The Economics of Sweetpotato Genetic Resource Conservation and Varietal Improvement in Asia

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Introduction

Although it ranks as the fifth most important food crop in the developing world (after rice, wheat, maize, and white potato), sweetpotato (*Ipomoae batatas*) has been relatively neglected by the global agricultural research community. With the exception of China, developing countries have generally not invested much in sweetpotato improvement. However, in the past two decades a number of national programs in Asia have sustained modest programs in sweetpotato genetic resource conservation and breeding. At the international level, CIP has had a research program of global sweetpotato improvement since the mid 1980s. AVRDC and IITA did some sweetpotato research even prior to this but later divested of their sweetpotato improvement programs.[2] Among industrialized countries, only the United States and Japan have had sustained efforts in sweetpotato research and development.

The purpose of this paper is to report the results of a survey of sweetpotato genetic resource conservation, varietal improvement and its impact on farmers in Asia. In early 2002 we sent a questionnaire to national agricultural research programs to obtain information on sweetpotato varietal releases in their country since 1981 and estimates of area planted to indigenous and improved varieties in major sweetpotato growing areas. In addition, we gathered information on holdings of sweetpotato genetic resources, the prime material for varietal improvement, and the cost of maintain *ex situ* field collections of sweetpotato accessions. These surveys were conducted with the support of ANSWER, the Asian Network for Sweetpotato Genetic Resources, which is dedicated to collecting, preserving and using sweetpotato genetic resources for crop improvement (Rao and Hermann, 2001).

Main Survey Findings

Table 1 shows the countries surveyed and responses received. Information on sweetpotato genetic resource holdings was received from ten of the eleven countries surveyed. Five countries and the CIP regional office in Bogor, Indonesia, provided detailed estimates of costs associated with maintaining *ex situ* field collections of sweetpotato accessions. For varietal releases, all countries provided complete lists of official releases in their respective countries since 1981 except Japan and South Korea.

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[2] CIP is the International Potato Center in Lima, Peru. AVRDC is the Asian Vegetable Research and Development Center in Taiwan, China. IITA is the International Institute for Tropical Agriculture in Ibadan, Nigeria.

By far the most difficult data to provide was varietal adoption. Vietnam, Thailand and Malaysia provided fairly complete estimates of area planted by variety for each major sweetpotato growing region in their country. China, Philippines and Indonesia provided estimates of varietal adoption for selected regions only. No estimates of varietal adoption were received from India, Sri Lanka, and Papua New Guinea. All told, the estimates of varietal adoption covered 1.149 million hectares, or about 17 percent of the total sweetpotato area in Asia.

Currently there are 6,843 indigenous accessions (native landraces) of sweetpotato held in the genebanks of sweetpotato research programs in Asian countries (Table 2). In recent years most countries in Asia, often in collaboration with CIP, have introduced non-indigenous material into their breeding efforts. Besides CIP (and earlier, AVRDC and IITA), the breeding programs in Japan and the United States have also been sources of new genetic materials for developing-country sweetpotato breeding programs in Asia. Indigenous genetic resources together with introduced clones have been the source of parent material for breeding and selecting new varieties.

An important issue facing national agricultural research programs is how much to invest in conserving native crop germplasm. While it is recognized that some conservation may be essential for a successful breeding program, there may be diminishing returns from trying to maintain a large or complete set of existing accessions of indigenous germplasm. One problem is that it is difficult to assess the present and future value of the genetic traits held in the collections. Some traits may not be needed today but may become valuable in the future. On the other side of the coin is the cost of maintaining these accessions. If policy makers know these costs, they will be better able to judge whether it is feasible to keep future options open through genetic resource conservation.

In Table 3, we summarize the costs of maintaining *ex situ* field banks of sweetpotato in five national programs and the CIP regional office in Bogor, Indonesia. These estimates include an opportunity cost of land (based on local land rental rates), labor and materials for field preparation, planting, crop care, harvesting, and post-harvest handling. All of the genebank locations except China are in tropical or subtropical areas where the crop can be maintained in the field year-round. In China, sweetpotato roots must be kept in storage during the winter months. Storage significantly adds to the cost of maintaining the sweetpotato collection. The costs reported in Table 3 do not include the salaries of scientists involved in developing or improving the collections nor any costs associated with scientific research or breeding. The estimates can best be thought of as "marginal costs" (added cost) of expanding the field bank to include more accessions.

There is a wide range of reported costs of maintaining accessions, ranging from US$1.28 per accession at the CIP office in Bogor to US$21.33 per accession at the Xuzhou Sweetpotato Research Center in Jiangsu, China. However, the largest single cost at Xuzhou is for storage during winter. If storage is excluded, then the cost of maintaining an accession in China is only US$2.32. China could significantly save on the cost of maintaining genetic resources if it consolidated its collections in a location where year-round cropping is possible, such as Hainan Island. This would alleviate the need for over-

winter storage. The next highest cost is at Orissa, India, where conservation costs US$10.67 per accession per year. The cost at all other locations is under US$5.00 per accession per year, even after taking into account that 2-3 crops of sweetpotato must be grown each year. On average, the cost of maintaining a sweetpotato germplasm in a field bank appears to be about US$2.00 per accession per year.

Over the last two decades a total of 113 sweetpotato varieties were released in the seven Asian countries listed in Table 4, not counting an additional 53 native land races that were screened and released in Papua New Guinea.[3] Three-quarters of the 113 releases occurred in the 1990s. There is also a growing contribution of international agricultural research centers in sweetpotato varietal improvement in Asia. CIP, AVRDC or IITA contributed to the release of 16 out of the 113 varieties. In the last 5-year period (1996-2000), 20 percent of new releases had parentage from material provided by the international centers. The use of genetic resources from the international agricultural research centers indicates a widening of the genetic base used in sweetpotato varietal improvement.

The technical information on native land races, the advanced breeding lines, and the new varieties that have been bred from this material are important indicators of the scientific productivity of the national sweetpotato research programs. Perhaps more important for policy makers is the economic impact of these research investments at the farm level. In Table 5 we present some estimates of what these genetic resource conservation and breeding have achieved for farmers.[4] In the six countries that provided some estimates of variety adoption by farmers, 78 new varieties were released since 1981. Of these, at least 28 were being used by at least some farmers in 2001. The most successful variety in Asia (if not the world) is Xuzhou 18, which by 2001 had been adopted on 333,000 hectares in Jiangsu and Shandong provinces of China. This variety is high yielding and exhibits relatively high dry matter content, a desirable feature for feed and industrial use. Utilization of sweetpotato for animal feed and by industry (especially for starch for food products) currently accounts for nearly 80 percent of sweetpotato use in China (Huang et al.).

The area planted to improved sweetpotato varieties shown in Table 5 includes area planted not only to the official releases of national programs, but also area planted to other introduced foreign varieties. These other improved varieties accounted for about 12,000 hectares out of 504,500 hectares planted with improved varieties. China reported 439,000 hectares, or 55 percent of sweetpotato area, grown with improved varieties in the three provinces for which we have data. Area planted to improved varieties would be higher if data were available for other provinces as well. The Philippines reported the most intensive use of improved varieties, at about 68 percent of sweetpotato area in the main producing areas. Thailand reported 59 percent of sweetpotato area with improved varieties. Adoption rates were considerably lower in the other countries: 9 percent in selected regions of Indonesia, 4 percent in Vietnam, and none in Malaysia. Altogether, adoption of improved varieties in 2001 had reached 44 percent of sweetpotato area in the

[3] Details on each of these releases and their pedigrees can be found in Appendix Table A.
[4] Details on varietal adoption in each production region can be found in Appendix Table B.

reporting regions. Forty-three percent of sweetpotato area was planted with varieties developed and released by the national agricultural research programs.

We can offer some suggestive calculations on what the economic benefit of this varietal improvement effort has been for Asia's farmers. Let's assume that adoption of an improved variety raised farmers yield by 2.5 tons/ha on average. This is the figure applied by Walker et al. (2001) to assess the impact of adoption of improved varieties of white potato (*Solanum tuberosum*) in developing countries, and seems reasonable for sweetpotato as well. It represents about a 10-15 percent increase in average farm yield in areas grown with unimproved varieties and is probably a minimum yield (or value) benefit necessary to provide sufficient incentive to farmers to change variety. Assuming that the farm-gate value of sweetpotato is US$40/ton, this implies adoption resulted in US$100/ha in gross benefits. Fuglie et al. (1999) estimated that extension and seed multiplication costs for virus-free sweetpotato in Shandong Province amounted to US$47/ha assuming farmers replaced planting material every three years. Thus, the net benefit from adoption (not including research costs) is about US$53/ha, on average. This is a conservative (lower bound) estimate of net benefits, since in most cases yield benefits can be expected to be higher and extension and seed multiplication costs lower. For example, most farmers don't replace planting material every three years but save their own planting material for longer.

This rough estimation suggests that the adoption of improved sweetpotato varieties released by national programs in Asia resulted in a net economic benefit of at least US$26 million annually ($53/ha times 492,000 hectares). About 88 percent of these benefits (US$22.9 million) occurred in China, and 12 percent (US$3.1 million) went to Southeast Asia. The benefits would be considerably larger if we had a more complete estimate of area planted to improved varieties, especially for China. For both China and Southeast Asia, these benefits greatly exceed current sweetpotato research expenditures by national programs. So by this simple measure it appears that sweetpotato research has been a good investment in Asia even in areas where adoption of new varieties is relatively low. In fact, it suggests that governments have not been investing enough in sweetpotato research.

Conclusions

Although not much attention has been given to improving sweetpotato in Asia, the modest investments in sweetpotato genetic resource conservation and varietal improvement have already begun to pay off. By 2001, national programs in Asia had collected and characterized more than 6,800 native landraces of sweetpotato. Using these resources together with native and improved germplasm from other countries, these national programs released 113 improved sweetpotato varieties between 1981-2001. A growing share (20 percent in the late 1990s) of new varieties included genetic material provided by international agricultural research centers.

At least 28 of these new varieties were being grown by farmers on nearly half-million hectares in 2001. Actual area planted to improved sweetpotato varieties is undoubtedly

higher, as this only includes data on varietal use for 17 percent of the total sweetpotato area in Asia. Net benefits of adoption (not including research costs) are conservatively estimated at $53/ha/year, or $26 million per year in total for Asia. The net benefits from what has been achieved so far significantly exceeds current expenditures for sweetpotato research and development in these countries. In the years ahead these benefits should increase considerably as new varieties now under development are released and adopted by farmers.

While crop breeding is widely acknowledged as a good and worthwhile investment, how much to spend on crop genetic resource conservation is more controversial. While most of the native land races currently held in national genetic resource collections have yet to be used in breeding programs, it is difficult to assess the potential future value of these genetic resources. But one issue we can address is the cost of genetic resource conservation. The cost of maintaining sweetpotato genetic resources was found to vary widely in Asian national programs, from $21.33 per accession in China to $1.49 per accession in Indonesia. The major reason for the high cost in China is the need for over-winter storage. If storage is not required, it appears that Asian national programs should be able to maintain their collections (and add new accessions, if necessary) for about US$2.00 per accession per year on average.

References

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Table 1: Responses Received to Surveys of Sweetpotato Improvement in Asia

Country Surveyed	Germplasm holdings	Cost of ex situ collection	Varietal releases	Varietal adoption
China	X	X	X	X
India	X	X		
Indonesia	X	X	X	X
Japan	X			
Malaysia	X		X	X
Papua New Guinea	X		X	
Philippines	X	X	X	X
South Korea	X			
Sri Lanka			X	
Thailand	X	X	X	X
Vietnam	X		X	X

Table 2. Sweetpotato GR Holdings in Asian National Programs

Country	Institute	Type of accession	Number of available accessions	Number of accessions registered, but lost
China	Xuzhou Sweetpotato Research Center, Jiangsu	Native cultivars	820	200
		Released varieties	500	50
		Other materials *	700	100
India	Central Tuber Crops Research Institute, Orissa	Native cultivars	884	-
		Released varieties	9	0
		Other materials *	-	-
Indonesia	Research Institute for Food Crop Biotechnology, West Java	Native cultivars	1600	35
		Released varieties	6	-
		Other materials *	43	5
Indonesia	CIP Regional Office for East Southeast Asia and the Pacific (ESEAP), West Java	Native cultivars	1051	-
		Released varieties	2	-
		Other materials *	73	-
Indonesia	Research Institute for Legumes and Tuber Crops, East Java	Native cultivars	1100	100
		Released varieties	12	-
		Other materials *	-	-
Japan	National Institute of Crop Science, Ibaraki	Native cultivars	150	-
		Released varieties	45	-
		Other materials *	1100	15
Malaysia	Malaysian Agriculture Research and Development Institute, Kuala Lumpur	Native cultivars	31	644
		Released varieties	5	-
		Other materials *	36	20
Papua New Guinea	National Agricultural Research Institute, Morobe	Native cultivars	1067	531
		Released varieties	93	3
		Other materials *	33	-
Philippines	Philippine Root Crop and Training Center, Leyte	Native cultivars	705	574
		Released varieties	24	-
		Other materials *	62	-
South Korea	Mokpo Experiment Station, NHAES, Research and Development Administration, Chonnam	Native cultivars	12	-
		Released varieties	20	-
		Other materials *	104	-
Sri Lanka	Horticultural Research and Development Institute, Peradeniya	Native cultivars		
		Released varieties		
		Other materials *		
Thailand	Phichit Horticultural Research Center, Phichit	Native cultivars	105	-
		Released varieties	12	-
		Other materials *	119	-
Vietnam	Plant Genetic Resources Center, Vietnamese Agricultural Science Institute, Hanoi	Native cultivars	369	-
		Released varieties	4	-
		Other materials *	129	-
All Countries		Native cultivars **	6843	2084
		Released varieties	763	50
		Other materials *	2399	140

* Other materials include breeding lines, introduced cultivars, etc.
** Total count of native cultivars does not include CIP-ESEAP holdings, are also held in the Indonesian collections.

Table 3. Cost of Maintaining *Ex Situ* Genebank of Sweetpotato Accessions in the Field

Item	China Xuzhou Sweetpotato Research Center	India Regional Center of CTRI, Bhubaneswar	Indonesia International Potato Center (CIP)	Indonesia Research Institute for Legume and Tuber Crops	Philippines Philippine Root Crop Research and Training Center	Thailand Phichit Horticultural Research Center
	Xuzhou, Jiangsu	Khurda, Orissa	Bogor, West Javar	Malang, East Java	Baybay, Leyte	Muang, Phichit
Number of assessions in genebank	1300	311	485	500	850	400
Area of genebank (m2)	7500	1100	1700	1100	3870	1600
Costs of maintaining accessions in field:						
(figures in US$/1000m2/season)						
1. Land preparation	133.88	210.71	61.86	114.29	9.68	73.79
2. Planting	66.99	97.06	15.38	36.57	11.14	69.19
3. Crop maintenance	25.36	399.04	56.12	171.37	28.65	332.36
4. Harvesting and post-harvest handling	100.32	62.48	10.82	27.69	12.16	56.33
5. Storage	3295.61	-	-	-	-	-
6. Other costs*	75.69	236.52	38.91	193.36	48.13	70.34
Total cost per season	3697.85	1005.81	183.09	543.28	109.76	602.01
Number of season per year	1	3	2	3	3	2
Total cost per year ($/1000m2)	3697.85	3017.43	366.18	1629.84	329.28	1204.02
Number of accessions per 1000m2	173	283	285	455	220	250
Total cost per accession per year	21.33 (2.32) **	10.67	1.28	3.59	1.50	4.82
Exchange rate used in calucation (Local currency unit/US$)	8.2	48.89	8700	8700	51.00	43.45

* Other costs include land rental, office supplies, and miscellaneous expenses. A land rental cost has been included for all sites based on local land rental rates

** Cost per accession including storage costs is $21.33. Without storage costs it is $2.32 per accession.

Table 4. Sweetpotato Varieties Released in Asia Since 1981

Country	Period				Total	Number related to
	1981-1985	1986-1990	1991-1995	1996-2000		CIP/AVRDC/IITA
China	3	5	5	8*	13	-
Indonesia	4	2	1	7	14	5
Malaysia	-	-	1	2	3	1
Philippines	6	6	7	5	24	2
Papua New Guinea **	-	-	26 (53)	-	26 (53)	2
Sri Lanka	1***	-	3	5	9	-
Thailand	-	-	1	8	12^	1
Vietnam	4	1	3	4	12	5
Total	18	14	47 (74)	39	113 (140)	16
Number related to CIP/AVRDC/IITA	1	3	4	8	16	

* includes one release in 2001

** Of the 79 releases in PNG, 53 are native land races that were screened. These are totaled separately in the parentheses.

***released in 1971

^ includes 3 releases of unknown year

Source: Appendix Table A.

Table 5. Summary of Sweetpotato Variety Adoption in Asia

Country	Province/Region	Total sweetpotato area (ha)	Total area planted to improved variety (ha)	Area planted to varieties released by national programs (ha)	% area in IV	% area to nationally released IV	Major uses of sweetpotato
China	Jiangsu	200,000	190,000	184,000	95.0	92.0	food, starch and feed
	Shandong	530,000	249,100	249,100	47.0	47.0	food, starch and feed
	Beijing	70,000	0.0	0.0	0.0	0.0	food
	Total	800,000	439,100	433,100	54.9	54.1	-
Indonesia	East Java/Malang	2,294	229	229.4	10.0	10.0	food
	East Java/Blitar	230	35	0.0	15.0	0.0	food and sauce
	East Java/Mojokerto	735	110	0.0	15.0	0.0	food and sauce
	East Java/Magetan	2,195	110	109.75	5.0	5.0	food and sauce
	West Sumatera	3,249	325	324.9	10.0	10.0	food
	Total	8,703	809	664	9.3	7.6	-
Malaysia	Kelantan/Terengganu	200	0.0	0.0	0.0	0.0	food
	Kuala Bikam	300	0.0	0.0	0.0	0.0	food
	Total	500	0.0	0.0	0.0	0.0	-
Philippines	Central Luzon	10,000	6,900	3,500	69.0	35.0	food and feed
	Bicol region	25,000	13,750	13,750	55.0	55.0	food and feed
	Eastern Visayas	20,000	17,000	17,000	85.0	85.0	food, starch and feed
	Total	55,000	37,650	34,250	68.5	62.3	-
Thailand	Northern	10,000	7,550	6,300	75.5	63.0	food and starch
	Eastern	10,000	4,000	4,000	40.0	40.0	food
	Central Plain	2,262	2,081	1,041	92.0	46.0	food and starch
	North Eastern	3,433	2,197	1,957	64.0	57.0	food and starch
	Southern	1,202	60	60	5.0	5.0	food
	Total	26,897	15,888	13,357	59.1	49.7	-
Vietnam	Red river delta	56,700	1,134	1,134	2.0	2.0	food and feed
	Northern East	20,100	8,040	8,040	40.0	40.0	food and feed
	Nortern West	47,000	1,880	1,880	4.0	4.0	food and feed
	Middle north	97,600	0.0	0.0	0.0	0.0	food and feed
	Middle southern coastal	19,900	0.0	0.0	0.0	0.0	food and feed
	Highland western	6,800	0.0	0.0	0.0	0.0	food, starch and feed
	Northern East	10,600	0.0	0.0	0.0	0.0	food and feed
	Total	258,700	11,054	11,054	4.3	4.3	
All	Area listed above	1,149,800	504,501	492,425	43.9	42.8	

Source: Appendix Table B

Appendix Tables