening of new chemicals • effective dose of chemicals
c) Cultural	• crop rotation, tillage	• need to verify known practices • need to develop crop rotation scheme for the control of pests	• documentation and verification of existing practices • exchange of information
d) Biological	• not much is known	• need to identify biological control agents • need to document verify and exchange available information	• study on biological agents for the control of diseases • verification of different control methods

Table 4. High priority studies related to sweet potato management.

Area of concern	High priority studies
General	Documentation and exchange of information
Soil fertility	Verification/piloting of known practices. Development of cropping systems for soil fertility improvement.
Pests	Standardization of methods of loss assessment. Determination of farmers' perception of loss. Loss assessment studies (the Philippines and University of South Pacific). Pest species identification in specific areas. Identification of varieties, residues, natural enemies, pheromones, and botanicals for pest control. Identification of viruses/vectors
Diseases	Standardization of methods of loss assessment. Life cycle/epidemiology of disease-causing organisms. Quarantine policies for safe and efficient germplasm exchange.

Table 5. Priority needs for subsistence level of sweet potato processing, utilization, and marketing.*

Area of concern	The Philippines	Papua New Guinea	Indonesia
Nutrient content (protein, low sugar, etc.)	1	1	1
Storability (Processed and fresh roots)	1	2	1
Use as animal feed (Vine and root)	2	2	2
Development of new food products	2	3	2

*Scale used: 1 - most important, 2 — important, and 3 — less important.

methods of preparing sweet potato into whatever food item to increase its nutritional value, (2) breeding and selection of varieties with high protein content, and (3) introduction of high protein legumes, especially in Papua New Guinea.

The storability of fresh and processed roots was also considered important. Although information on storage is already available, especially in the Philippines, a more comprehensive study of what goes on during storage under tropical conditions in terms of losses to insect pests, diseases, and others is needed.

The last two areas were not considered as important as the first probably because on a subsistence level of production, the produce are not usually processed but consumed immediately.

For commercial level of processing, utilization, and marketing, nine areas of concern were identified (Table 6). Priority was placed on four areas, namely: development of new food products, development of new industrial products, standardization and storage of chips, and economics of substituting imported raw materials with sweet potato.

Table 6. Priority needs for commercial (market-oriented) sweet potato processing, utilization, and marketing.*

Area of concern	The Philippines	Taiwan	Papua New Guinea	Indonesia
Postharvest operation (grading, marketing, etc.)	1	3	3	2
Flour production	2	3	2	2
Feed (vines/roots)	2	3	3	2
Standardization and storage of chips (control of insects, fungi, etc.)	1	2	3	1
Economics, price by country	2	3	1	1
Nutrient status (flatulence problem, etc.)	–	2	1	3
New food products	1	2	2	1
New industrial products (starch, alcohol, etc.)	2	2	2	1
By-product utilization	2	3	3	2

*Scale used: 1 – most important, 2 – important, and 3 – less important

Networking

The group agreed that for a start, an international newsletter that would contain important information on sweet potato was necessary. This would help researchers know what data are available and what specific area should be given foremost attention.

The newsletter, to be called "International Sweet Potato Newsletter," will be published in the meantime by a Working Committee to be headed by Dr. Manuel K. Palomar of PRCRTC, who will at the same time be the editor of ISPN.

The committee members are J. Howard Bradbury of the Australian National University (ANU), Malcolm Levett of the Department of Primary Industry in Papua New Guinea, Lu Shu-Yun of the Beijing Agricultural University in China, Kenneth Mackay of IDRC Singapore, K.S. Pillai of Central Tuber Crops Research Institute (CTCRI) India, Enrique Chujoy of the International Potato Center (CIP), the Philippines, and Ponciano Batugal of PCARRD/CIP, the Philippines.

LIST OF PARTICIPANTS

Australia

J. Howard Bradbury
Chemistry Department
Australian National University
Canberra, A.C.T.

Angela Mason
Plant Research Institute
Department of Agriculture
Swan St.
Burnley, Victoria 3121

China, People's Republic of

Lu Shu-yun
Beijing Agricultural University
Beijing

Ye Yan-fu
Zhejiang Academy of
Agricultural Science
48 Shiqiao Rd.
Hangzhou

Xue Qi Han
Institute of Agrobiological
Genetics and Physiology
Jiangsu Academy of
Agricultural Sciences
Xiao Lingwei, Nanjing

China, Republic of

Ali Hsu
Taiwan Livestock Research
Institute
Hsin-Hua, Tainan, Taiwan 71210

Samson Tsuo
P.O. Box 42 AVRDC, Shanhua
Tainan, Taiwan

Hiroko Takagi
AVRDC
P.O. Box 42
Shanhua, Tainan, Taiwan

India

G.M. Nair
CTCRI, Trivandrum 695017

K.S. Pillai
CTCRI
Trivandrum 695017

Indonesia

Y.P. Karafir
Faculty of Agriculture
UNCEN P.O. Box 23
Amban Manokwari
Irian Jaya

Roberto Soenarjo
CRIFC
Jl. Merdeka 99
Bogor

Japan

Itaru Shiotani
Mie University
1519 Kamihama, Tsu 514

Malaysia

Khelikuzzaman M. Hussain
Miscellaneous Crops Division
MARDI
Serdang, Selangor

M.S. Saad
Dept. of Agronomy and Horticulture
UPM 43400
Serdang, Selangor

Micronesia

Ruben S. Dayrit
College of Micronesia
Ponape 96941

Papua New Guinea

Matthew B. Kanua
P.O. Box 339
Mt. Hagen, WHP

Malcolm P. Levett
Department of Primary Industry
HAES
P.O. Box 384
Kainantu, EHP

Sam Rangai
Laloki Research Station
P.O. Box 417 Konedobu, NCA

Peru

Fermin de la Puente
International Potato Center
P.O. Box 5969
Lima

John Dodds
International Potato Center
P.O. Box 5969, Lima

Masaru Iwanaga
International Potato Center
P.O. Box 5969, Lima

The Philippines

D.L. Alcober
ViSCA
Baybay, Leyte 7127-A

C.A. Baniqued
Root Crops Research Section
Bureau of Plant Industry
Manila

P.A. Batugal
PCARRD-CIP
Los Baños, Laguna

E. Chujoy
CIP
P.O. Box 933
Manila

E.S. Data
ViSCA
Baybay, Leyte 7127-A

M.M. Escalada
ViSCA
Baybay, Leyte 7127-A

R. Estioko, Jr.
Banao, Guinobatan
Albay

D.E. Eusebio
Bureau of Plant Industry
Los Baños, Laguna

Z.N. Ganga
NPRCRTC, Benguet State University
La Trinidad, Benguet

D.P. Gapasin
PCARRD
Los Baños, Laguna

R.M. Gapasin
ViSCA
Baybay, Leyte 7127-A

J.G. Jandoc
USP-CA, Tagum, Davao

E.S. Maape
Claveria Experiment Station
Department of Agriculture
Dalwangan, Malaybalay,
Bukidnon

E.D. Malacad
USM, Kabacan, Cotabato

A.C. Medellin
DA-BPI-BES
Gabi, Ubay, Bohol

L.G. Nallana
ACIAR Embassy
15th Flr., Bank of PI Bldg.
Ayala Ave. Makati, M. Manila

T.E. Navarro
Tarlac College of Agriculture
Camiling, Tarlac

R.L. Raymundo
Isabela State University
Echague, Isabela

N.P. Pascual
ViSCA
Baybay, Leyte 7127-A

F.A. Saladaga
ViSCA
Baybay, Leyte 7127-A

G.E. Sajise, Jr.
UPLB-CA Research &
Training Station
La Granja, La Carlota City
Negros Occidental

F.S. Talle
Central Mindanao University
Musuan, Bukidnon

Truong Van Den
ViSCA
Baybay, Leyte 7127-A

E.S. Villanueva, Jr.
DA Experiment Station
La Granja, La Carlota City
Negros Occidental

L.G. Villegas
DA-Tiaong Expt. Station
Lagacag, Tiaong, Quezon

F.G. Villamayor, Jr.
ViSCA
Baybay, Leyte 7127-A

Singapore

Kenneth T. MacKay
IDRC. P.O. Box 101
Tanglin, Singapore 0924

Solomon Islands

Ruth Liloqula
M.A.L, P.O. Box 613
Honiara

Sri Lanka

K.P.U. de Silva
CARI, P.O. Box 11
Peradeniya

S.D.G. Jayawardena
CARI, P.O. Box 11, Gannoruwa
Peradeniya

Thailand

Narin Poolperm
Pichit Horticultural Research Centre
6600

Tonga

Pita Taufatofua
Research Division
M.A.F.F. Nukualofa

Vietnam

Mai Thach Hoanh
Institute of Food Crop
Agricultural Ministry
Hai Hung

Nguyen Quy Hung
Institute of Agricultural Technology
121 Nguyen Binh Khiem St.
Ho Chi Minh City

Western Samoa

Rupeni Tamani
University of the South Pacific
Alafua Campus
Apia

LIST OF OBSERVERS

Visayas State College of Agriculture

E. Abogadie
J. Arcaya
J. Bacusmo
M. Bacusmo
G. Batoctoy
N. Belonias
A. Burdeos
E. Cabia
B. Cajes
C. Calibo
N. Calomot
M. Capuno
O. Capuno
R. Capuno
A. Castañares
P. Cerna
R. de la Cruz
Z. Cuevas
A. Dalion
M. Dembinski
J. Diamante
L. Diamante
F. Duatin
A. Escasinas
F. Evangelio
G. Gerona
R. Gerona
F. Godoy
D. Gonzal
L. Gonzal
M.F. U. Granados
R. Guarte
E. A. Gundaya
R. Javier
E. Landerito
J. L. Lim
A. Loreto
M. Loreto
M.T. Loreto
J. Magallanes
A. Mariscal
A. Mercado
P.P. Milan
E. Monreal
L. Moreno
T.T.T. Nguyen
M. Oracion
R. Orias
V. Palermo
M.K. Palomar
J. Pardales, Jr.
R. de Pedro
M. Pepino
N. Pido
B.C. Pilapil
A. Polea
I. Printianto
M. Quevedo
M. Quirol
M.C. Ramirez
L. de los Reyes
L. de la Rosa
Z. de la Rosa
C. Sajise
O. Sanchez
B. Satentes
R. Sebidos
A. Solis
M. Tabinas
R.L. Talatala
D.L.S. Tan
E.E. Tulin
A. Valida
E. Vasquez
L. Villacarlos
R. Villegas
A. Villordon

Camarines Sur State Agricultural College

J. Batanes
N. Corporal
J.Obias
J. Osea

Dept. of Agricutlure, RCPC, Abuyog, Leyte

Z. Sultan

The Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) is the central body of the government tasked to coordinate all research and development efforts in agriculture, environment, and natural resources sectors. Among its functions is to review and evaluate R&D programs/projects being implemented by member agencies of the National Agriculture and Resources Research and Development Network.

The Visayas State College of Agriculture (ViSCA) is one of the biggest agricultural colleges in the Philippines. It embraces the three-fold function of instruction, research, and extension to achieve its goal of agricultural and rural development. The government of ViSCA is vested on a Board of Trustees as constituted by Presidential Decree No. 470, which was promulgated on 24 May 1974. Its administration and the exercise of the general powers as set forth in Act No. 1459 are vested on the Board of Trustees and the President of the college as authorized by the Board.

The Philippine Root Crop Research and Training Center (PRCRTC) was established on 21 March l977 by virtue of Presidential Decree No. ll07. Under the decree, the Center is mandated to spearhead the development of the root crop industry in the Philippines.