Appendix B: Seminar transcript

POTATO VIRUSES AFTER THE XXth CENTURY: EFFECTS, DISSEMINATION AND THEIR CONTROL

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Introduction

Soon after its introduction to Europe prior to 1570, potato crops started to suffer "degeneration" or "running off". This was attributed to physiological changes in the cultivars due to continuous vegetative propagation (Salaman, 1970). It was not until the XIXth century that the true cause of degeneration was found to be due to diseases, especially those caused by viruses. Thus, for successful potato production, major efforts have been made to control virus diseases by eliminating them from clonal (seed tubers) and seed-propagated stocks. The effectiveness of these procedures relies on appropriate identification of the causal viruses and the development of accurate, sensitive and low-cost virus detection technology.

More than 35 different viruses are known to affect potatoes. In addition, the potato spindle tuber viroid (PSTVd) and few phytoplasma organisms can affect the crop and cause severe damage. Worldwide potato leafroll (PLRV), potato virus Y (PVY), potato virus A (PVA), potato virus X (PVX), potato virus M (PVM) and potato virus S (PVS) are the most important when their distribution and effect on yield is combined.
In the last 10 years a number of re-emerging viruses and newly emerging viruses are threatening the crop. These viruses have the potential of severely limiting potato production in the future if their control is not considered immediately.

A list of the viruses currently found naturally infecting potatoes is shown in Table 1.

Table 1. Plant virus genera or families having one or more members that affect potatoes (Modified from Salazar, 1996).

Virus genus or family	Member virus (es)*	Particle size (nm)	Means of natural transmission	Geographic distribution
Alfamovirus	AMV, PYV	58 +52 + 42 x 18	Aphids	Worldwide
Bunyaviridae	ToSWV	80 (enveloped)	Thrips	S.America, S.E.Asia
Carlavirus	PVS, PVM	640 x 11	Mechanical, aphids	Worldwide
	PVP, PRDV		Mechanical, aphids?	S. America
Comovirus	APMoV	28 (diam.)	Mechanical; beetles?	Andes
Crinivirus	PYVV	c. 720	White flies	South America
Cucumovirus	CMV	30 (diam.)	Aphids	Europe
Geminiviridae	BCTV, PYMV	17 (pairs)	Leafhopper	South America
	SALCV	17 (triplets)	Unknown	Peru
Ilarvirus	TSV	28 (diam.)	Thrips	Brazil, Peru
Luteovirus	PLRV, SYV	25 (diam.)	Aphids	Worldwide
Necrovirus	TNV	26 (diam.)	Fungus	Europe, Andes
Nepovirus	PBRV, TRSV, ToBRV, AVB(O) PVU	28 (diam.)	Nematodes	Europe, USA
Potexvirus	PVX, PAMV,	520 x 13	Mechanical; fungus?	Worldwide
	PapMV, PepMV		Mechanical	Andes
Potyviridae	PVY, PVA, PVV	740 x 11	Aphids	Worldwide
	WPMV		?	Peru
Rhabdoviridae	PYDV, EMDV	380 x 75	Leafhopper	USA, Iran
Tobamovirus	TMV, 14R	300 x 17	Mechanical	Andes, USA
Furovirus	PMTV	100-150 x 18-20	Fungus	Europe, Andes
Tobravirus	TRV	190 x 22, 45x22	Nematode	Europe, USA
Trichovirus	PVT	640 x 10	Mechanical, seed	Andes
Tymovirus	APLV	28 (diam.)	Beetles	Andes

*Acronyms are those accepted by The International Committee on Taxonomy of Viruses (ICTV). AMV, alfalfa mosaic; PYV, potato yellowing; ToSWV, tomato spotted wilt, PVS, potato virus S; PVM, potato virus M; PVP, potato virus P; PRDV, potato rough dwarf; APMoV, Andean potato mottle; PYVV, potato yellow vein; CMV, cucumber mosaic; BCTV, beet curly top; PYMV, potato yellow mosaic; SALCV, *Solanum* apical leaf curling; TSV, tobacco streak; PLRV, potato leafroll; SYV, *Solanum* yellows; TNV, tobacco necrosis; PBRV, potato black ringspot; TRSV, tobacco ringspot; AVB (O), arracacha virus B strain Oca; PVU, potato virus U; PVX, potato X; PAMV, potato aucuba mosaic; PapMV, papaya mosaic; PepMV, pepino mosaic; PVY, potato Y; PVA potato A; PVV, potato V; WPMV, wild potato mosaic; PYDV, potato yellow dwarf; EMDV, eggplant mottle dwarf; TMV, tobacco mosaic; 14R, 14R virus; PMTV, potato mop-top; TRV, tobacco rattle; PVT, potato T, and APLV, Andean potato latent viruses.

Importance of potato viruses

According to their distribution, incidence in the crop, analysis of risk factors and effect on yield potato viruses listed in Table 1 can be grouped in order of importance into six broad categories (Table 2). Please note that this unpublished classification was developed on the basis of the author’s experience.

Table 2. Categorization of importance of potato viruses based in three characteristics*

Category	Viruses	Effect on yield	Risk analysis	Distribution
1	PLRV, PVY, PVA	Up to 90%	1	1
2	APMoV, PVX, PAMV, PVV, PMTV, TRV, PYVV	Up to 40%	1	2
3	AMV, PYV, PBRV, TBRV, PVP, PVS, PRDV	Up to 20%	1-2	2
4	PVT, APLV, PVU, WPMV, EMDV, TNV, TRSV, AVB (O)	Up to 10%	1-3	2
5	SALCV, ToSWV, PYDV, TSV, BCTV, CMV, APLV, PYMV	Up to 10%	2-3	2
6	14R, PapMV, PepMV, WPMV, SYV	Unknown	1-3	3

*Names of viruses as in Table 1. Risk analysis based mainly on capability to spread by vectors or other dissemination pathways. Level 1, highest risk.

Distribution: 1, worldwide; 2, restricted to a region or country; 3, few reports or very restricted distribution.

Viruses in categories 1, 2 and some in category 3 can be considered the most economically important in potato production worldwide. Yield reduction by these viruses is usually higher than 50% in most susceptible cultivars. Some viruses like APMoV or AMV have a restricted distribution but they cause significant yield losses where they occur. PLRV, a polerovirus (Fam. Luteoviridae), and the potyviruses, PVY and PVA, Fam. Potyviridae, are without doubt the most important viruses for the crop. One factor that contributes to their importance is that they are readily transmitted by several species of aphids, a common pest in potatoes. PLRV is transmitted in nature in a persistent manner by several aphid species in particular, *Myzus persicae* Sulz, the most important vector. The virus survives mainly in infected volunteer potatoes and in wild hosts, although it appears that the importance of wild hosts for survival and spread is higher in tropical countries. PVY and PVA are transmitted in a non-persistent manner by several aphid species. *M. persicae* is the most efficient and common vector in nature. PVY is extremely variable and three groups of strains are recognized (PVY^{O}, PVY^{N} and PVY^{C}). However, several other strains or isolates with particular characteristics have caused outbreaks in potato in the last 10 years. The most damaging at present is PVY^{NTN} that causes ringspots on the tubers.

Viruses in category 2 are either important in some regions where potatoes are cultivated (e.g. APMoV in the Andes) or pose a significant risks if introduced to other regions (e.g. PYVV in S. America). Some viruses in this category are widespread (e.g. PVX) or localized to certain regions (e.g. PMTV).

Viruses in categories 3 to 6 are of more restricted distribution and their effect on yields usually are not high. Information on these viruses can be found in the literature.

Virus threats in the XXIst Century

A number of viruses are of concern in at least the first part of this century. Some can be considered re-emerging while others are previously unrecorded on potatoes. Among the re-emerged viruses we can include PVY^{NTN} , PYVV and to some extent PMTV.

The PVY^{NTN} was first recorded in Europe by 1980 (Beczner et al., 1984) and since then outbreaks have been reported in many regions in the world. The virus, which is not an apparently uniform entity, causes necrotic ringspots on tubers of several cultivars, usually causing severe economic losses due to reduce market value and harvest yield (Fig. 1). The virus exists in the Andes in native cultivars; and thus it is believed to originate in the Andes and remained undetected in Europe for many years. The virus probably spread to Europe and North America in the last two decades due to inappropriate application of new technologies during seed production, such as the use of monoclonal antibodies for its detection in seed programs (Salazar et al., 2000).

PYVV, a crinivirus (Fam. Closteroviridae) has for more than 50 years affected potato crops in Colombia and Ecuador, sometimes sporadically, but other times affecting a large number of plants in a crop. Since 1985 this virus has spread, most likely through infected seed tubers from Colombia and Ecuador to Venezuela and Peru (Fig.2), respectively. The spread is directly correlated to the establishment, spread and incidence of its white fly vector, *Trialeurodes vaporariorum*. Yield reductions due to PYVV are around 50% in most cultivars (Salazar et al., 2000a).

In recent years Europe and North America have reported relatively high incidence of “spraing” symptoms caused by PMTV (Fig. 3). The virus, transmitted by the fungus *Spongospora subterranean*, is widely distributed, though not frequent in some regions in the world.

The unnamed virus, SB26/29, appeared as the causative agent of a newly-emerging virus disease (Fig. 4) in Southern Peru by 1985 (Tenorio et al., 2001). Adults and nymphs of the psyllid, *Russelliana solanicola,* transmit the virus very efficiently in a semi-persistent manner. The spread of this virus followed the rapid spread of the vector. CIP virologists believe that if this virus is not controlled it might, in few years, become a severe threat to potatoes in South America and probably to the rest of the world.

The importance of emerging viruses in the Andes, such as PapMV or PepMV is yet unknown. PepMV is known to affect severely tomato crops grown under glasshouse in Europe and North America.

Approaches to Control

Approaches to virus control can in practice be reduced to two technologies: seed production and development of resistant cultivars. These two technologies depend directly on the availability of detection methods for the viruses. These methods in turn, require certain specific characteristics for efficiency of application among which sensitivity (signal/reactant ratio), accuracy (conformity to a standard), specificity (reaction with desired antigen), reproducibility (consistency of results), possibilities of application in large scale (automation), and low cost are the most important. Fortunately, the enzyme-linked inmunosorbent assays (ELISA) in all its variants and the nucleic acid spot hybridization test (NASH) have these desirable characteristics. Although the polymerase chain reaction (PCR) is the most sensitive technique, it has not yet found a place in programs for large-scale application due to its susceptibility to give false results and its elevated cost.

Due to the large number of viruses that affect the crop and the prohibitive cost of testing for all of them, reagents directed to the detection of virus groups or genera (e.g. Carla-, potex- and potyviruses) rather than individual viruses should be encouraged. A similar approach is applicable to the detection of all viruses and disease agents transmitted through the true potato seed (TPS) should be developed. This approach underlies the strategy for virus control being developed at CIP.

Seed production has been used around the world for more than a century and the technology is well-developed. However, many developing countries in tropical regions apply the procedures, and even tolerances, adopted by developed countries located in temperate regions and with different ecologies without making a pre-evaluation of the existing pathogens and conditions for their development.

Resistance to viruses has not been used extensively **in** potato breeding programs despite information already available on resistance genes (Table 3). In many cases breeding barriers between cultivated and wild species discourage the use of the latter as sources of resistance. The use of biotechnological approaches may help reduce or eliminate these barriers.

Table 3. Genes for resistance to potato viruses and PSTVd (adapted from Salazar, 1996)

Solanum **Species/Cultivar/ Clone**	**Genes** [a]	**Type of resistance**[b]	**Virus or Viroid**
S. tuberosum (cvs.)	Nx_{tbr} ,(Nx)	H	PVX- groups 1,3
S. sparsipilum	Nx^{spl}	H	PVX- groups 1,3
S. tuberosum	Nb_{tbr}	H	PVX- groups 1,2
S. chacoense/S. microdontum	Nx_{chc}	H	PVX- All groups
S. andigena, USDA 41956	Rx_{adg}	RE	PVX- all except HB
S. acaule	Rx_{acl}	RE	PVX- all except HB
S. sucrense	Rx_{suc}	RE	PVX all strs.
S. tuberosum	Na_{tbr}	H	PVA
	Nc_{tbr}	H	PVY[c]
S. microdontum / S. chacoense	Ny_{chc}	H	PVY all strs.
S. hougasii	Ry_{hou}	RE	PVY all strs.
S. demissum	Ry_{dms}	H	PVY all strs., PVA
S. stoloniferum	Ry_{sto} (Ry)	RE	PVY all strs., PVA
	Ry_{sto}^{na}, Ry_{sto}^{n2}	RE	PVY all strs., PVA
	Na_{sto}	H	PVA
	Ry_{sto}^{n1} (Ryn)	H	PVY all strs. No PVA
	Ry_{sto}^{rna}	RE	PVY- all strs.
S. andigena	Ry_{adg}	RE	PVY- all strs.
	Ry_{ant}, Ry_{tlx}	RE	PVY
S. acaule OCH 13823/24	Polygenic	rm	PLRV
S. brevidens	Polygenic	ri,rm,vr	PLRV
S. x edinense	Polygenic	ri	PLRV
S. acaule, S. tuberosum	Polygenic	y	PLRV
S. tuberosum ? cvs Apta, Carla	Polygenic	H	PLRV
S. tuberosum	Polygenic	RE	PVS
S. andigena	Rs_{adg}	RE	PVS
S. acaule	Rp_{acl}	REM	PSTVd

[a.] Codes used are those reported or given by the author following established procedures.

[b.] H= hypersensitivity, RE: extreme resistance (= inmunity); rm = resistance to multiplication; ri: resistance to infection; vr= resistance to the vector; REM= extreme resistance to mechanical inoculation.

Conclusions

A major factor causing spread of particular viruses are the significant changes in climatic conditions worldwide. For instance, the spread of PYVV in recent years has apparently been favored by climatic conditions that permitted the spread and establishment of its white fly vector *T. vaporariorum.* This factor combined with the uncontrolled movement of infected seed tubers across borders and the existence of susceptible weeds (mainly Fam. Polygonaceae) in or around farmer's fields in Venezuela and Peru has led to the successful establishment of PYVV in these countries.

Other viruses such as PapMV and PepMV, recently discovered in native potato cultivars in the Andes may become threats to potato crops if allowed to spread to environments where other susceptible crops or weeds are common. Already PepMV has become a major threat to tomato production in several countries.

A few viruses have practically disappeared from potato crops as a result of more effective control of insects by farmers leading to reduced numbers of their vectors, or due to the intrinsically unfavorable characteristics for their dissemination. PYDV and PAMV or PVY^{C} are examples. The leafhopper vectors of PYDV do not seem to be as common on potatoes as previously, probably due to frequent insecticide applications in potatoes or nearby crops. Control of weed hosts for vectors also plays an important role in reducing the incidence of virus of potato viruses. In the case of PAMV and PVY^{C}, their spread by aphids was conditioned by the vector feeding first on plants infected with virus-transmissible strains of PVY ('helped transmission'), a disadvantageous feature for the spread of these viruses.

Many developing countries follow regulations established in developed countries in their seed production, virus detection programs without having made appropriate and extensive surveys to determine the important viruses in the crop. This situation may lead to future outbreaks of new viruses or new strains of known viruses, as was probably the case for PVY^{NTN} now found in several countries in the world. Aphid-transmitted viruses such as PLRV or the potyviruses are thought to continue to affect potatoes in the XXIst century and it is likely that new viruses or strains of these viruses will continue to appear in the crop. As new vectors become established in the crop (e.g. white flies or psyllids) viruses from other crops or weeds vectored by these insects might become adapted to potato. Evidence for this already exists in the case of *Solanum* apical leaf curling virus, a geminivirus with three-partite particles, and found affecting potatoes in the low jungle valleys in Peru (Hooker and Salazar, 1983).

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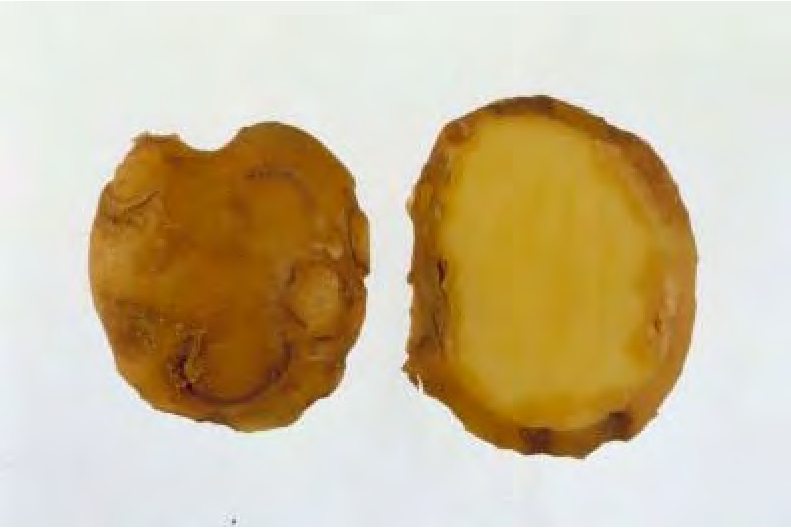

Fig. 1. Typical PVY^{NTN} symptoms in tubers

Fig. 2. Field infection with PYVV in the Peruvian Andes (left) and close up of an infected plant (right)

Fig. 3. “Spraing” symptoms (necrotic ring) in tuber affected
With PMTV

Fig. 4. Plants affected by SB 26/29 disease (left) and yield comparison of healthy and infected plants (right).

Appendix C: Award address transcript

FUELING GROWTH, HEALTH AND PROSPERITY

I do not have enough words to describe the emotion that I feel in receiving this award I realize that for those who worked close to Professor Derek Tribe the occasion is appropriate for wonderful remembrances of a man who contributed so much to Australian as well as to agricultural research worldwide.

I sincerely thank the Management of the International Potato Center (CIP) for selecting me among my colleagues for this nomination and the Crawford Fund selection committee that selected me from a number of excellent contributors to international agricultural research. I hope that I can carry the award with the distinction that it is worth. The award I am receiving today is not only for my work alone but that of many in CIP that one way or another contributed to a successful outcome.

CIP, with headquarters in Lima, Peru, is the fifth Center founded as part of the Consultative Group for International Agricultural Research. Its original 1972 mandate on potatoes was modified in 1985 to include sweetpotatoes, and around 1992 CIP also began to undertake work on other Andean root and tuber crops. To effectively deliver outputs targeted to developing countries, CIP established key regional and country liaison offices around the world.

The financial support of international organizations such as ACIAR has been fundamental for to the development of CIP's programs. Likewise, the scientific input from collaborators from advanced institutions in industrialized countries is vital for CIP to achieve its goals.

This presentation, uses as its title that of our last annual report 'Fueling, growth, health and prosperity' and I have chosen to speak only on subjects in whom the Australian government has contributed either directly or indirectly.

The potato tuber is a cornerstone of our diets and a pillar of many countries' economies. This highly nutritious crop is more profitable than any other staple crop; potatoes are unparalleled as producers of food, jobs and cash. The International Potato Center's work with this crop for more than 30 years has shown that the crop is particularly suited to places where land is limited and labor is abundant – conditions that can be found in most countries of the developing world.

The potato typically has a harvest index of 75-85 percent. As you all know, this means that only less than one-fourth of the plant material produced by sunlight, water, nutrients, labor, and other inputs is 'wasted'. Compared with other crops, that is an astounding figure.

In developing countries as a whole, the growth rate in potato production has nearly doubled over the past twenty years, confounding many commodity projection specialists and outstripping the growth rates for many other major food commodities.

Over the past decade, as growth in production for maize, wheat, and rice slowed, potato output has surged ahead, increasing the crop’s relative importance.

For instance, in the highland areas of southern China and Vietnam, potato is an off-season crop planted in rotation with rice and maize. Because potatoes are viewed as vegetables there (as they are in most tropical areas), they bring relatively high prices at the market. The potato is also becoming more important in sub-Saharan Africa, where rural populations are typically dependent on a small number of seasonal staples and where very few potatoes have traditionally been grown. Although they are unlikely to displace mainstays such as manioc or sweet potatoes in most of the African continent, potatoes are already proving to be a welcome new source of dietary diversity.

Recent collaborative research involving CIP and other CGIAR centers indicates that growing trends will continue. Worldwide, demand for potatoes is expected to increase by 40 percent between 1995 and 2020, maintaining its lead over rice, wheat and maize. By 2020, the developing world’s needs for potatoes will more than double what it was in 1993.

An unprecedented explosion in demand will accompany this increase in production. As populations grow, cities get larger and industrial and market infrastructure gets more sophisticated, processed potatoes will become a much bigger part of the picture.

About half of the increased production will result from an expansion in the land area devoted to potatoes, mainly from the displacement of less competitive crops or the planting of potatoes between the growing seasons of other commodities. The other half will have to come from increased yields and reduced losses. Fortunately, no major crop is as promising in those regards as the potato.

Solutions to many of the potato’s problems can be found in the crop’s own impressive genetic diversity. This diversity has come about naturally as the potato has evolved and is also the product of thousands of years of breeding by farmers and scientists. This germplasm serves as the basic materials from where valuable genes are recovered to solve specific problems caused by diseases, such as late blight, bacterial wilt, viruses or pests, or to improve nutritional and agronomic characteristics of the crop.

Researchers have worked hard to collect and characterize the potato’s genetic wealth, preserving it in gene banks. At CIP, we hold the largest collection of potato genetic materials in the world. The results of their efforts are felt every day, as scientists use the genetic materials from thousands of traditional, wild and modern potato varieties to fashion improvements ranging from drought tolerance and pest resistance to better digestibility and flavor.

In common with the potato, sweetpotatoes are also a crop that is rapidly developing as a source of food and nutrients essential for humans and animals.

Preserving potato and sweetpotato diversity for the generations to come is one of major goals at CIP. At present CIP holds more than 3000 native potato accessions and a similar number of wild relatives. More than 2,500 accessions of sweetpotatoes are also maintained at CIP using the most advanced technology available at present

As we speak of technological advances, we cannot fail to mention the role of today's biotechnologies. At the Potato Center, biotechnology is relied on for crucial applications that range from tissue culture to genetic characterization of gene bank accessions. We are conducting this research cautiously with the strictest of control, and at the same time, we are assisting our partner countries in establishing guidelines that will ensure a safe environment for research on, testing and use of GMOs. We are particularly careful to ensure that those of us working at the center of origin of potato crops do not permit – either accidentally or intentionally -- the release of modified organisms into the environment before they are thoroughly tested.

There is no one crop that does not need good quality seed to increase yield and production. Therefore, helping developing countries to produce high quality seed has been one of the most important priorities of CIP's research. In some areas such as in South East Asia the support and direct participation of ACIAR in the 80's was definitively instrumental to achieve our goal.
The work done in China, and the reason for my presence here tonight, is the successful work conducted in China to increase sweetpotato yields.

Back in 1985 CIP scientists visiting China found that infection with viruses was the major factor that limited production of sweetpotatoes. We were right in believing that the only solution was to develop a "clean seed" production program, known to be fundamental for achieving good yields in potatoes. However, for this development to be successful several aspects had to be first considered and solved. These were the identification of the viruses involved in causing the yield reduction, the development of the most appropriate technology for their detection and elimination and the transfer of the knowledge to the country scientists were the most important aspects considered. Transfer of the technology followed the strategy of "training the trainers" since CIP realized that given the size of the country and the operation, it was impossible for CIP alone to disseminate the technology alone. After 4 years of efforts a virus-free propagation system was developed by scientists in the Shandong Academy of Agricultural Sciences that made available to farmers in the province more than 200,000 tons of virus-free planting material. Since field viruses continue to attack sweetpotatoes and reduce their vitality a continuous supply of virus-free seed is needed making the approach self-sustainable.
The success of the approach developed has been carefully evaluated in recent years. Comparisons have shown that virus-free seed allowed farmers to obtain much higher yields, to the point that in few cases the virus-free seed tripled the yield of the farmer's own seed.

This simple but successful story was big news in China and demands for virus-free seed came from several provinces. Today, the impact of this virus-free seed technology represents additional earnings to the farmers in China in excess of A$ 800 million and has directly benefited more than 4 million farm families.

Still some countries are suffering low yields of potato and sweetpotatoes due to diseases, mainly caused by viruses, and here again the key role of good quality seed has been recognized

Seeds are not only required for high yields. There are a number of examples of its importance to rapidly produce food needed in countries suffering crop devastations due to unexpected catastrophic climatic conditions, diseases or even political unrest. Excellent examples of the value of seed are Caribbean countries affected by hurricanes, or countries affected by war, such as Afghanistan, where the international community has played an important role to help their crops recover are excellent examples of the seed value. More recently the Seeds of Life for East Timor organized through the CGIAR centers and supported by Australia provides a most vivid example of the seed's importance. Among its other values, seed is also an important vehicle to disseminate improved technologies through new varieties.

CIP does not do the work alone. Links and support of several regional networks are essential part of our program. Networks such as PRAPACE in sub-Saharan Africa (SSA), Papa Andina and CONDESAN in the Andes among others, help us to deliver our outputs. PRAPACE was originally established to improve potato production in SSA countries and is a good example where the strategy of "neighbors helping neighbors" has been successful in improving potato and sweetpotato technology. PRAPACE also participates in the rather recently organized VITAA (Vitamin A for Africa) partnership with the participation of several countries, and aims to deploy orange flesh sweetpotatoes in Africa. These sweetpotatoes, rich in beta-carotene, are sought as the best natural solution to combat malnutrition in children deficient in Vitamin A, the main cause of blindness in 500,000 children yearly in Africa and the deaths of 24,000 from malnutrition.

But CIP does not work only with potatoes or sweetpotatoes. There are a large number of Andean root and tuber crops that can fill the needs in some countries of the required food and nutrition. Some of them are also known to carry necessary metabolites required to fight diseases and health disorders such as diabetes. Some of these crops may find conditions to grow in parts of the world other than the Andes. One of these examples is the commercial production of Oca (*Oxalis tuberosa*) in New Zealand.

I, as many of my fellow colleagues in CIP, strongly believe that these root and tuber crops would become the solution to hunger, health and poverty alleviation in the XXIst century.

Appendix D: CD Photo record

Date prepared: 6 December 2003