Are viruses important in Native Seed Systems in Huancavelica, Peru?
Viruses and Andean Potato Seed Systems

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Abstract

The Huancavelica region is a hotspot for cultivated potato genetic diversity; De Haan (2009) has recently characterized 3481 accessions belonging to 38 farming families in a cross section of the region, of which 557 were unique cultivars on morphological grounds and 406 unique cultivars based on fingerprints.

To understand how potato varieties are maintained through time and to direct efforts to improve seed, a study in the community of Ccaspata, ranging from 3700 to 4000 m.a.s.l. and part of the larger community of Chopcca, has identified the main viruses harbored in the local varieties and has attempted to quantify their effect on yield. The main findings in this community are that virus free plants are detected in a significant proportion (40%), the main viruses being PVX, PVS, APMV and APLV whereas PVY and PLRV were found in very low frequencies. When varieties rated positive were compared with varieties rated free only virus S showed yield loss. The large quantity of varieties maintained by farmers makes it difficult to differentiate if the varieties are tolerant or if the viruses are "soft" and do not produce severe yield loss. 100% of all plants of some varieties were found to be completely free of all virus such as Puca Huayro (S.Chaucha), while with others, such as Azul Qanchillo, (S. juzepsukii) no plant free of virus was detected.

Introduction

The knowledge that viruses are mainly seed-transmitted and therefore responsible for seed degeneration has influenced how modern Potato seed is produced. The key to this system is that clean plants (virus and pathogen free) are kept in vitro in laboratories and, when needed, are multiplied first in greenhouses to obtain minitubers, which are again multiplied over two more field generations specifically for seed purposes from which certified seed is obtained. It is often argued that low yields obtained by subsistence farmers of native varieties is due to the virus load the seed carries, and much effort is invested in providing small farmers with clean seed, some of which are cleaned up in the laboratories where they are kept and distributed. Highland potato growers are urged to join the modern seed technology system, called "flush out system", where seed always starts in a laboratory and goes through several years from seed to eventually only for eating and thus it never returns as seed. For the first generation greenhouses are established, and there are now several located in high Andean communities. Few native varieties, mainly those linked to a growing market of colored chips, are now available for this kind of seed multiplication scheme. They were given a "special dispensation" by INIA and SENASA (the national research and plant health Institutes) and were entered in the official potato variety registry. The vast majority of native varieties, about 2 to 3 thousand (Tapia 2008), are excluded from the varietal registry a prerequisite for seed certified schemes, however, it is these varieties which sustain the livelihood of highland potato farmers a rough estimate is 160,000. (www.papa Andina)

In the Chopcca community the district of Yauli in Huancavelica Peru, almost all seed planted originates from their own saved seed store, and they differentiate between food and seed only after harvest. A small percentage of their seed is obtained from their neighbors, relatives and local markets. (de Haan 2009) The objective of this study was to identify the health status of their commonly used seed, and to assess the yield differences between virus-free and virus-infected plants in the same varieties. Modern laboratory assays to identify virus make these studies possible. Most yield loss studies have been carried out outside the country and those in Peru only on improved varieties, so there is very little knowledge of the effect of viruses on the yield of native varieties, owing perhaps to the fact that there are numerous varieties being grown, that these are maintained at the family level and mostly grown as mixtures in the same field (De Haan 2009 Jackson1980). These fields with varietal mixtures are called Chaqro. (Chaqro).

Material and methods

Assessment of Virus Infection in Seed in Chopcca: A seed fair was held in Ccasapata in September of 2006, 42 families donated seed for a future "seed bank". Varying numbers of tubers of 82 varieties were planted the following growing season in observation plots in a communal field in Ccasapata at 3, 800 m.a.s.l. When plants emerged 834 leaf samples were collected and ELISA tests (Enzyme-linked immunosorbent Assay) performed for 6 virus (PVY, PVX, APMoV, PVS, APLV, and PLRV) in CIP's virology laboratory.

All varieties were harvested and stored separately according to variety and virus status. Varieties that had enough seed to plant in a replicated trial (minimum of 15 tubers of clean vs. 15 infected) were planted in a balanced designed with three replicates, where each block had two subplots, clean and infected. This trial was planted in Ccasapata in November 2008, this time in a field at 3900 m.a.s.l., and harvested in May 2009. Twelve varieties and four virus status were selected for this trial (Table 1). Leaves of all plants were again sent to CIP's virology laboratory to confirm their status as "clean" or infected in February of 2009.

Table 1. Virus free and infected varieties from Ccasapata grown in trial in the 2008-9 growing season

Treatment Nº	Cultivar	Clean	infected PVX	infected PVS	infected APMoV	infected APMoV + PVS
1	Occe ruiro	15			15	
2a	Ccori marquina	15			15	
2b	Ccori marquina	15		15		
3	Cuchillo Paqui	15			15	
4	Promesa	15			15	
5	Ccollce tupo	15			15	
6	Yuraq tucco **	15				15
7	Llunchuy waqachi	15	15			
8	vaquilla wacran	15	15			
9	Taragallo	15	15			
10	Puqya	15	15			
11	Occe palta	15	15			
12	Yuraq sari- huasahuasina	15		15		

Results and discussion

Virus Infection: Table 2 gives the viruses identified in 834 plants comprising 82 varieties grown in the 2007-8 season from seed donated by 42 families of the Community of Ccasapata

Table 2. Virus identified in 82 Native Varieties from Ccasapata 2008

VIRUS (1)	Nº SAMPLES	%	VIRUS (2)	Nº SAMPLES	%	VIRUS (3)	Nº SAMPLES	%	TOTAL
Virus free	**340**	**40.8**							
PVX	263	31.5	PVX+APLV	25	3.0	PVX+APLV+APMoV	2	0.24	
PVS	52	6.2	PVX+PVS	24	2.88	PVX+PVS+APMoV	2	0.24	
APMoV	46	5.5	PVX+APMoV	20	2.40	PVX+PLRV+APMoV	2	0.24	
APL.	22	2.6	APLV+APMoV	12	1.44	PVX+PLRV+APLV	2	0.24	
PVY	**4**	**0.5**	PVS+APMoV	7	0.84	PVX+PLRV+PVS	1	.12	
PLRV	**2**	**0.2**	PVX+PVY	2	0.24				
			PVX+PLRV	2	0.24				
			PLRV+APMoV	1	0.12				
			PLRV+PVS	1	0.12				
			PVY+APMoV	1	0.12				
			PVS+APLV	**1**	**0.12**				**834**
TOTAL	**729**	**87.41**		**96**	**11.51**		**9**	**1.08**	**100%**

The data on virus infection obtained from leaves collected in the 2007-8 growing season from 82 varieties, originally obtained at the seed fair from 42 families and processed in the CIP laboratories is notable: firstly, no virus was detected in a large number of plants (40%) , secondly, a negligible presence of the two most serious potato viruses, PVY and PLRV, , was identified; and, finally, no virus was detected in six varieties, that is, they seemed to be virus free. (Table Nº3). The most prevalent virus by far was PVX (31%) while PVS and APMoV (Andean potato mottle virus) were similar in prevalence 5.5% and 6.2%, respectively. APMoV is vectored by plant-to-plant contact and the cucumber beetle *Diabrotica* spp. also seems to play an important role (L. Salazar, 1995). Andean Potato latent Virus (APLV) was found only in four plants. Around 100 plants (12%), were infected with two viruses simultaneously, mostly PVX combined with a second virus. Only 9 plants (1%) were infected with three viruses simultaneously. The results in Ccasapata were similar to those published by De Haan (2009) who sampled 22 farms in 8 communities (1317 samples) and found that PVY and PLRV were present in low frequencies. The most prevalent virus was also PVX and APMoV was found in third position similar to ours. He concluded that the most serious virus (averaging 18%) was precisely APMoV. PVS, which is also mechanically transmitted was included in our study (but not in De Haan´s) and was also found to be prevalent.

Table 3. Varieties where no virus infection was detected

Ccoepa Sullun
Cuchipa Acan
Botijuela
Yana Botijuela
Liberteña *
Puca Huayro

* improved variety

Yield Trial: 2008-9

The overall effects on yield, tuber numbers, and tuber size are given in tables 4, 5 and 6

Table 4. Effects of three viruses on yield (g/plant) in 12 cultivars

	Variety	N	Infected Average	Healthy average	Simple effects Pr > F	Virus
1	Occe ruiro	3	1320	880	**	APMoV
3	Cuchillo paqui	3	1027	840		APMoV
4	Promesa	3	1391	851	**	APMoV
5	Ccollce tupo	3	1485	1195		APMoV
6	Yuraq tucco	3	1334	1151		APMoV + PVS
7	Llunchuy waccachi	3	995	665	*	PVX
8	vaquilla wacran	3	1020	702	*	PVX
9	Taragallo	3	865	978		PVX
10	Puqya	3	586	606		PVX
11	Occe palta	3	1200	1082		PVX
12	Yuraq sari- huasahuasina	3	1331	1458		PVS
2a	Ccori marquina	3	1262	951		APMoV
2b	Ccori marquina	3	885	1075		PVS
	Average		1131	956		

Table 5. Effects of viruses on tuber number in 12 cultivars

	Variety	N°	Tuber Number /plant			Virus
			Infected average	Healthy average	Simple effects Pr > F	
1	Occe ruiro	3	55	48		APMoV
3	Cuchillo paqui	3	46	35		APMoV
4	Promesa	3	56	51		APMoV
5	Ccollce tupo	3	42	51		APMoV
6	Yuraq tucco	3	62	76	*	APMoV + PVS
7	Llunchuy waccachi	3	35	28		PVX
8	vaquilla wacran	3	36	26		PVX
9	Taragallo	3	44	50		PVX
10	Puqya	3	25	29		PVX
11	Occe palta	3	47	66	**	PVX
12	Yuraq sari- huasahuasina	3	63	63		PVS
2a	Ccori marquina	3	42	49		APMoV
2b	Ccori marquina	3	35	41		PVS
	Average		45	47		

Table 6. Effects of virus on tuber size in 12 cultivars

	Cultivar	N	Tuber (g)/plant Infected average	Healthy average	Simple effects Pr > F	Virus
1	Occe ruiro	3	24	19		APMV
3	Cuchillo paqui	3	22	24		APMV
4	Promesa	3	25	16	*	APMV
5	Ccollce tupo	3	35	24	**	APMV
6	Yuraq tucco	3	22	15		APMV + PVS
7	Llunchuy waccachi	3	29	23		PVX
8	vaquilla wacran	3	29	28		PVX
9	Taragallo	3	20	19		PVX
10	Puqya	3	23	21		PVX
11	Occe palta	3	26	16	**	PVX
12	Yuraq sari- huasahuasina	3	21	24		PVS
2a	Ccori marquina	3	30	20	**	APMV
2b	Ccori marquina	3	25	27		PVS
	Average		25	21		

APMoV: All 5 varieties infected with APMoV statistically yielded no different from the "healthy" counterpart, except for Occe Ruiro, and Promesa, both which significantly out-yielded their healthy counterparts (Table 7). ELISA data from previously "healthy" plants of Occe Ruiro in three repetitions and Cuchillo Paqui in two were positive to APMoV. For the analysis, varieties were still classified as "clean" . It was not possible to tell if the titer increased and now became detectable, or if they had become infected after leaf samples were taken in the previous growing season, or they were escapes. The yield increase is mainly given by a remarkable increase in tuber size whereas there is little or no effect on tuber numbers, which are high to begin with in many native varieties.

Table 7. Yield comparison of 5 varieties, which are infected and free of Andean Potato Mop Top Virus, transmitted by *spongospora subeterranea*

Cultivar Name	Yield g/pl				tuber No. /pl			Tuber wt (ave /pl)			
	APMV	Healthy	%		APMoV	Healthy	%	APMoV	Healthy	%	
Cuchillo paqui	1027	840	122		46	35	130	22	24	94	
Occe ruiro	1320	880	150	**	54	48	114	24	19	127	
Yuraq tucco	1334	1151	116		62	76	82	22	15	142	**
Promesa	1391	851	163	**	56	52	109	25	16	153	*
Ccori Marquina	1262	951	163		42	49	85	30	20	153	**
Ccollce tupo	1485	1195	124		42	51	83	35	24	147	
Average	1303	978	140		51	52	100.6	26	20	136	

Potato Virus X: Of five varieties infected and free of PVX, the yield data shows an increase in yield, number of tubers and tuber weight in three of the varieties, namely Llunchuy Waqachi, Vaquilla Wacran and Occe Palta, which also appears to be due to an increase in tuber wt and/or tuber number. The varieties Puqya and Taragallo, commonly found among the households, showed a slight reduction (not significant) in yield and tuber numbers, indicating these varieties to be sensitive to this virus (table 8).

Table 8. Yield comparison of 5 varieties which are infected and free of Potato Virus X

Cultivar Name	Yield g/pl				tuber No. /pl			Tuber wt (ave /pl)			
	PVX	Healthy	%		PVX	Healthy	%	PVX	Healthy	%	
Llunchuy Waccachi	995	665	**150**	*	35	30	86	29	23	122	
Vaquilla Wacran	1020	702	**145**	*	36	27	75	29	28	107	
Taragallo	865	978	**88**		44	50	113	20	19	104	
Puqya	586	601	**97**		25	29	116	23	21	114	
Occe palta	1200	1082	**111**		47	66	**140	26	16	158	**
Average	**933**	**806**	**1182**		**37**	**40**		**25**	**21**	**120.9**	

This surprisingly higher yield response of infected varieties had been noted by Salazar (1995 p183) when he compared native varieties which had been cleaned but which yielded less than the infected original. He suggests that through long co- evolution the viruses gradually become less virulent to the obligate host. Potatoes and viruses may have been co-evolving for more then ten thousand years, which could explain why in the high Andes the prevalent viruses are considered “soft”. He also mentions that a cross protection operates on virus infected plants which are less susceptible to late blight (*Phythopthora infestans*). First noted by Munro and Muller in 1951, this was confirmed by others (Fernandez and Thurston 1975, Kalra et al 1989), and could be playing an increasingly important role in the high Andes, as late blight climbs to areas where it was rarely a problem before.

Potato Virus S: Table 9 shows the yield comparison of two varieties infected and free of virus S.

Table 9. varieties which are infected and free of Potato Virus S.

	Yield g/pl		%		tuber No. /pl			Tuber wt (ave /pl)		
	PVS	Healthy			PVS	Hea	%	PVS	Healthy	%
Yuraq sari- Huasahuasina	1330.7	1458.0	**91.3**		63.4	63.4	100.0	20.8	23.5	88.7
Ccori Marquina	884.83	1075.33	**82**		35.12	40.73	86	25.25	26.51	95

The two varieties studied, Yuraq Sari Huasahuasina, and Ccori Marquina infected with potato virus S lost 10 and 20% yield compared to the “clean” variety**.** The community farmers note that Yuraq Sari Huasahusina probably came in from Huasa Huasi where Carlos Ochoa’s breeding program was testing advanced clones for releasing improved varieties. The tuber characteristics are those of an improved variety (shallow eyes, smooth oval shape and white skin) but is now part of their varietal portfolio together with Liberteña which also originates from a breeding program, both seem to react in opposite directions, Huasahusina showing sensitivity to virus and Liberteña tolerance or resistance, demonstrating that virus resistance is an important feature to varietal durability.

APMoV+ PVS: Only one cultivar with a double infection entered the trial, Yuraq Tucco and this was PVS and APMV. Here we see a yield increase with the infection and can only infer that APMV maybe also cross protecting the variety, but only further tests would shed light. (Table 10).

Table 10 . Comparison between healthy and Virus S+APMOV. : Yield comparison of 2 varieties which are infected and free of Potato Virus S.

	Yield g/pl		%		tuber No. /pl		%		Tuber wt (ave /pl)		%
	APMV+PVS	Healthy			APMV+PVS	Healthy			APMV+PVS	Healthy	
Yuraq tucco	1334	1151	**116**		62	76	82	*	22	15	143

Final conclusions

Results shown in this study are preliminary but important in that expected yield losses were not realized except for virus S, showing a mutual relationship which evolved over centuries where the virus pathogen may offer some advantages to the host, this however needs to be proven in further studies.

Studies of the interactions between a virus and its host, and how both of these are affected by the environment, are lagging behind in the Andes because of the large number of varieties that are grown, and the secondary worldwide importance of the viruses found. However, the remarkable fact that this seed system has proved to be sustainable over time merits a closer look.

Another important aspect is seed transmission or self infection. A study of differences amongst infected mother plants passing virus infection to their daughter tubers in differing environments was not completed in time to be included in this report, but will shed further light on how native seed systems maintain varieties, as Bertschinger (1992) reported that Yungay, an imorved varietyinfected with Potato virus Y did not transmit this virus to its daughter tubers at high altitudes, whereas they were 97% infected in his lowland site.

Some varieties will probably be shown to be resistant to viruses such as Puca Huayro where all tubers tested in this study were free of virus and as yet unpublished results from a Papa Salud report shows that Puca Huayro is resistant to five viruses:

PVX PVY PVA, PVM and PVS (http://www.neiker.net/neiker/germoplasma/Patata/castellano/Datosdeevaluacion.html.)

Understanding of the scientific and social aspects of current Andean seed systems could help establish better adapted model for improved seed, where Andean farmers play a key role due to the ecological advantages of their communities. This overlooked opportunity, could fail if global climate warming changes the conditions under which potatoes are grown today.

Citations

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