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Comments are invited.

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Varietal change in potatoes in developing countries and the contribution of the International Potato Center: 1972-2007

INTRODUCTION

Potato is the most important food crop in the world after maize, rice, and wheat, with a total planted area of almost 20 million hectares and production of 320 million tons in 2007. Although the Andean region in South America is the center of origin, the potato developed as a crucial staple crop in Europe and the United States and only in the second half of the twentieth century did it begin to play a greater role in developing countries. Over the past ten years, growth of potato production in developing countries has been much faster than anticipated and has overtaken developed country production.

CIP's research addresses the most significant of the factors limiting potato yields in the principal regions and ecological zones in developing countries (Fuglie, 2007). It engages in a wide range of activities from genetic improvement to crop management and pest and disease control. Much of the focus of the Center's work and investment, however, is in providing diverse improved genetic material to potato growing regions in developing countries so that national breeding programs can identify and develop varieties adapted to their local conditions. Thus the contribution of CIP research to potato production, particularly in the low income and lower middle income regions that constitute CIP's target countries, is of interest for researchers and stakeholders alike. End products of this research are advanced potato breeding materials that are distributed to countries for their final testing and release as varieties, and therefore assessing the contribution of CIP by measuring the adoption of CIP-related varieties is not only common sense but also sound standard practice (Alston *et al.*, 1995).

The rate of varietal replacement in potatoes is lower than wheat, maize and rice, even in developed countries (Walker, 1994). Strong consumer preferences for particular varieties with a highly defined set of attributes inhibit varietal change, as is spectacularly demonstrated by the continuing dominance of Russet Burbank for processing in North America, even though it appeared more than a century ago. Progress in breeding is slower because of the complex genetic make up and inheritance of the potato. Most cultivated potatoes have four different variants (rather than the usual two found in maize or rice) of each of the genes that contribute to controlling each trait, and these are re-shuffled each time a cross is made to introduce a new trait or traits and transmitted in a complex way to the offspring. This makes it impossible to take an existing preferred variety and incrementally improve it through conventional breeding methods. Added to this, in Europe and North America demand for genetic resistance is low for a high value crop where the cost of chemical pest control is not a significant constraint. Furthermore, the use of bulky potato tuber as a seed source also slows the expansion of new varieties as large volumes of seed have to be planted per unit area and multiplication rates from one generation to the next are low compared to other crops. This is a particular constraint in developing countries where weak seed programs often limit diffusion of new varieties even where progress is made in breeding.

During the 1990s potato crop improvement programs in 30 developing countries were surveyed to gather information about varietal change and ascertain CIP's contribution after 25 years of breeding (Walker *et al.*, 2003). This survey found that about 50 percent of the area planted with potatoes in developing countries was of varieties bred by national agricultural research systems (NARS) alone. CIP, in partnership with NARS, contributed about 6 percent of the area. Although a modest contribution compared to areas under cereal crops of CGIAR origin, the figure still represented a respectable rate of return of about 15 percent to investments on potato breeding at CIP, given that varietal change in potatoes is generally slower than in cereals.

The present study updates those findings with data collected in 2007 and throws new light on varietal change and potato production in developing countries. More specifically, the study concentrates on the adoption of CIP-related varieties in those countries. The study compares the information gathered in 2007 with the previous data collected in the 1990s for varietal release and varietal adoption.

POTATO BREEDING AT CIP

In this section we present a brief history of potato breeding at CIP. This is important for three reasons. Firstly, it provides the context and time frame for our estimation of the investment cost in breeding. Secondly, the adoption of breeding materials related to CIP can only occur when they are sent to developing countries, so that an understanding of when different types of breeding materials were actually made available is important to estimate the starting point for different benefit flows to distribution of breeding materials. Finally, an understanding of potato breeding helps to identify the source of the benefits which accrue to the adoption of CIP-related varieties. Broadly speaking these are related to a) resistance or tolerance to specific biotic or abiotic factors which cause yield loss, b) general improvements in the agronomy of the potato, for example, through earliness or better adaptability, and c) quality improvements which have value in consumption or market. Any particular variety will provide a set of benefits from these factors, and we can assume that adoption will only occur when the value of the set of benefits of a new variety exceeds that of the variety or varieties which it will displace. So understanding breeding targets and the types of characteristics which CIP-related materials contain should allow more informed estimates of the sources and size of benefits. Ideally, it would be possible to identify the specific benefits associated with particular genes or sets of genes e.g. for late blight resistance. In practice, we do not yet have sufficient information to do this although progress is being made through modeling, and we do have some estimates for specific cases which provide supporting evidence to estimate the gain through the adoption of CIP-related traits.

CIP was established in 1971 in Peru at the center of potato biodiversity and an immediate priority was to consolidate the world potato collection. Developed country breeding programs concentrated on temperate long day conditions, had a narrow genetic base and did not aim at tropical and subtropical environments. At this time, it was estimated that less than one percent of the existing variability of *Solanum* had been utilized in breeding programs worldwide, although adapted material could already be found in different agro-climatic conditions ranging from the cold and long-days of the Andes to the tropical regions of Africa and Asia. CIP's breeding philosophy was to use the ample variability of the genetic resources in the world potato collection, avoiding the narrowing of the genetic base, and to combine desirable attributes in advanced breeding materials for the use of national breeding programs.

Initially, CIP set up research contracts with advanced research institutes covering several breeding objectives, including resistance to late blight and cyst nematodes, while its own facilities and scientific staff were developed. By 1973, a program to breed varieties especially suitable for developing countries was being established, utilizing the diverse target environments for growing potato in Peru, where experimental stations were being set up. Two years later a breeding strategy to develop four different breeding populations had been defined, with multiple breeding targets including screening of germplasm for resistance to cyst nematodes, Phoma blight (*Phytophthora erythroseptica*), Erwinia, viruses (PLRV, PVX and PVY), as well as the characterization of selected germplasm for protein and frost tolerance. During this period CIP held a series of planning conferences to review the state of the art of potato breeding and set new priorities. Breeding for resistance to PLRV, immunity to PVY and root-knot nematodes resistance were given higher priority, whilst priority for tuber quality and protein were lowered. New objectives appeared, although with lower priority, such as resistance to tuber moths and resistance of tubers to late blight (CIP, 1977).

By 1979, the potato breeding strategy focused on developing just two breeding populations for the cool highlands and warm tropics. Breeding for resistance and tolerance (bacterial wilt, late blight, virus, nematodes, tuber moths, frost, etc.) was conducted separately with the idea that these resistances would be later combined. Subsequently, frost tolerance and nematode resistance were dropped as breeding objectives, and materials with these traits were incorporated into the two breeding populations.

By 1988 a breeding population for the hot and warm tropics was available which included traits for earliness, yield, heat tolerance, immunity to potato viruses PVX and PVY and resistance to PLRV, and a new population B with horizontal resistance to late blight was under development for the cool tropical highlands.

In 1992 agro-ecological analysis was used to reprioritize CIP's research. The priority agro-ecology for potato became the subtropical lowlands. Breeding for heat tolerance in non-traditional potato areas in tropical countries was reduced.

By 1995 the breeding strategy continued on two breeding populations defined by a primary trait for resistance:

a) The Virus Resistance Population for the Lowland Sub-tropics (known by the acronym LTVR, standing for Lowland Tropics Virus Resistance population) with resistance to PVY, PLRV, PVA as primary traits, and heat tolerance and earliness as secondary traits.
b) The late blight resistant population (known as the "B population") with resistance to late blight as primary trait and reduced crop cycle, tuber appearance and postharvest quality as secondary traits.

At this time breeding for bacterial wilt resistance was stopped as little clear progress had been made. The development of these two breeding populations continued until the present. In 2002, cross breeding between the populations started. The primary and secondary traits present in these populations are likely to represent the most important current source of benefits in CIP-related breeding materials.

Alongside of developing breeding materials for clonally propagated potatoes CIP also implemented a breeding program for botanical or true potato seed (to be distinguished from true seed distributed to breeders from which they select clones). True Potato Seed (TPS) appeared in CIP's research program in 1978 and was expected to be fully developed by the mid 1990's (CIP, 1987). TPS distribution began in 1984. Whilst TPS apparently held great promise as a way to lower seed production costs, in practice this potential has not so far been realized, and the adoption of TPS of CIP provenance worldwide is probably less than 10,000 hectares. The TPS program was stopped in 2009.

Distribution of in-vitro germplasm to different countries for evaluation primarily by CIP's own research programs started as early as 1974. The distribution of genetic material to national breeding programs increased during the 1970s, requiring improvements in methods and procedures to introduce, maintain, test, document and disseminate breeding materials. CIP also made available and distributed varieties from other country potato programs. As a result of these efforts between 1981 and 1985, 14 cultivars originated in CIP's breeding program had been named or released by at least one developing country. The distribution of the more advanced breeding materials originating from CIP took longer. The first materials from the B population, for example, were distributed in 1994.

The number of potato materials distributed in the form of clones and populations from 1979 to 2008 is presented in Figure 1. The distribution increased rapidly from 1,350 accessions in 1980 and peaked to 7,730 accessions in 1989, the latter corresponding to 3,897 populations[1] and 3,833 clones (in the form of in vitro plants and tuber genotypes). Since 1994 distribution has declined. In the three year average 2006-2008 the distribution was 1,005 accessions, corresponding to 95 populations and 910 clones.

[1] A population is a true seed cross or a tuber family.

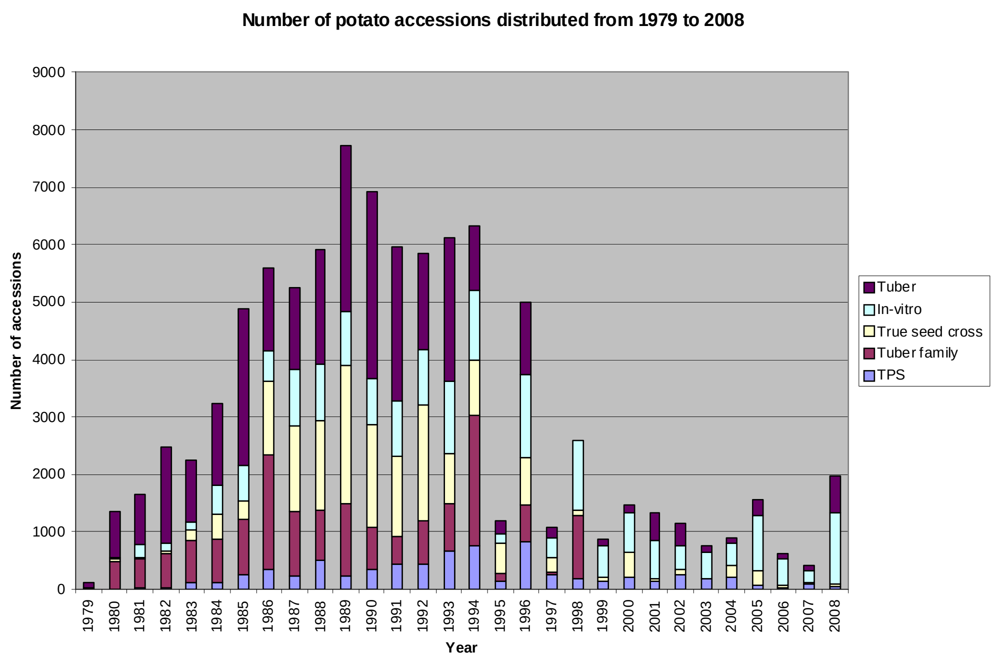


Figure 1. Number of distributed potato materials, 1979 – 2008.

SURVEY METHODOLOGY AND COUNTRY COVERAGE

The study in the 1990s sought to analyze worldwide adoption of CIP-related potato varieties and surveyed the breeding programs of 30 developing countries in Asia, sub-Saharan Africa and Latin America. Only the potato-producing regions of Middle East and North Africa were not covered because most of the countries in these regions export to the European Union and rely on imported supply of tuber seed of potato varieties from Western European breeding programs. But 24 out of the 26 largest potato producers in the rest of the regions were covered, including detailed data from 14 provinces in China. This study actually involved two surveys, the first between 1993 and 1994, and the second which concluded in 1999, but related to the 1997 calendar year. For simplicity we will refer to this as the "1997 study". This elicited information on potato-producing areas, varietal release and adoption, seed production, research capacity through scientific staffing, and potential demand for CIP programs.

In 2007, a follow-up survey questionnaire collected information on the number of varieties released in each region, on breeders' estimated adoption rate for each variety and on the origin of these varieties to determine their parentage with CIP potato material[2] (see Annex 6 for survey instrument). For some countries additional information was collected on the number and research specialization of scientific staff. The survey was sent via e-mail to the leaders of 23 national potato breeding programs in countries covered in 1997 where CIP was known to have had impact. Argentina, Mexico, Brazil and Chile in Latin America, Sudan in Africa and Taiwan and South Korea in Asia were not surveyed, because it was known that little use had been made of CIP breeding materials. Nevertheless, the 23 country sample represented almost 80 percent of total potato area in the developing world.

Using publicly available data (FAO, 2008) on potato area, the estimated adoption rates were converted to estimated area under each variety by country in 2007[3]. With the information on the origin of each variety it was possible to estimate the area planted with material related to CIP in each country and to compute the aggregate estimated figure for all countries. Given its size and the area under potato varieties related to CIP, China deserved a closer scrutiny. Based again on regional programs' and country experts' opinion, and verifying with CIP available information, data for China was disaggregated into 14 different potato producing regions for which data on total potato area was collected[4].

The number of total potato producing countries in each region and the number of countries surveyed is shown in Table 1. Even though the sample represents only one quarter of the total number of potato-producing countries, more than 76 percent of total potato production is captured, with a greater coverage in Asia than in Africa and Latin America. Since the countries surveyed were also those where CIP breeding material was known to have more impact on varietal release, the risk of missing important potato areas with significant CIP impact is reasonably low.

[2] CIP's breeding material refers to potato products from CIP's breeding program; CIP potato material includes not only potato products from CIP's own breeding program but also those from breeding programs from other institutions and countries, as well as native cultivars, all of them distributed by CIP.
[3] The exceptions are Ethiopia and Bangladesh, where there was reason to believe that FAO data was significantly downwardly biased and better estimates existed from expert opinions (see Annex 2).
[4] The survey procedure included confronting national experts with the reported information for 1997, asking them to correct or confirm those results and go from there to complete the 2007 data.

Table 1. Production and area for total and surveyed potato-producing developing countries by region, 2005 – 2007 average.

	Africa	Asia	Latin America	Total
Total number of potato producing countries	37	27	21	*85*
Sample (2007)	8	10	5	*23*
Sample (1997)	9	11	10	*30*
Region: potato production (million of metric tons)	14.5	121.8	15.7	*152.0*
Sample: potato production in the sample (million of metric tons)	3.8	105.7	6.7	*116.2*
% of total regional production	26.1%	86.8%	42.7%	*76.4%*
Region: potato area (thousands of hectares)	1,415	7,870	954	*10,239*
Sample: potato area (thousands of hectares)	614	6,875	569	*8,058*
% of total regional area	43.4%	87.4%	59.6%	*78.7%*

Source: FAO (2008) and survey data.

One important issue is how to attribute released potato varieties to CIP. CIP's breeding strategy focuses on generating and distributing advanced breeding populations and advanced clones. Turning an advanced breeding population into a successful variety involves local crosses, selection and field evaluation and may take many years. Where national programs select from advanced clones provided by CIP the process may be faster. Furthermore, there is an additional lag before finished varieties are adopted by farmers and become popular, if ever. Even in developed countries such as the United States, only a small proportion of the total number of released varieties actually reaches substantial adoption areas (Walker, 1994). Therefore, to track the progenitors of each variety in developing countries and determine CIP's contribution is a difficult task that oftentimes relies on the records of breeding programs and memories of scientists in those countries and at CIP.

The study classified released varieties by their origin into four general categories:

a) Developing country National Agricultural Research Systems (NARS):
   - NARS-bred varieties with no CIP role
   - NARS-selected varieties from crosses unrelated to CIP
   - NARS-released native variety
   - NARS borrowing non CIP-related varieties from other developing countries NARS

b) CIP-NARS:
   - NARS-bred varieties distributed by CIP
   - NARS selections from CIP crosses
   - NARS crosses from CIP progenitors

c) Developed country NARS:
   - Varieties introduced from developed country NARS

d) Other:
   - Native varieties (landraces which are grown by farmers, mostly in the Andes, which were not developed through scientific breeding methods)
   - Sports (somatic mutations), farmer varieties, private sector varieties

The second category includes the three principal ways in which attribution to CIP can be documented. In the first, CIP has played a role in maintaining and making available selected advanced clones and varieties developed by NARS breeding programs in developing countries. CIP makes these materials available to other users as pathogen-free clones for testing and varietal release (e.g., the advanced clone Achirana INTA from Argentina was distributed by CIP to China where it was tested and released as the variety CIP-24). In the second situation, CIP has used native and improved gene bank materials to make crosses and supplied them to NARS who have made selections leading to variety release. In the third situation CIP provided breeding materials for use by NARS with the capacity to make their own crosses for selection and variety release.

The following section presents and discusses the information that emerged from the 2007 survey and contrasts it with the situation in 1997.

RESULTS AND DISCUSSION: RELEASE AND ADOPTION OF CIP-RELATED VARIETIES

This section presents the results from the 2007 survey and compares it with the previous data elicited in 1997, drawing conclusions on the evolution of potato breeding programs where CIP has had the greatest influence, and attempting to identify CIP's contribution. Data on release and adoption of potato varieties in 2007 is presented and compared with 1997 data for the same 23 surveyed countries, organized by category of genetic material according to the classification presented in the previous section. Since the survey data contains information on specific varieties and their attributes, a brief discussion at the end of the section hints at potential factors leading to successful varieties, whether or not the latter are related to CIP.

The number of released varieties by country and region are presented in Table 2. It is apparent from the data that NARS breeding programs have fared fairly well in the 10 years since 1997, and that CIP has played a significant role as a source of potato material. By 2007, breeding programs in the 23 surveyed countries reported the release of 681 varieties. Of these, 251 varieties related to CIP potato material. The total number of varieties released increased over this 10 year period by 82 percent whilst CIP-related varieties increased by 109 percent. Hence, the share of total number of released varieties related to CIP increased from 32 to 37 percent, adding 131 new CIP-related varieties to the available stock of potato material in these countries.

CIP's role was largest in sub-Saharan Africa which had a greater number of CIP-related varieties than other regions – 84 percent of the 64 new varieties originated from CIP-NARS collaboration. In Rwanda, Burundi, Madagascar, Congo D.R. and Ethiopia, almost all varieties released are linked to CIP. In Kenya, there are several varieties with progenitors from developed countries, while in Uganda the national breeding programs has picked up pace in releasing varieties developed on their own or with the collaboration of other NARS. However, CIP-related varieties in these two countries still account for more than 55 percent of releases.

In Asia, China accounts for more then 63 percent of the total releases in the region. Because of the size of its breeding program, China also leads in terms of release of CIP-related material with 37 varieties. In India, CIP progenitors are recognized in 6 varieties. In Asia as a whole, CIP-related varieties represent around 20 percent of the total number of releases, a proportion significantly lower than the contribution to Africa which may be partially explained by the presence of large and strong breeding programs particularly in China and India.

Latin America represents a mixed case, with large national programs that use very little, if any, of CIP germplasm (such as Brazil, Argentina and Chile), and with smaller programs with long standing ties with CIP, such as Bolivia and Ecuador. Nevertheless, in the sampled countries the number of released varieties between 1997 and 2007 increased 57 percent. CIP-related varieties represent 42 percent of the total for the region, up from the 34 percent share in 1997. Peru is a special case in Latin America because CIP has its germplasm collection and breeding program there and works in close collaboration with the national program and other partners. As a consequence, CIP-related varieties represent more than 70 percent of total releases. The number of CIP-related varieties released in Peru is only slightly inferior to the same figure for China (34 vs. 37) and larger than for any other potato producing country in the world.

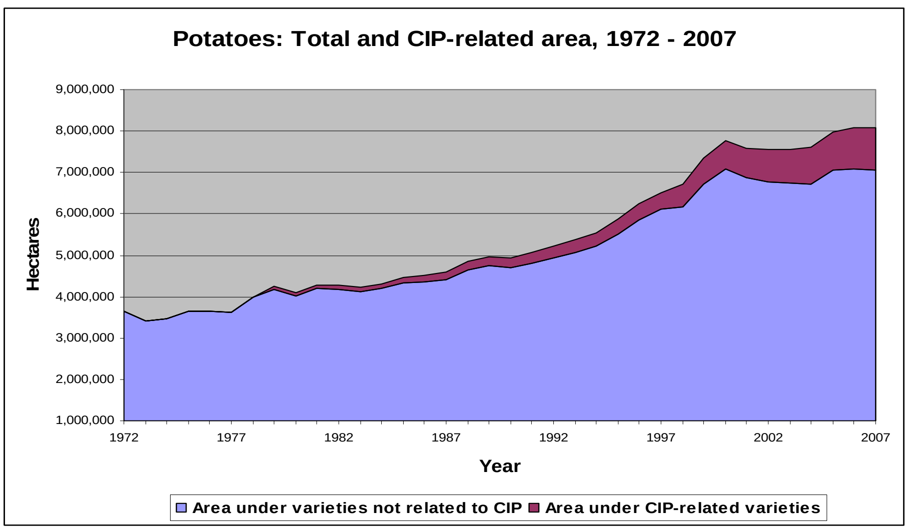
Table 2. Number of varieties released in sample countries: 1997 vs. 2007.

Region	Country	Source released varieties									
		1997					2007				
		Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	Developing country NARS	Developed country NARS	CIP-NARS	Other	Total
Africa	Burundi			7		**7**			15		**15**
	Congo, D R			7		**7**			10		**10**
	Ethiopia			7		**7**			16		**16**
	Kenya	1	11	3		**15**	1	12	7		**20**
	Madagascar		1	7		**8**		1	22		**23**
	Rwanda		1	13		**14**	1	1	15		**17**
	Tanzania	2	2	2		**6**	2	2	5	4	**13**
	Uganda	2		5		**7**	8		13		**21**
	Total	**5**	**15**	**51**	**0**	**71**	**12**	**16**	**103**	**4**	**135**
Asia	Bangladesh	1	5	3		**9**	1	21	6		**28**
	Bhutan	2	2	1		**5**	2	2	2		**6**
	China	89	6	12	5	**112**	176	6	37	38	**257**
	India	33		1		**34**	36		6		**42**
	Indonesia	2	2			**4**	2	2	10	2	**16**
	Nepal	2	1			**3**	2	1	3		**6**
	Pakistan	2	10			**12**	4	10	1		**15**
	Philippines		8	5		**13**	2	8	5		**15**
	Sri Lanka			4		**4**			5		**5**
	Vietnam	1	3	11		**15**	1	3	11		**15**
	Total	**132**	**37**	**37**	**5**	**211**	**226**	**53**	**86**	**40**	**405**
Latin America	Bolivia	10	6	11		**27**	10	6	13		**29**
	Colombia	18			1	**19**	36	1	1	2	**40**
	Ecuador	7		4	1	**12**	10		7	1	**18**
	Peru	13		15		**28**	14		34		**48**
	Venezuela	1		2		**3**	1		5		**6**
	Total	49	6	32	2	**89**	71	7	60	3	**141**
	Total	**186**	**58**	**120**	**7**	**371**	**309**	**76**	**249**	**47**	**681**

Source: 1997 and 2007 survey data.

Table 3 presents the adoption area for each category of potato material and for each region, estimated with the procedure described in the methodology section. Since 1997, total potato area in the sample of developing countries surveyed increased by 25 percent, reaching more than eight million hectares in 2007. At the same time, the area under cultivation with varieties related to CIP potato materials surpassed one million hectares worldwide, a 150 percent increase from the 410,000 hectares registered in 1997. As a result, the share of area under CIP related varieties increased from 6.4 percent to 13.1 percent during the period, making this category the second largest source of genetic material for planted varieties. This can be more clearly seen in Figure 2, where an extrapolation of logistic curves between the points marked by the 1997 and 2007 surveys shows how the share of CIP related varieties has been increasing over time.

Figure 2.
Potatoes: total and CIP-related area, 1972 – 2007.



Source: Based on FAO (2008) and survey data.

The largest share amongst the different categories of genetic material still corresponds to varieties developed by national breeding programs on their own, with more than 5.1 million hectares, representing 63 percent of the total 8 million hectares planted with potatoes in the surveyed countries. On the other hand, developed country clones dropped from a 21 percent share of area in 1997 to 11.4 percent in 2007, mostly due to a large decrease in area planted with this type of material in China. The area planted to developed country clones is slightly over 900,000 hectares, less than the area planted to CIP-related varieties.

In all three regions the area under CIP-NARS varieties has increased significantly. In Asia, potato area increased more than three-fold in comparison with 1997, primarily due to rapid growth in China. In fact, 57 percent of the increase in area under CIP-related varieties occurred in China (372,000 hectares) which on its own contributes to about a half of the million hectares under CIP-related material. Due to its size and regional heterogeneity, data for China disaggregated into 14 main potato producing provinces is analyzed later.

Table 3 shows that CIP-distributed and NARS released category has declined in importance, both in absolute and relative terms, while the other two categories have increased in importance from 45 percent to 83 percent. Furthermore, NARS are increasingly using CIP materials for breeding rather than just selecting from CIP crosses. There are long-term implications for CIP, since stronger breeding programs have evolving demands to be considered when developing CIP's breeding strategy.

The adoption of CIP-related varieties has increased in all three regions that are the focus of the study, but there are country differences within and across regions. The trends observed for some of the countries are consistent with what was expected 10 years ago (Table 4). In Africa, CIP-related material has been adopted extensively in all countries in the past 10 years. There is a large impact of CIP work in Kenya, Uganda, Rwanda, Tanzania and Ethiopia. In these five countries the aggregate area under CIP-related varieties has increased by more than 230,000 hectares, a third of the world-wide increase in area reported since 1997. Together with China, where the increase is of more than 312,000 hectares, they represent more than 85 percent of the total increase in area under CIP- related varieties between 1997 and 2007. Outstanding varieties include Kirundo in Rwanda, Victoria in Uganda and Tigoni in Kenya. In some other African countries such as Burundi and Congo D.R., where CIP-related material is almost the only source of varieties, the area has apparently decreased following the reported downward trend in potato area in these countries. In Madagascar the situation is almost unchanged, with CIP remaining an important source of material, but there is a slight increase in planting of varieties from developed countries.

In Latin America, CIP's contribution is especially strong in Peru where CIP-related varieties have been adopted in more than 100,000 hectares. There is a significant presence of CIP-related varieties in Ecuador (22 percent of total country area), and in Bolivia the area has doubled since 1997. CIP-related varieties are also important in Venezuela's potato producing regions, although the total area is relatively small.

Table 3. Regional adoption of potato varieties by category, 1997 vs. 2007 (thousands of hectares).

	1997					2007				
Source	**Africa**	**Asia**	**Latin America**	**Total ('000 ha)**	**(%)**	**Africa**	**Asia**	**Latin America**	**Total ('000 ha)**	**(%)**
Developing country NARS	**20.9**	**3,575.2**	**390.2**	**3,986.2**	**61.8**	**3.0**	**4,888.0**	**247.3**	**5,138.3**	**63.8**
NARS Bred, No CIP role	0.2	3,097.3	318.1	3,415.6	52.9	0.5	4,374.3	181.7	4,556.5	56.5
NARS selected, No CIP role		387.1		387.1	6.0	0.9	424.0	16.6	441.6	5.5
NARS sharing, no CIP Role	19.0	90.7	8.4	118.1	1.8	1.6	89.6	3.2	94.4	1.2
Released native varieties	1.8		63.6	65.3	1.0		0.1	45.8	45.8	0.6
Developed country NARS	**27.6**	**1,299.7**	**29.5**	**1,356.8**	**21.0**	**25.1**	**872.5**	**19.9**	**917.6**	**11.4**
CIP-NARS	**165.5**	**166.7**	**78.1**	**410.3**	**6.4**	**382.4**	**538.0**	**132.7**	**1,053.2**	**13.1**
CIP distributed, previous NARS release	127.4	85.5	9.6	222.5	3.4	86.3	72.8	17.2	176.3	2.2
CIP Cross, NARS selected	31.6	12.3	68.4	112.4	1.7	195.0	190.1	115.5	500.6	6.2
NARS Cross, CIP Progenitor	6.5	68.9	0.0	75.4	1.2	101.1	275.1		376.2	4.7
Other	**148.9**	**394.1**	**155.6**	**698.6**	**10.8**	**202.9**	**576.4**	**169.3**	**948.6**	**11.8**
Native varieties	40.1		137.6	177.7	2.8	4.5		128.9	133.4	1.7
Old introduced degenerated material	44.7	35.2		79.9	1.2	119.1	80.4		199.5	2.5
Sport, no breeding or CIP involved							47.2		47.2	
Farmer or private sector variety			8.2	8.2	0.1	35.6	0.2	24.8	60.6	0.8
Others	64.2	358.9	9.8	432.8	6.7	43.8	448.6	15.6	508.0	6.3
Total Area	**362.9**	**5,435.7**	**653.3**	**6,451.9**	**100.0**	**613.5**	**6,874.9**	**569.2**	**8,057.6**	**100.0**

Source: 1997 and 2007 survey data.

Table 4. Area under CIP-NARS varieties and from other sources by country, 1997 vs. 2007 (thousands of hectares).

Region	Country	Source released varieties										Change ('000 ha)
		1997					2007					
		Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	
Africa	Burundi	0.2		14.9		**15.0**	0.5		9.5		**10.0**	-5.4
	Congo, D R		0.1	24.3		**24.4**			20.0		**20.0**	-4.3
	Ethiopia	0.2	5.6	6.1	35.7	**47.5**	1.6	4.8	56.0	97.6	**160.0**	49.9
	Kenya		20.9	6.7	67.5	**95.0**		15.8	43.9	62.2	**121.9**	37.2
	Madagascar		0.5	35.6	9.0	**45.0**		4.2	32.1	5.9	**42.3**	-3.4
	Rwanda		0.6	43.4	1.0	**45.0**		0.3	135.6	0.2	**136.0**	92.2
	Tanzania	3.2		5.6	26.3	**35.0**	0.9		19.3	16.9	**37.0**	13.7
	Uganda	17.4		29.1	9.5	**56.0**			66.1	20.2	**86.3**	37.0
	Total	**20.9**	**27.6**	**165.5**	**148.9**	**362.9**	**3.0**	**25.1**	**382.4**	**202.9**	**613.5**	**216.9**
Asia	Bangladesh	11.6	83.5		28.0	**123.2**	11.2	289.1	5.6	67.1	**373.0**	5.6
	Bhutan	1.3	2.8	1.5	0.0	**5.6**	0.1	3.3	0.1	0.1	**3.7**	-1.4
	China	1,984.6	1,046.3	127.2	341.8	**3,499.8**	3,702.1	353.2	448.4	290.3	**4,794.0**	321.2
	India	1,499.6			0.0	**1,499.6**	1,096.2	0.0	43.0	196.6	**1,335.9**	43.0
	Indonesia	0.2	46.5		0.3	**47.0**	0.1	62.2	0.1	0.4	**62.8**	0.1
	Nepal	68.8	13.2	28.5	5.8	**116.3**	58.2	32.3	35.8	20.6	**146.9**	7.3
	Pakistan		81.5	0.0	18.2	**99.6**		111.8		1.2	**113.1**	
	Philippines		6.9	0.1		**7.0**		5.4	0.1		**5.5**	0.0
	Sri Lanka		7.1			**7.1**		5.4	0.0		**5.5**	0.0
	Vietnam	9.0	12.0	9.4		**30.4**	20.1	9.8	4.8		**34.7**	-4.6
	Total	**3,575.2**	**1,299.7**	**166.7**	**394.1**	**5,435.7**	**4,888.0**	**872.5**	**538.0**	**576.4**	**6,874.9**	**371.3**

Table 4. Area under CIP-NARS varieties and from other sources by country, 1997 vs. 2007 (thousands of hectares) (continued).

Region	Country	Source released varieties										Change ('000 ha)
		1997					2007					
		Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	
Latin America	Bolivia	48.2	16.5	9.6	63.3	**137.7**	38.9	19.5	17.2	58.7	**134.2**	7.5
	Colombia	167.7			16.7	**184.4**	95.7			6.8	**102.6**	
	Ecuador	47.1			18.6	**65.8**	8.8		11.4	31.5	**51.7**	11.4
	Peru	125.6		66.5	56.4	**248.5**	87.1		102.1	69.0	**258.3**	35.6
	Venezuela	1.5	13.0	1.9	0.5	**16.9**	16.7	0.4	2.0	3.3	**22.5**	0.1
	Total	**390.2**	**29.5**	**78.1**	**155.6**	**653.3**	**247.3**	**19.9**	**132.7**	**169.3**	**569.2**	54.7
	Total	**3,986.2**	**1,356.8**	**410.3**	**698.6**	**6,451.9**	**5,138.3**	**917.6**	**1,053.2**	**948.6**	**8,057.6**	642.9

Source: 1997 and 2007 survey data.

In Asia, NARS varieties have predominated, including Kexin 1 in China as the world's most planted variety (over 900,000 hectares) and Kufri Bahar and Kufri Jyoti in India (over 400,000 hectares combined). In 2007, material from Chinese breeding programs accounted for a large share of the area (more than 77 percent), nevertheless 10 percent of the potato area was planted with CIP-related varieties, up from 3.5 percent in 1997. CIP's contribution is now acknowledged in India with 43,000 hectares (with only one variety). Nepal continues to be a country with a strong presence of CIP-related varieties, making up almost one -quarter of the total potato area in the country. Bangladesh and Vietnam also account for some areas planted with material related to CIP, nearly 5,000 hectares each. In Bangladesh there has been strong growth in potato production, although 82 percent of the new area devoted to potatoes is under varieties from developed countries. In Bhutan, the area under CIP-related material is decreasing, while the area planted with clones from developed countries is increasing, although from a very small base

The number of released varieties adopted in the different regions and countries (Table 5) also shows an increasing CIP contribution, except for Latin America, where it has remained constant since 1997 (19 varieties adopted). However, in Latin America the area increased significantly and some of the released varieties with CIP origin have gained popularity among farmers, such as Canchan-INIA in Peru, grown in more than 57,000 hectares, and Perricholi in almost 20,000 hectares. In Bolivia the area is more evenly distributed between seven different varieties with CIP provenance.

In Africa, almost 60 percent of the planted varieties have a CIP origin (58 out of 99). In Burundi and Congo D.R. all varieties are of CIP origin. In Uganda and Tanzania, the few varieties related to CIP occupy a large area, proportionally. For example, the number of adopted CIP-related varieties in Uganda dropped from 10 in 1997 to five in 2007, while the area more than doubled to 66,000 hectares. This indicates an increasing concentration of potato production in fewer varieties. In Tanzania, the area planted with material related to CIP is almost exclusively of only one variety (Kikondo). A similar trend towards concentration can be seen in Kenya, where a single variety (Tigoni) occupied more than 36,000 hectares in 2007. In Rwanda, the two most popular varieties (Kirundo and Mabondo) are planted in a combined area of 92,000 hectares.

Table 5. Number of varieties adopted in developing countries: 1997-2007.

Region	Country	Source released varieties									
		1997					2007				
		Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	Developing country NARS	Developed country NARS	CIP-NARS	Other	Total
Africa	Burundi	1	-	6	-	7	1	-	7	-	8
	Congo DR	-	1	7	-	8	-	-	9	-	9
	Ethiopia	1	2	3	1	7	1	2	9	1	13
	Kenya	-	3	3	6	12	-	4	2	7	13
	Madagascar	-	1	7	2	10	-	1	10	4	15
	Rwanda	-	5	7	3	15	-	5	14	3	22
	Tanzania	2	-	2	4	8	1	-	2	4	7
	Uganda	2	-	10	5	17	-	-	5	7	12
	Total	6	12	45	21	84	3	12	58	26	99
Asia	Bangladesh	1	5	-	1	7	1	5	1	1	8
	Bhutan	1	1	1	1	4	1	1	1	1	4
	China	49	5	8	1	63	114	2	21	25	162
	India	13	-	-	-	13	11	-	1	1	13
	Indonesia	1	11	-	2	14	1	2	2	5	10
	Nepal	2	2	7	1	12	3	2	8	2	15
	Pakistan	-	9	-	2	11	-	14	-	1	15
	Philippines	-	6	2	-	8	-	6	2	-	8
	Sri Lanka	-	3	-	-	3	-	4	1	-	5
	Vietnam	1	4	5	-	10	1	5	8	-	14
	Total	68	46	23	8	145	132	41	45	36	254

Table 5. Number of varieties adopted in developing countries: 1997-2007 (continued).

Region	Country	Source released varieties									
		1997					2007				
		Developing country NARS	Developed country NARS	CIP-NARS	Other	Total	Developing country NARS	Developed country NARS	CIP-NARS	Other	Total
Latin America	Bolivia	5	3	5	9	22	5	3	7	9	24
	Colombia	8	-	-	5	13	15	-	-	4	19
	Ecuador	4	-	-	8	12	4	-	1	7	12
	Peru	20	-	10	23	53	16	-	8	55	79
	Venezuela	4	3	4	1	12	3	1	3	4	11
	Total	41	6	19	46	112	43	4	19	79	145
	Total	115	64	87	75	341	178	57	122	141	498

Source: 1997 and 2007 survey data.

In China, there are 21 different varieties with CIP progenitors and they are grown in large areas in different provinces, so this case deserves closer scrutiny. A more detailed look at the most popular varieties in China and the provinces where they have been adopted shows that 10 different varieties with CIP origin are grown in more than 20,000 hectares each (Table 6). The most widely adopted CIP-related variety in China is Cooperation 88, which was released in 1995 and was first introduced into China in 1987 as a true seed cross (see Box No. 1). This variety is grown in 118,000 hectares according to the survey, although some sources point to a higher area.

Box No. 1

The name "Cooperation" is an acknowledgement from Prof. Wang Jun of the Yunnan Normal University of the joint activities that led to the release of the variety, where CIP played a principal role by providing the true seed cross material, testing and selecting the variety jointly with local breeders. Cooperation 88 became popular after the break down of the resistance to late blight in the variety Mira, which occupied more than 945,000 hectares in 1998, and the variety is now adopted in areas where previously Mira was planted. Though Cooperation 88 stands as a long cycle cultivar (up to 150 days) and it adapted well to spring season in the Southwest of China is also widely planted in the winter season in the region. Between 1996 and 2000, adoption of Cooperation 88 picked up quickly, fostered by a rapid development of the economy in China and an increased demand from newly installed potato processing plants. Central planning also helps successful technologies promoted by government and state agencies to be adopted at a faster pace.

In Sichuan, four different varieties (Chuanyu 4, 5, 6 and 8) occupy a similar area of 112,000 hectares, representing more than 40 percent of the potato area in the province. Almost 15 percent of the aggregated potato area in the provinces of Hubei and Chongging is sown with E-potato 1 and 4, which recognize CIP parents. This represents an additional 65,000 hectares of CIP-related varieties. Jizhangshu 8, introduced from CIP as an advanced clone, is sown in around 42,700 hectares in three different provinces (Hebei, Shanxi and Inner Mongolia). CIP 24, the only variety linked to CIP through its name, occupies more than 29,000 hectares alone. The success of these varieties in China shows that once a variety becomes popular and begins to be adopted by Chinese farmers its potential adoption area is very large.

Table 6: Varieties planted in China and related to CIP, 2007.

Name of Variety	Initial introduction from CIP	Main provinces of cultivation	Estimated area in 2007 (Hectares)	Share in province(s) %
Cooperation 88	True seed cross	Yunnan, Guizhou, Guangxi	118,000	11.3
Chuanyu 5	True seed cross	Sichuan	62,933	22.6
Jizhangshu 8	Advanced clone	Hebei, Shanxi, Inner Mongolia	42,700	4.5
Zhangshu 7	True seed cross	Hebei	39,300	28.7
Chuanyu 4	True seed cross	Sichuan	33,827	12.1
E-potato 4	Parent	Hubei, Chongging	31,467	7.4
E-potato 1	Parent	Hubei, Chongging	30,680	7.2
CIP 24	Advanced clone	Inner Mongolia, Ningxia, Shanxi, Yunnan	29,107	2.0
Zhangshu 2	Parent	Henan, Chongging	23,600	7.7
Tianshu 8	Parent	Gansu	23,600	3.6
Tian potato 2	True seed cross	Yunnan	11,013	2.5
Chuanyu 6	Parent	Sichuan	9,440	3.4
Chuanyu 8	Advanced clone	Sichuan	7,080	2.5
Kexin 10	Parent	Heilongjiang	4,720	2.2
Kexin 11	Parent	Heilongjiang	4,720	2.2
Ningshu 12	Parent	Ningxia	4,720	2.3
Tianshu 6	True seed cross	Gansu	2,360	0.4
E-potato 5	Parent	Hubei, Chongging, Sichuan	2,000	0.3
Others (12 varieties)	True seed cross 8 parent 3, advanced clone 1	Sichuan, Yunnan, Hubei, Beijing Central and South	6,433	0.8

Source: 2007 survey data and Kaiyun Xie (personal communication).

Most successful varieties: a hint to explanatory factors

Two major factors have contributed to the increase in the adoption of CIP-related varieties: a) the increase in total potato area in developing countries, from seven million hectares as recorded in 1997 to more than 10 million hectares estimated in 2007 for 30 different countries; and b) the success and popularity amongst farmers of specific varieties that also have good market acceptance.

Contribution to the increase in potato area and in CIP's share is for the most part due to the success of specific varieties in different countries. China alone accounts for 50 percent of the increase in CIP-related varieties, with Cooperation 88, a late blight resistant variety used for table and chipping, contributing with more than 118,000 hectares.

In India, material reported as planted with CIP parentage corresponds to only one variety highly suitable for processing (Chipsona-I). In Peru, more than 57,000 hectares were planted with "Canchan" in 2007, highly successful amongst farmers because of its market acceptance and good cooking quality, although its late blight resistance has mostly broken down. In Rwanda, Ethiopia, Kenya and Uganda only five varieties, each with over 20,000 hectares, together total 177,000 hectares.

Table 7 presents summary information for the 20 most popular CIP-related varieties planted in more than 15,000 hectares each. On aggregate, they account for almost 800,000 hectares. Late blight resistance is mentioned as a primary strength and is present in varieties that occupy almost 50 percent of this area (35 percent of the total area planted with CIP-related material). High yields, closely followed by culinary quality and taste, are present in almost 35 percent of the area. Earliness and market acceptance (including for processing) account for 20 percent and 17 percent respectively[5].

The amount of potato breeding materials distributed to NARS has declined progressively to about 12 percent of what was distributed in 1994 (see Figure 1). This decline might negatively affect the share of varieties using CIP potato materials. However, the percentage of varieties released by NARS from CIP potato materials has increased from 32 percent to 37 percent in the period from 1997 to 2007, as shown in Table 2. It may be argued that the reduced distribution is compensated by the better targeting and trait quality of potato materials distributed, so that the efficiency of distribution has not declined. In contrast, it may be argued that CIP should increase the distribution of potato materials in order to sustain the rate of variety releases and adoption, as the variety development process may take eight to 15 years. The consequences of this reduced distribution of potato materials need further study.

[5] The results in Table 7 refer to the 2007 survey responses by breeders and experts in the countries. CIP conducted standard evaluation of varieties released by NARS for late blight resistance and the results of this trial do not necessarily confirm these responses for the environments in which they were evaluated (Pérez et al., 2006).

Table 7. Most popular CIP-related varieties over 15,000 hectares by country in 2007.

Country	Variety Name	Estimated Area (hectares)	Adoption %	CIP Role	Year of release	Strength of variety	Weakness of variety	Main uses of variety
ASIA								
China	Cooperation 88	118,000	2.5%	CIP Cross, NARS selected	1995	Late blight (LB) resistance and nice shape	Late maturity	Table, Chipping
China	Chuanyu 5	62,933	1.3%	NARS Cross, CIP Progenitor	2004	Earliness and LB resistance	Short dormancy	Table
China	Jizhangshu 8	47,200	1.0%	CIP Cross, NARS selected	2006	High yield and good taste	Late maturity and long flowering season	Table
India	Chipsona-I	43,016	3.2%	NARS Cross, CIP Progenitor	1998	Highly suitable for processing	Susceptible to viruses, wart & cyst nematode	Processing
China	Zhangshu 7	39,300	0.8%		2004	Resistant to PLRV,PVY,PVS and LB	Susceptible to PVX	Chipping
China	Chuanyu 4	33,827	0.7%	NARS Cross, CIP Progenitor	1996	High yield and high LB resistance	Susceptible to Sunlight	Table
China	E-Potato 4	31,467	0.7%	NARS Cross, CIP Progenitor	2004	High yield and easy to store	Susceptible to viruses	Table
China	E-Potato 1	30,680	0.6%	NARS Cross, CIP Progenitor	1995	LB Resistance	Susceptible to BW	Table, Chipping
China	CIP-24	29,107	0.6%	CIP distributed, NARS released	1982	LB Resistance and wide adaptability	Late maturity, susceptible PVX & PVY	Table
China	Tianshu 8	23,600	0.5%	NARS Cross, CIP Progenitor	2001	High yield		Table
China	Zhangshu 2	23,600	0.5%	NARS Cross, CIP Progenitor	1990			Table
AFRICA								
Rwanda	Kirundo	54,505	40.0%	NARS Cross, CIP Progenitor	1989	Culinary quality	Thin skin	
Rwanda	Mabondo	38,154	28.0%	NARS Cross, CIP Progenitor	1989	Culinary quality	Susceptible to Nematodes	
Kenya	Tigoni	36,567	30.0%	CIP Cross, NARS selected	1998	High yield, LB resistance, big tubers	Sensitive to bacterial wilt	Market
Uganda	Victoria	30,217	35.0%	CIP Cross, NARS selected	1991	High yield, early maturity, good market	Susceptible to late blight	Market
Ethiopia	Jalene	20,800	13.0%	CIP Cross, NARS selected	2000	LB resistance, shape, taste, high yield		Table
Tanzania	Kikondo	18,524	50.0%	CIP distributed, NARS released	1987	High yield; Yellow flesh; Intermediate LB resistance	Apical sprouting	Chips, Table
Ethiopia	Tolcha	17,600	11.0%	CIP Cross, NARS selected	1993	LB resistance, good taste, low degeneration	Not very high yield	Table
LAC								
Peru	Canchan	57,884	22.4%	CIP Cross, NARS selected	1990	Earliness, culinary quality	Susceptible to LB	Table, Market
Peru	Perricholi	19,734	7.6%	CIP Cross, NARS selected	1984	High yield	Susceptible to LB	
Peru	Amarillis	18,210	7.1%	CIP Cross, NARS selected	1993	LB resistance, culinary quality	Surface greening, susceptible to handling	

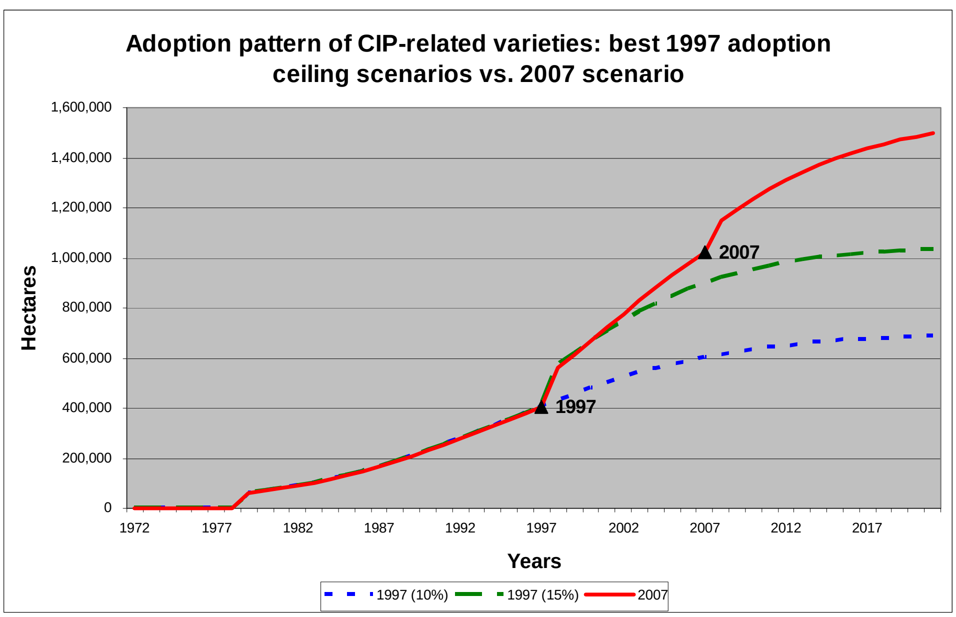
Source: 2007 survey data.

RETURNS TO CIP INVESTMENT ON POTATO BREEDING REVISITED

The 1997 analysis assumed three different adoption scenarios: a stagnant adoption rate of CIP-related varieties at 5.8 percent (400,000 hectares), and two moderately optimistic adoption ceiling scenarios that were considered feasible: 10 percent and 15 percent. The higher adoption ceiling resulted in an estimate of more than one million hectares under CIP-related varieties in 2021. These scenarios led to rates of return to the investment on breeding made by CIP of between 15 and 17 percent.

The one million hectare milestone estimated in the earlier study for 2021 was actually reached in 2007, more than ten years earlier than predicted by the best scenario envisioned in 1997. Maintaining the expected productivity effects of variety change, the current adoption area in 2007 implies rates of return of around 20 percent, assuming a feasible growth rate to reach 1.5 million hectares from the current situation. A graphic representation of these scenarios is shown in Figure 3.

Figure 3. Assumed adoption patterns for CIP-related varieties, 1997 vs. 2007.



The following assumptions are used to re-estimate the returns to CIP's investment[6]:

a) Project duration of 50 years until 2021.
b) Source of benefit is a yield increase of 2.0 tons per hectare in adopted area. As discussed and documented extensively in Walker *et al.* (2003), this gain is plausible for varietal replacement in potatoes and represents a 10 – 15 percent yield increase with respect to the average yields in developing countries. A considerable part of this benefit is likely to have accrued from late blight resistance and also from virus resistance; these are specific traits included in many CIP materials which are usually absent in the varieties they have replaced. Since the yield gain is the only source of benefits considered for this analysis, other sources, such as reduced fungicides costs and savings in management, are embedded in this parameter. For example, the adoption of the late blight resistance variety Amarilis in Peru produced average net yield gains of 9 percent but additional benefits include reduced use of fungicides and lower total costs (Maldonado *et al.*, 2008; L. Salazar, pers. comm.). In Uganda, average yield gains for superior late blight resistant varieties top 2.7 tons per hectare compared with local varieties with very low yield (less than 4 tons per hectare). In Kenya, yield gains are lower, near 0.97 tons per hectare, in part because average yield gains for local varieties were found to be higher at 8.5 tons per hectare. However, net returns from improved varieties increased more than 80 percent due to reduced labor costs (Kaguongo *et al.*, 2008).
c) Potato price is US$ 110 per ton, and remains constant throughout the project duration.
d) Additional costs of NARS research, seed and extension equivalent to 50 percent of gross benefits.
e) Breeding costs estimated as a 55 percent cost share on total potato crop improvement expenditures by CIP.
f) Net benefits adjusted to 2007 prices using US Consumer Price Index.
g) Logistic patterns of diffusion, 2007 total potato area for the 23 countries surveyed held constant (no growth in total area), and a discount rate of 10 percent.
h) Two adoption ceiling scenarios: one million hectares remaining constant through the rest of the period (no growth in area), and a second scenario with an adoption ceiling of 1.5 million hectares in 2021. The first scenario represents an adoption rate of 13 percent with respect to the current 2007 area; the second assumes a potential adoption rate of 18.5 percent and is selected because it would represent another important (and feasible) milestone.

[6] These assumptions are kept similar to those in Walker *et al.* (2003) to facilitate comparisons.

The results show that the increase in area under CIP-related varieties has generated higher returns to CIP investment (Table 8). The rate of return of 20 percent is consistent with the range of rates of return to investments in agricultural research (Alston *et al.*, 2000). The rate is 3.3 percent higher than the best case scenario pictured with 1997 data and closer to the 26 percent rate estimated for a successful variety – Canchan – in Peru (Fonseca *et al.*, 1996). The increase in the rate of return and in the discounted benefits can be broken down into two sources related to the speed and extent of adoption:

a) A higher than expected speed of adoption increases the net present value because benefits are captured earlier (given a positive discount rate); this is the case when the one million hectares point is reached in 2007 instead than at the end of the project.
b) A higher adoption ceiling at the end of the project increases the value of the benefits in those years due to larger coverage[7].

Table 8. Returns to CIP investment, 1997 vs. 2007 estimations.

Survey year	**1997**	**1997**	**2007**
Area under CIP-related materials (Ha)	410,000	410,000	1,053,000
Adoption ceilings in 2021 (%)	10%	15%	18.5%
Internal Rate of Return (IRR)	15.8%	16.7%	20.0%
Net Present Value (NVP), million US$	$51	$71	$121

Source: Walker *et al.* (2003) and authors' calculations.

Increased levels of adoption in the future will continue to increase benefits and returns. However, even assuming that adoption remains constant at the 2007 level, does not lead to a large reduction in benefits. The rate of return would still be slightly below 20 percent and the net present value of benefits would be reduced to 113 million dollars. On the other hand, reducing the discount rate to 5 percent increases the benefits to more than 500 million dollars. In the long term, this rate of return is more realistic and increases the benefits because the revenues produced after the research lag are discounted at lower rates. Therefore, it is also a reassurance that the estimated net benefits are on the conservative side. The results follow the conclusions in the previous study that net benefits are relatively more sensitive to the discount rate than to the level of adoption.

[7] At 2007 prices and all else equal, achieving 1 million hectares earlier contributes to a 4.7 million dollars increase in the Net Present Value and the higher adoption ceiling contributes to 6.9 million dollars.

The results are more sensitive to a reduction in the source of benefits, although the returns remain positive. By reducing the yield increase to 1.5 tons per hectare instead of 2.0 tons per hectare, the internal rate of return is reduced to 11.4 percent and the net present value to 14.4 million. With a discount rate of 5 percent, however, the net present value with reduced yield gains is almost 200 million dollars and is still higher than the base calculation with a 10 percent discount rate.

The attribution issue notwithstanding, it seems that if adoption rates of CIP-related varieties continue at present levels, they generate a stream of net benefits that is enough to pay not only for CIP investment in breeding but also for all CIP resources allocated to potato research. In that case, the estimated rate of return is 12.4 percent and the NPV amounts to 45 million dollars.

CONCLUSIONS

The one million hectare milestone comes earlier than previously forecasted and has important implications. It seems to indicate that, as already suggested in Walker *et al.* (2003), diffusion of CIP-related material has picked up speed and may have not reached yet the saddle point of theoretical adoption paths that are typical of individual varieties. If new materials are developed and are successful in responding to farmers' demands, the aggregate area under CIP-related varieties will continue to produce positive returns to investment in CIP's potato breeding programs.

Some of the factors that may contribute to a further increase in area under CIP-related varieties are:

a) The area under potato production in the developing world is a driving force as long as it continues to increase. Future increases in area probably imply more agro-ecological heterogeneity and more need for varieties adapted to these conditions. Breeding programs, such as the one at CIP, whose objective is to maintain variability as source of resistance to pests and diseases, will find more opportunities for the advanced and diverse material they produce.
b) Strengthening breeding programs in developing countries that have by now a long history of collaboration with CIP will continue to seek advanced materials and populations for local selection, and increase the chance that the finished varieties they release will have some type of parentage with CIP material.

c) Genetic materials that carry desired attributes (late blight resistance, high yield, market acceptance, cooking quality) and are sought by farmers will contribute to rapid increases in area, since successful potato varieties are widely adopted in most countries. If superior varieties, such as Cooperation 88 in China or Canchan in Peru, are released for each country or agro-ecological condition, they have the potential to be adopted in large areas.

The study also shows that CIP-related varieties are making a significant contribution in some of the poorer countries especially in Africa e.g., Burundi, Congo D.R., Rwanda, Uganda. For an institution whose mandate is primarily pro-poor research this result is relevant and reassuring of the direction of its research program.

When prices of food crops that are commercialized in the international market increase (as was the case in 2008 for rice, maize and wheat) substitution occurs and potatoes, as a domestic crop which is little traded internationally, acts as a safeguard staple for poor consumers. Thus, development and availability of appropriate varieties and crop technologies will be crucial to meet an increased potato demand at affordable prices for the poor. A relatively high level of return to potato breeding shows that maintaining and strengthening this investment is beneficial. There are also new challenges to breeding for pro-poor traits such as drought tolerance, which is likely to be increasingly important as global warming takes its toll, and CIP is including this in its breeding program. The study shows the extent of worldwide adoption of CIP-related varieties, since this is an important outcome of the CIP mandate and provides an estimate of the overall impact which is likely to have been achieved, but providing a finer grained analysis of the impact and its specific contribution in local contexts to poverty, hunger and malnutrition remains an important task for the future.

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ANNEX 1. TIMELINE OF DEVELOPMENT OF POTATO BREEDING AT CIP.

Date	Strategy and breeding objectives	Key events
1971		Agreement establishing CIP signed[8]
1972	Vision is to target tropical and subtropical environments incorporating resistance breeding using broad genetic base available in world potato collection. CIP sets up research contracts with advanced research institutes covering diverse breeding objectives relevant to specific problems of developing countries while its own facilities and scientific staff are being developed.	CIP opens and starts world potato collection based on germplasm donated earlier by Peru[9]. Research contracts for field testing breeding materials with late blight resistance in the Regional CIP Program in Mexico (continuation of former Rockefeller Program); germplasm enhancement of Andigena, and research on resistance to cyst nematode (Cornell University); use of diploid potatoes for variety development (North Carolina State University); use of new parental material and breeding methods to increase productivity, germplasm management, utilization of wild species in breeding, and genetic control of bacterial wilt resistance (University of Wisconsin). Distribution of breeding materials begins[10].
1973	Breeding program set up to utilize diverse target environments for growing potato in Peru. CIP research projects (later thrusts); including breeding varieties adapted to extreme conditions and potato pests for developing countries. Screening of germplasm for resistance to cyst nematodes begins. Characterization of selected germplasm for nutrient content (protein) and frost tolerance commences.	Hybridization for genetic improvement begins[11]. Three Outreach and Training, later Regional Research and Training, are established for South America, Mexico; Central America and the Caribbean; and Middle East and North Africa.
1974	Experimental field stations in coastal, highland and tropical sites established in Peru. Breeding materials from research contracts tested in Peru. Screening of germplasm for resistance to Phoma blight and viruses (PLRV, PVX). Research on drought tolerance included in new research contract.	Outreach and Training in Tropical Africa established. Distribution of potato breeding materials developed by CIP begins[12].

[8] Agreement between the Government of Peru and North Carolina State University establishing CIP. January 20, 1971.
[9] In 1972 the CIP collection consisted essentially of the Peruvian collection. The acquisitions and collections in the 1970s consolidated it as the world potato collection.
[10] CIP distributed materials since 1972; however records of distributions are missing for the period 1972- mid 1979; no distribution was made during 1978 until mid 1979 due to the PSTV disease outbreak.
[11] Many crosses were made in CIP. Lists of such crosses were kept by respective owners and have not been registered in any CIP database. Further, the CIP book of crosses is opened. The book initially included crosses acquired from Research Contracts (mainly University of Wisconsin); but since 1975, it includes CIP crosses for export, a practice that continues today.
[12] Distribution of potato material to external recipients was in the form of botanical seed while in Peru it was both botanical seeds and tubers. Very likely this initial distribution consists of native germplasm and derived material from the potato collection. The distribution is mainly internal, in CIP-Lima (4,756 tuber seed lots and 1,578 seed lots distributed overall; the latter included 199 "hybrid seed lots").

ANNEX 1. TIMELINE OF DEVELOPMENT OF POTATO BREEDING AT CIP (continued).

Date	Strategy and breeding objectives	Key events
1975	Four potato breeding populations are developed: for adaptation to highland tropics (cold tolerance), for the lowland tropics (heat tolerance), of cultivated S. tuberosum and of Andean cultivated potato species[13.] Breeding for late blight resistance begins in Peru. Screening of selected germplasm for resistance to Phythopthora erythroseptica, Pectobacterium carotovorum (Erwinia carotovora) and PVY begins[14.]	Regional Research and Training in South West Asia, South-Central Asia and Southeast Asia established.
1976		Distribution of in vitro potato plants begins[15.]
1977		Research contract with Cornell on trichomes[16.]
1978	TPS research begins.	
1979	CIP potato breeding strategy described with two breeding populations aiming at the cool highlands and warm tropics[17.] Breeding for resistance (bacterial wilt, late blight virus, nematodes, frost, tuber moths, etc) conducted separately and resistances later incorporated into these populations.	Breeding using ploidy manipulation including haploids and 2n gametes started.
1980	Incorporation of virus resistance into cool highlands and warm tropics populations begins. Development of breeding materials combining resistances including late blight, PVX, PVY, black wart, cyst nematodes and frost tolerance in the cool highlands population; and bacterial wilt and late blight with tropical adaptation in the warm tropics population.	
1983		Distribution of TPS begins.

[13] The germplasm distributed abroad is mainly in the form of sexual seed and not tubers, following quarantine standards. Improved potato material is distributed n the form of hybrid seed or tuber families. Procedures are established for the international distribution of in vitro plants; a test shipment of in vitro plants was successfully sent to USDA. In the CIP book of crosses 423 out of 628 crosses are for frost tolerance and 95 for late blight resistance.

[14] The CIP book of crosses registers 125 CIP crosses in 1975. The number of CIP crosses in the book increased rapidly to 628 and 1002 respectively in 1975 and 1976; this peaked to 2,921 in 1992. For comparison the number of crosses registered in 2005, 2006 and 2007 is 148, 517 and 187 respectively.

[15] In vitro plants were distributed to 6 countries. This was a pioneer effort, as most potato distributed elsewhere at that time was either in the form of tubers or botanical seeds. The distribution of improved breeding material in 1976 is 146 true seed crosses with tolerance to frost sent to 5 countries.

[16] In the 1972, 1973, 1974, and 1975 CIP Annual Reports there is no mention of trichome research in the contract with Cornell. These Annual reports emphasize Cornell contribution with the Andigena material. In 1972 the contract included "1) the development of population of andigena germplasm useful to potato breeding programs throughout the world, and 2) the research for resistance to aggressive races of the Golden Nematode and allied species and the incorporation of this resistance intro tetraploid clones". Trichome research in CIP is mentioned in the Annual Report 1976, but not in connection with Cornell or any other collaborator. Only in the Annual Report 1977, a research contract with Cornell on trichomes shows up.

[17] The terms lowland tropics, warm climates, hot lowlands have been used interchangeably in CIP Annual Reports. No definition of "warm tropics" was found in Annual Reports. The objective in the warm tropics was to expand potato cultivation into non-traditional potato areas where high temperature was a limiting factor, these included parts of Bangladesh, Southeast Asia, South Pacific, Caribbean, Brazil, jungle of Peru, Southern China, Egypt and Kenya.

ANNEX 1. TIMELINE OF DEVELOPMENT OF POTATO BREEDING AT CIP (continued).

Date	Strategy and breeding objectives	Key events
1987	First screening of 36 families of Andigena potato materials consisting of 30,000 genotypes with race 0 of Phytophthora infestans to identify general resistance (horizontal resistance), this material will give rise to the population B.	
1988	Population for the hot and warm tropics with earliness, yield, heat tolerance and immunity to potato viruses PVX and PVY and resistance to PLRV available after 3 years of development. Population B with horizontal resistance to late blight under development.	Further screening of crosses TBR x ADG for horizontal resistance using race 0 of *P. infestans* to augment the population B.
1992	Agro-ecological analysis to prioritize CIP's research[18.] The priority agro-ecology for potato becomes the "Subtropical Lowlands"[19.] CIP reduces breeding for heat tolerance in non-traditional potato areas in tropical countries[20.] Frost tolerance and nematode dropped as breeding objectives, materials with these traits incorporated in other populations.	Advanced potato clones developed by CIP breeding available as in vitro plant, increases to 234 from only 11 in 1982-1984.
1993		In 1993 Annual Report changes from a comprehensive summary format to a case-story type of publication. It is no longer possible to track the development of the research program based on the Annual Report.
1994		Distribution of first materials from B population[21.]
1995	Breeding strategy focusing on two major potato production constraints: the B population with resistance to late blight as primary trait and reduced crop cycle, tuber appearance and postharvest quality as secondary traits and the Lowland Tropics Virus Resistance Population (LTVR) with resistance to PVY, PLRV, PVA as primary traits, and heat tolerance and earliness as secondary traits.	CIP potato breeding (hybridization) was stopped in the regions.

[18] Breeding of the lowland tropic population and incorporation of virus resistance continued, although at a reduced pace. Furthermore, there was an apparent change in institutional strategy focusing the testing of almost finished products (short term impact) rather than developing breeding materials (longer term impact), possibly with the exception of breeding for LB resistance, as Late blight had scored No. 1 in the priority setting of potato .

[19] CIP, Annual Report 1992.

[20] "Subtropical lowlands" replaced "warm tropics" as of 1992 in CIP's new agro-ecology classification. "Subtropical lowlands" was defined as regions with 10C or above more than 8 months but not all 12 months of the year, less than 1,500 masl, and more than 3 cm summer rainfall in the driest month. This excluded the humid and semiarid tropics which had 10C or above all 12 months of the year; and less than two dry months in the year (humid tropics) or more than that (semiarid tropics). Furthermore CIP's 1992 classification differed from the CGIAR 1992 regional agro-ecological zones http://www.fao.org/wairdocs/TAC/X5756E/x5756e0j.htm. The previous term "warm tropics" included both the humid and semiarid topics and part of the subtropical lowlands. References to breeding for "warm tropical lowlands" or "warm climates" were dropped in Thrust II (Breeding) in 1992. Further, the Humid and Arid Tropics of the new agro-ecological classification do not appear in the 1992 priorities for research investment.

[21] Crosses of population B were received in the Philippines from Juan Landeo for LB breeding in Yunnan China in 1994, and this was the first recipient in the regions.

ANNEX 1. TIMELINE OF DEVELOPMENT OF POTATO BREEDING AT CIP (continued).

Date	Strategy and breeding objectives	Key events
1995	Breeding for bacterial wilt stopped; evaluation of last generation bred for BW resistance undertaken[22.]	
1998	Use of LTVR (triplex progenitors) to introgress virus resistance into Population B.	
2001	Incorporation of resistance to late blight from population B into the LTVR population begins[23.]	
2002	Incorporation of tolerance to heat into population B begins. A few LTVR clones used here[24.] Experimental cross breeding between B population and LTVR population for combination of primary traits and hybrid vigor.	
2009	TPS breeding stopped.	

[22] W. Amoros, personal communication.
[23] W. Amoros, personal communication.
[24] M. Gastelo, personal communication.

ANNEX 2. TOTAL POTATO AREA BY REGION AND COUNTRY*.

No.	Region	Country	FAO average 2004-2006	CIP Survey 2007	Survey 1997
1	Africa	Burundi	**10,000**	15,000	15,000
2	Africa	Congo, DR.	**19,983**	20,000	24,361
3	Africa	Ethiopia	58,503	**160,000**	47,497
4	Africa	Kenya	**121,891**	120,842	95,000
5	Africa	Madagascar	**42,265**	45,000	45,000
6	Africa	Rwanda	**136,263**	92,000	45,001
7	Africa	Tanzania	**37,047**	38,000	35,000
8	Africa	Uganda	**86,333**	86,000	56,000
9	Asia	Bangladesh	299,357	**373,200**	123,200
10	Asia	Bhutan	**3,668**	3,800	5,631
11	Asia	China	**4,793,950**	4,902,667	3,499,824
12	Asia	India	**1,335,900**		1,499,638
13	Asia	Indonesia	**62,845**	65,923	47,025
14	Asia	Nepal	**146,893**	150,864	116,291
15	Asia	Pakistan	**113,067**	117,400	99,600
16	Asia	Philippines	**5,465**	7,000	7,000
17	Asia	Sri Lanka	**5,467**	5,200	7,136
18	Asia	Vietnam	**34,667**	30,370	30,370
19	Latin	Bolivia	**134,217**	137,650	137,655
20	Latin	Ecuador	**51,684**	48,000	65,784
21	Latin	Peru	**258,294**		248,551
22	Latin	Colombia	**102,550**	160,000	184,399
23	Latin	Venezuela	**22,461**	24,000	16,939

* For the purpose of the study, potato area was taken from Faostat (FAO, 2008), with the exception of Ethiopia and Bangladesh.

ANNEX 3. POTATO AREA PLANTED BY VARIETY IN LATIN AMERICA: 1997 vs. 2007.

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
1	Peru	Canchan	CIP-NARS	26,346	57,884	3	1
2	Peru	Yungay	NARS	29,577	37,582	2	2
3	Colombia	Parda Pastusa	NARS	122,741	36,098	1	1
4	Colombia	Diacol Capiro	NARS	17,186	25,330	2	2
5	Ecuador	Superchola	Other	8,196	24,808	3	1
6	Colombia	Pastusa Suprema	NARS	-	19,792	-	3
7	Peru	Perricholi	CIP-NARS	31,317	19,734	1	3
8	Peru	Amarillis	CIP-NARS	1,243	18,210	26	4
9	Bolivia	Desiree	Developed country NARS	13,765	17,448	3	1
10	Bolivia	Waycha	NARS	19,271	13,422	1	2
11	Bolivia	Lukys, Choquepitos(amarga)	Other	13,765	13,019	2	3
12	Peru	Chaccro	Other	-	12,863	-	5
13	Bolivia	Imilla negra	NARS	12,389	12,080	4	4
14	Ecuador	I-Friapapa	CIP-NARS	-	11,370	-	2
15	Peru	Cica	NARS	13,173	11,262	7	6
16	Venezuela	Granola	NARS	8,300	10,929	1	1
17	Peru	Peruanita	NARS	13,919	10,797	6	7
18	Peru	Amarilla/Lim	Other	5,717	9,712	13	8
19	Peru	Andina	NARS	5,965	8,110	12	9
20	Bolivia	Qollus (incluye Phiños)	Other	8,259	8,053	6	5
21	Peru	Huayro	Other	11,930	7,284	8	10
22	Peru	Ccompis/FBL	NARS	15,410	6,832	5	11
23	Bolivia	Malcacho	Other	6,883	6,711	9	9
24	Bolivia	Otras variedades (mostly landraces)	Other	8,259	6,711	7	7
25	Bolivia	Sani negra	Other	6,883	6,711	8	8
26	Bolivia	Sani Imilla	NARS	9,636	6,711	5	6
27	Colombia	Criolla	NARS	-	6,050	-	4
28	Venezuela	Kennebec	NARS	4,600	5,717	2	2
29	Bolivia	Phureja	Other	-	5,369	-	11
30	Bolivia	Robusta	CIP-NARS	-	5,369	-	12
32	Peru	Chaska	CIP-NARS	4,971	5,269	15	12
38	Bolivia	Jaspe	CIP-NARS	-	4,027	-	15

ANNEX 3. POTATO AREA PLANTED BY VARIETY IN LATIN AMERICA: 1997 vs. 2007 (continued).

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
42	Bolivia	Runa Toralapa-Perricholi	CIP-NARS	4,130	3,355	14	16
52	Bolivia	Revolucion	CIP-NARS	2,065	2,013	17	19
59	Venezuela	Andinita	CIP-NARS	1,145	1,429	3	3
64	Bolivia	Polonia	CIP-NARS	1,377	1,342	18	20
82	Peru	Unica	CIP-NARS	-	672	-	35
84	Bolivia	Rosita	CIP-NARS	1,377	671	21	23
98	Bolivia	Puka Toralapa - 720055	CIP-NARS	688	403	22	24
103	Venezuela	Tibisay	CIP-NARS	-	333	-	9
105	Venezuela	Caribay	CIP-NARS	219	271	10	10
111	Peru	Atahualpa	CIP-NARS	-	155	-	52
114	Peru	Chata roja	CIP-NARS	-	130	-	55
126	Peru	Maria Huanca	CIP-NARS	497	77	34	63
	Peru	Tahuaqueña	CIP-NARS	1,243	-	25	-
	Venezuela	Clon “Lirio rojo” 1)	CIP-NARS	300	-	8	-
	Venezuela	Clon Tibisay	CIP-NARS	268	-	9	-
	Peru	Amapola	CIP-NARS	249	-	49	-
	Peru	Guise	CIP-NARS	249	-	46	-
	Peru	Kori INIA	CIP-NARS	249	-	48	-
	Peru	Molinera	CIP-NARS	124	-	52	-

Source: 1997 and 2007 surveys.

ANNEX 4. POTATO AREA PLANTED BY VARIETY IN ASIA: 1997 vs. 2007.

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
1	China	Kexin 1	NARS	333,563	912,534	3	1
2	India	Kufri Bahar	NARS	424,858	424,549	1	1
3	India	Kufri Jyoti	NARS	387,109	424,015	2	2
4	China	Mira	Developed country NARS	945,445	206,107	1	2
5	Bangladesh	Diamant	Developed country NARS	-	205,150	-	1
6	China	E-Potato 3	NARS	-	196,667	-	4
7	China	Longshu 3	NARS	-	196,667	-	3
8	India	Others	Other	-	196,644	-	13
9	China	Hui-2	NARS	-	157,333	-	6
10	China	Ningshu 4	NARS	-	157,333	-	5
11	China	Weiyu 3	NARS	-	157,333	-	7
12	China	Favorita	Developed country NARS	79,265	147,107	7	8
13	China	Cooperation 88	CIP-NARS	3,333	118,000	53	9
14	China	Dongnong 303	NARS	62,483	118,000	12	10
15	China	Longshu 5	NARS	-	118,000	-	12
16	China	Ningshu 8	NARS	-	118,000	-	11
17	India	Pukhraj	NARS	-	105,670	-	3
18	China	Qingshu 168	NARS	-	94,400	-	13
19	China	Bashu 10	NARS	60,000	88,893	13	14
20	China	Chuanyu 56	NARS	75,033	78,667	8	15
21	Bangladesh	Local	Other	28,037	67,140	2	2
22	China	Chuanyu 5	CIP-NARS	-	62,933	-	16
23	China	Kexin 18	Other	-	62,933	-	17
24	Indonesia	Granola	Developed country NARS	43,126	59,702	1	1
25	Bangladesh	Cardinal	Developed country NARS	13,690	59,680	3	3
26	China	Bashu 8	NARS	-	55,067	-	18
27	China	Jinshu 7	NARS	95,333	55,067	6	19
28	India	Badshah	NARS	90,233	52,768	6	4
29	China	Jizhangshu 8	CIP-NARS	-	47,200	-	20
30	China	Kexin 12	NARS	-	47,200	-	21
37	India	Chipsona-I	CIP-NARS	-	43,016	-	6

ANNEX 4. POTATO AREA PLANTED BY VARIETY IN ASIA: 1997 vs. 2007 (continued).

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
44	China	Zhangshu 7	CIP-NARS	-	39,333	-	32
45	China	Chuanyu 4	CIP-NARS	20,000	33,827	32	33
47	China	E-Potato 4	CIP-NARS	-	31,467	-	35
52	China	E-Potato 1	CIP-NARS	-	30,680	-	40
53	China	CIP-24	CIP-NARS	24,944	29,107	27	41
64	China	Tianshu 8	CIP-NARS	-	23,600	-	48
70	China	Zhongshu 2	CIP-NARS	61	23,600	63	54
93	China	Dian Potato 2	CIP-NARS	-	11,013	-	69
96	Nepal	Khumal Seto-1	CIP-NARS	6,678	9,548	4	6
97	China	Chuanyu 6	CIP-NARS	-	9,440	-	71
113	Nepal	NPI - 106	CIP-NARS	9,447	7,492	3	8
116	China	Chuanyu 8	CIP-NARS	-	7,080	-	85
120	Nepal	Khumal Rato-2	CIP-NARS	-	6,023	-	9
122	Bangladesh	Others (New TPS varieties)	CIP-NARS	-	5,595	-	8
128	China	Kexin 10	CIP-NARS	-	4,720	-	93
129	China	Kexin 11	CIP-NARS	-	4,720	-	94
131	China	Ningshu 12	CIP-NARS	-	4,720	-	96
150	Nepal	BR 63.65	CIP-NARS	3,048	3,819	8	11
151	Nepal	Rosita	CIP-NARS	2,769	3,525	10	12
156	Viet Nam	Hong Ha (2+7)	CIP-NARS	-	2,635	-	4
159	China	Dianshu 6	CIP-NARS	-	2,360	-	113
171	Nepal	NPI – T/0012	CIP-NARS	2,769	2,057	9	13
173	Nepal	Perricholi	CIP-NARS	2,667	1,910	11	14
188	Nepal	I - 1124	CIP-NARS	1,141	1,469	12	15
190	Viet Nam	KT-3	CIP-NARS	-	974	-	6
202	China	Kangqing 9-1	CIP-NARS	-	787	-	142
216	China	Yushu CA	CIP-NARS	-	787	-	156
194	China	Chuanyu 10	CIP-NARS	-	787	-	134
195	China	Chuanyu 39	CIP-NARS	6,667	787	49	135
220	China	Zhongshu 7	CIP-NARS	-	787	-	160
226	Viet Nam	KT-2	CIP-NARS	-	347	-	9
227	Viet Nam	VC-38.6	CIP-NARS	-	347	-	8
228	Viet Nam	Red skin/Dalat	CIP-NARS	-	343	-	10
237	Bhutan	Yusikap	CIP-NARS	1,510	147	2	2

ANNEX 4. POTATO AREA PLANTED BY VARIETY IN ASIA: 1997 vs. 2007 (continued).

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
245	Indonesia	Repita	CIP-NARS	-	63	-	9
240	Indonesia	Balsa	CIP-NARS	-	63	-	3
247	Philippines	Dalisay	CIP-NARS	70	55	8	7
248	Philippines	Montanosa	CIP-NARS	70	55	7	8
249	Viet Nam	CFK-69.1	CIP-NARS	40	45	9	11
250	Viet Nam	B71-240.2	CIP-NARS	30	35	10	13
251	Viet Nam	P-3	CIP-NARS	-	35	-	12
252	Sri Lanka	Hillstar	CIP-NARS	-	27	-	4
	China	Er potato 1	CIP-NARS	42,167	-	20	-
	China	CFK 69.1	CIP-NARS	20,000	-	31	-
	China	Zhongdianhong	CIP-NARS	10,000	-	45	-
	Viet Nam	Hong Ha 7	CIP-NARS	4,500	-	4	-
	Viet Nam	Hong Ha II	CIP-NARS	4,500	-	3	-
	Viet Nam	Red skin	CIP-NARS	300	-	8	-

Source: 1997 and 2007 surveys.

ANNEX 5. POTATO AREA PLANTED BY VARIETY IN AFRICA: 1997 vs. 2007.

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
				1997	2007	1997	2007
1	Ethiopia	Local	Other	35,656	97,600	1	1
2	Rwanda	Kirundo	CIP-NARS	-	54,400	-	1
3	Rwanda	Mabondo	CIP-NARS	6,495	38,080	3	2
4	Kenya	Tigoni	CIP-NARS	2,850	36,567	6	1
5	Kenya	Nyayo	Other	28,500	30,473	1	2
6	Uganda	Victoria	CIP-NARS	1,680	30,217	8	1
7	Ethiopia	Jalene	CIP-NARS	-	20,800	-	2
8	Tanzania	Kikondo	CIP-NARS	5,250	18,524	2	1
9	Ethiopia	Tolcha	CIP-NARS	-	17,600	-	3
10	Tanzania	Arka	Other	24,500	14,819	1	2
11	Rwanda	Cruza 148	CIP-NARS	11,172	13,600	2	3
12	Rwanda	Gikungu	CIP-NARS	-	13,600	-	4
13	Uganda	Cruza	CIP-NARS	-	12,950	-	2
14	Uganda	Kinigi	CIP-NARS	-	12,087	-	3
15	Congo DR	Cruza	CIP-NARS	11,995	10,191	1	1
16	Kenya	Ngure	Other	6,650	9,751	5	3
17	Madagascar	Meva	CIP-NARS	3,150	9,721	7	1
18	Madagascar	Pota	CIP-NARS	10,350	9,298	1	2
19	Uganda	Rwangume	CIP-NARS	-	8,633	-	4
20	Kenya	Tana Kimande	Other	-	8,532	-	4
21	Burundi	Cruza 148	CIP-NARS	14,100	8,300	1	1
22	Uganda	Bumbamagara	Other	-	7,770	-	5
23	Kenya	Asante	CIP-NARS	-	7,313	-	5
24	Kenya	Dutch Robijn	Developed country NARS	-	6,095	-	6
25	Rwanda	Kigega	CIP-NARS	-	5,440	-	5
26	Kenya	Others	Other	19,950	4,876	12	13
27	Ethiopia	Chiro	CIP-NARS	-	4,800	-	4
28	Ethiopia	Menagesha	CIP-NARS	-	4,800	-	5
29	Congo DR	Mabondo	CIP-NARS	5,683	4,596	2	2
30	Congo DR	Gahinga	CIP-NARS	-	4,396	-	3
32	Madagascar	Jaingy	CIP-NARS	-	4,227	-	4
39	Rwanda	Victoria	CIP-NARS	-	2,992	-	6
41	Rwanda	Sangema	CIP-NARS	23,383	2,720	1	7

ANNEX 5. POTATO AREA PLANTED BY VARIETY IN AFRICA: 1997 vs. 2007 (continued).

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
40	Rwanda	Kinigi	CIP-NARS	520	2,720	5	8
45	Uganda	Nakpot5	CIP-NARS	-	2,245	-	8
48	Madagascar	Miova	CIP-NARS	3,600	2,113	5	6
46	Madagascar	Lava	CIP-NARS	10,350	2,113	2	5
49	Madagascar	Diamondra	CIP-NARS	-	1,691	-	10
52	Ethiopia	Awasha	CIP-NARS	2,141	1,600	4	7
53	Ethiopia	Genet	CIP-NARS	-	1,600	-	10
54	Ethiopia	Guassa	CIP-NARS	-	1,600	-	12
56	Ethiopia	Sissay	CIP-NARS	1,071	1,600	5	8
58	Ethiopia	Zengena	CIP-NARS	-	1,600	-	13
61	Rwanda	Nderera	CIP-NARS	-	1,360	-	9
63	Madagascar	Avotra	CIP-NARS	-	1,268	-	11
67	Madagascar	Maharevo	CIP-NARS	-	845	-	12
68	Tanzania		CIP-NARS	-	741	-	5
69	Burundi	Ingabire	CIP-NARS	150	500	7	3
73	Madagascar	Mailaka	CIP-NARS	2,250	423	8	14
72	Madagascar	Kinga	CIP-NARS	4,500	423	4	13
76	Congo DR	Kinja	CIP-NARS	-	300	-	4
77	Rwanda	Gahinga	CIP-NARS	260	272	8	10
79	Burundi	Sangema	CIP-NARS	150	200	2	4
78	Burundi	Ruhanyura	CIP-NARS	-	200	-	5
80	Congo DR	Sangema	CIP-NARS	3,279	200	3	5
81	Rwanda	Mizero	CIP-NARS	-	136	-	11
82	Rwanda	Ngunda	CIP-NARS	-	136	-	12
84	Burundi	Majambere	CIP-NARS	150	100	4	6
83	Burundi	Jubile	CIP-NARS	150	100	5	7
85	Burundi	Rukinzo	CIP-NARS	150	100	6	8
86	Congo DR	Mariva	CIP-NARS	305	100	7	7
87	Congo DR	Sesseni	CIP-NARS	551	100	5	6
88	Congo DR	Montsama	CIP-NARS	-	60	-	8
89	Rwanda	Atzimba	CIP-NARS	260	54	11	18
94	Rwanda	Montsama	CIP-NARS	1,299	54	4	13
99	Congo DR	Murhula, Baseko, Enfula	CIP-NARS	-	40	-	9

ANNEX 5. POTATO AREA PLANTED BY VARIETY IN AFRICA: 1997 vs. 2007 (continued).

Rank in Region (2007)	Country	Variety Name	Source	Area (hectares)		Rank in Country	
	Uganda	Cruza 148	CIP-NARS	12,880	-	2	-
	Uganda	Malirahinda	CIP-NARS	5,600	-	3	-
	Uganda	Sangema	CIP-NARS	4,480	-	5	-
	Ethiopia	AL-624	CIP-NARS	2,874	-	3	-
	Congo DR	Mantsama	CIP-NARS	2,002	-	4	-
	Kenya	Tana	CIP-NARS	1,900	-	10	-
	Kenya	Ashante	CIP-NARS	1,900	-	9	-
	Uganda	Rosita	CIP-NARS	1,680	-	6	-
	Madagascar	Atzimba	CIP-NARS	1,350	-	9	-
	Uganda	Bufumbira	CIP-NARS	560	-	16	-
	Uganda	CIP 381403.8	CIP-NARS	560	-	13	-
	Uganda	CIP 382171.4	CIP-NARS	560	-	12	-
	Uganda	Kabale	CIP-NARS	560	-	10	-
	Uganda	Kisoro	CIP-NARS	560	-	9	-
	Congo DR	Murhula, Baseko, Engula	CIP-NARS	436	-	6	-
	Tanzania	Mkomboze	CIP-NARS	350	-	7	-

Source: 1997 and 2007 surveys.

ANNEX 6. SURVEY INSTRUMENT.

Table 1. Origin of varieties officially released by National Program.

Year of release	Year of first use in NARS	Official name	CIP-Role (code *)	Source of material Country/institution	Related to CIP (Yes or No)	Propagation: Clonal or TPS	CIP number	Pedigree - Parentage Female x Male

The data of this table is registered in our database; if the information is not correct you can modify it and add the new varieties for the missing years.

*Code Type	Description of CIP Role
1	NARS Bred, No CIP role
2	NARS selected, No CIP role
3	Developed country clone, NARS released
4	CIP distributed, NARS released
5	CIP Cross, NARS selected
6	NARS Cross, CIP Progenitor
7	Sport, no breeding or CIP involved
8	Farmer or private sector variety
9	Native varieties
10	Old introduced degenerated material
11	NARS sharing, no CIP Role
12	Released native varieties
13	Others

Table 2. Adoption of Potato Varieties

Total Area harvested in hectares/season: ______ Year: 2006

Source of estimate: ______

Variety Name	Estimated area harvested (%)	CIP-Role (code **)	Trend in area*	Strengths of variety	Weakness of variety	Main uses of variety
	~100%					

This table shows the percentages estimated of the area adopted for each potato variety and the total area harvested in the respective year. We need to update this information for the year 2006 or to the most recent year available. If the potato is harvested more than once during the year as a consequence of successive cropping the area is counted as many times as harvested.

The International Potato Center (CIP) seeks to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research and related activities on potato, sweetpotato, and other root and tuber crops, and on the improved management of natural resources in the Andes and other mountain areas.

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Table 3. Description of varieties listed in table 2 which do not appear in Table 1. (Non-released important varieties)

Name	Pedigree	Source	Year of introduction or first cultivation

Table 4. Personnel in Potato Research.

Year: 2006

Staff strength in number of full-time scientists

Educational level	Breeding and germplasm	Seed production
P. School/Technical		
BSc		
MSc		
PhD		

P School: professional school