Phytophthora infestans Characteristics and Activity in Ecuador. Country Profile

P.J. Oyarzun[1], J. A Taipe[2] and G. A. Forbes[3]

Abstract

About 55,000 ha of potatoes are grown yearly in the cool climate of the Ecuadorian highlands. Temperature and rainfall allow for year-round production. Late blight (*Phytophthora infestans*) occurs throughout the year and first begins just after emergence. Producers that have the economic means must use fungicides intensively because of the constant presence of inoculum, the introduction of a new pathogen genotype, and susceptibility of local cultivars. The cost of chemical protection against *Phytophthora infestans* is estimated to be between US$ 5 and 25 millions. Frequently, small farmers are not able to buy fungicides. In 2000, 30% of the fields surveyed were eventually abandoned due to late blight. Late blight management is complex and should be based primarily in the reduction of the rate of epidemic increase. New cultivars are being developed that have higher levels of field resistance. New management strategies are being established for optimum use of fungicides. Nonetheless, factors that impede the adoption of IPM are dispersion and fragmentation of farmers' fields, limited farmer knowledge about blight, and farmer dependence on recommendations from chemical companies. Several organizations have recognized this problem and have united forces to improve farmer knowledge and farmer participation in the generation of late blight management strategies. Examples are industry collaboration, farmer field schools, organizations of the potato production chain, and multiple collaborative projects with national and international research and development organizations.

Resumen

Oyarzun, P.J., Taipe, J.A., and Forbes, G.A. 2001*. Phytophthora infestans* su Actividad y Particularidades en el Ecuador, Perfil de País. pp. 17–27 en: Fernández-Northcote E. N. (ed), Memorias del taller internacional Complementando la resistencia al tizón (*Phytophthora infestans*) en los Andes, Febrero 13–16, 2001, Cochabamba, Bolivia, GILB, Taller Latinoamerica 1. Centro Internacional de la Papa, Lima, Peru.

En Ecuador se cultiva anualmente bajo condiciones de temporal, unas 55,000 ha de papa. La precipitación y temperatura permiten su cultivo en la sierra todo el año. Aquí, el tizón tardío (*Phytophthora infestans*) ataca desde la emergencia. La presencia constante de inóculo, el ingreso de un nuevo genotipo, y la susceptibilidad de los cultivares comerciales al patógeno, obligan al productor pudiente económicamente, a un uso intensivo de fungicidas. Los costos de protección contra *Phytophthora infestans* se estiman entre US$ 5 y 25 millones. A menudo los pequeños productores no están en condiciones económicas de proteger al cultivo con fungicidas. El 30% de las parcelas prospectadas en el 2000 en la zona central fueron abandonas debido al tizón. El manejo del tizón es complejo y se considera que debe estar basado primariamente en la reducción de la tasa de infección. Nuevos cultivares con niveles más altos de resistencia de campo y formas alternativas de manejo o uso racional de fungicidas están siendo desarrolladas. Sin embargo, la dispersión y fraccionamiento de las parcelas del productor, su escaso conocimiento de la enfermedad y su dependencia de las recomendaciones de las casas de agroquímicos, entre otros factores, son fuertes impedimentos para una difusión más rápida del MIP. Varias organizaciones han reconocido estas limitaciones y han unido esfuerzos para profundizar el conocimiento y facilitar la participación del productor en la generación de soluciones para el manejo del tizón. Como ejemplos podemos citar la colaboración con la industria, las escuelas de productores, la organización de la cadena productiva de la papa y los múltiples proyectos colaborativos con organizaciones nacionales e internacionales de investigación y desarrollo.

---

[1] INIAP National Program of Roots and Tubers-Potato. Email: oyarzun@fpapa.org.ec

[2] National Program of Roots and Tubers -Potato IPM-CRSP.

[3] International Potato Center, Quito, Ecuador; currently at International Potato Center, Lima, Peru

Ecology and epidemiology of late blight

The context of potato production

An estimated 55,000–60,000 ha are planted to potato in the Ecuadorian mountains throughout the year at different times and in different geographical locations (Andrade and Oyarzun, 1999). Past official yield estimates varied between 7–8 t/ha (Herrera et al., 1999), although surveys and studies carried out since 1992 with farmers in four production zones mention yields of about 13 t/ha (Andrade y Oyarzun, 1999). Potatoes are grown on rather irregular land on valley sides with slopes of up to 45% situated between the inter-Andean and sub-Andean ecologies at altitudes ranging from 2400–3800 masl (Uquillas et al., 1992).

Late Blight: Incidence and losses

The main biological factor limiting potato yields in Ecuador is late blight (Crissman et al., 1998b; Programa Nacional de Raíces y Tubérculos-Papa-FORTIPAPA-INIAP, 1996; Uquillas et al., 1992). In extreme climatic conditions, crops can be destroyed within a few days of the appearance of the first symptoms. A crop of temperate climates, the best times for growth are also those of major risk of late blight epidemics. A vast number of small-scale peasant farmers use no inputs whatsoever (fungicides included), due to a lack of financial resources, and heavy losses, including total crop destruction, are common.

The continual presence of epidemics at different stages of development generates high and constant pressure of "lancha" (as late blight is known in Ecuador) to which the crop is exposed immediately after emergence. Late blight of potato owes its name to its appearance at about the same time as flowering in temperate zones, but it certainly is not 'late' in Ecuador. To avoid disease, some farmers, especially in the southern part of the inter-Andean corridor, cultivate potatoes during the dry season. They obtain yields that are lower than the national average due to water deficiency; only 25% of them were able to irrigate in 1993.

General statistics on the economic damage caused by LB (Late Blight) are lacking. Although the moderate to low temperatures slow down the development of epidemics, it is easy to find plots that have been abandoned due to blight during the wet season. Of a sample of 40 plots studied during the 2000 season in the provinces of Chimborazo and Bolivar located in the center of the country, 12 were abandoned because of the disease (Oyarzun et al., 2001). Other estimates of the disease between 1998 (Barrera and Norton, 1998) and 2000 were an incidence of late blight of about 30% with an average of 5% severity. It should be noted that in experiments undertaken 1997–1999 the epidemic could not be controlled once the disease had attained a level of 1% despite repeated fungicide applications. (Andrade Piedra and Revelo, 1997; Jaramillo et al., 1998).

Cost of protection. With the average number of fungicide treatments varying between five and fifteen depending on precipitation and the financial capacities of the farmer (Crissman et al., 1998c), and a total cost of each application (fungicide plus labor and other costs) of 40 USD per hectare, the cost of prevention is 200 to 600 USD. This means that the country imports fungicides costing to 10–25 million dollars per year, or the equivalent of 8 to 20% of the commercial value of the potato production just to control late blight.

Damage/Losses. It has been observed experimentally that improved cultivars such as I-Esperanza and I-Gabriela, with a higher potential yield, have higher yield losses as disease increases than does I-Catalina. The resistance of I-Catalina confers a certain degree of yield tolerance to LB (Andrade Piedra and Revelo, 1997).

Climate in the potato growing region

A large proportion of potato cultivation takes place in the sub-paramo — paramos are natural, high-altitude grasslands — particularly in the wet Andean sub-paramo. Potatoes are also grown in lowland valleys (Cañadas, 1984). The current trend is for movement towards the paramo, itself. In these conditions, diurnal temperature variations are far greater than seasonal variations (Figure 1). Frost is particularly frequent on the flat valley bottoms and on the lower slopes. Farmers try to avoid this problem by planting on the hillsides. For every 100m increment in altitude, the temperature drops by approximately 0.6 °C and the potato crop requires 15 more days to reach commercial maturity (Knapp, 1991). Above 3600 m, the ability of *Phytophthora infestans* to cause epidemics is greatly reduced (Forbes, unpublished results).

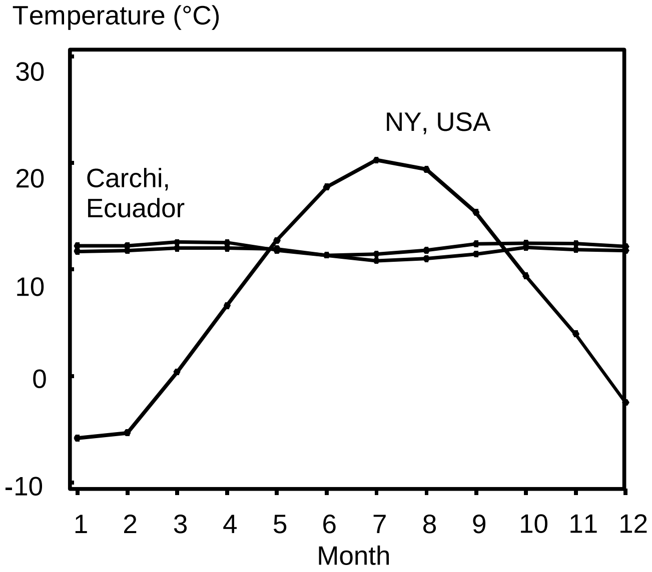


Figure 1. Comparison of the temperatures in an equatorial region with those in a temperate region.

Although several types of climate can be distinguished, the semi-humid to humid meso-thermic climate is predominant in the inter-Andean region, except in sheltered valleys. Annual rainfall varies between 500–2000 mm with a bimodal distribution pattern. Relative humidity varies between 65–85% during the day, with wider variations during the night. The number of sunshine hours ranges from 1000–2000 per year. Average temperatures are between 9–15°C, although the maximum temperatures do not exceed 30°C and the minimum temperatures rarely go below zero. In addition, a cold high mountain climate is always found above an altitude of 3000 m, with mean temperatures of about 10°C, maximums that can reach 20°C and minimums that frequently fall below zero. The rains last for a longer period, but are lighter than at lower altitudes. Relative humidity is generally greater than 80%. The highest elevation where this type of climate is found is the paramo.

Solar radiation in Ecuador is high and relatively constant throughout the year. Clouds can affect up to 50% of the daily sunshine hours (Ducrot et al., 1998). In the past few years there have been several climatic disturbances due to the phenomenon of El Niño – South Oscillation (ENSO). The periods of drier weather have become more erratic in consequence.

The population of *Phytophthora infestans* in Ecuador

The discovery in 1993 that a new population of *P.infestans* had been introduced into Ecuador stimulated a renewed interest in the study of this plant pathogen (Escobar, 1994; Forbes et al., 1997; Programa Nacional de Raíces y Tubérculos-Papa-FORTIPAPA-INIAP, 1996). Since then, the population structure of this pathogen has been the object of several studies. The first concerned the possible epidemiological relations between attacks on tomato (*Solanum esculentum*) and potato, two crops that are widely cultivated throughout the country. On the basis of genetical markers (RFLP, alloenzymes, and mitochondrial haplotype), aggressiveness on both hosts and compatibility type, several differences were brought to light (Oyarzun et al., 1998). All the isolates obtained from potato epidemics in 1995 corresponded to a single genotype (clonal lineage), called EC-1. This lineage is typical of the populations of *P.infestans* encountered in Ecuador and Colombia (Forbes et al., 1997). All isolates from tomato, excepting one obtained from a fruit lesion, corresponded to the genotype denominated US-1, the genotype responsible for epidemics around the world since the 18th century, now called the 'old' population. During 1999, isolates of *P.infestans* were collected from 100 potato fields spanning the length of Ecuadorian Highlands. All were EC-1.

Research into virulence on differential varieties of potato and tomato demonstrated that isolates of *P.infestans* that were apparently identical based on race characteristics on potato differentials, presented different avirulence genes on tomato differentials. Isolates from potato tested on potato differentials had complex virulence, whereas simple virulence was revealed on tomato differentials. With isolates from tomato the opposite was found. Several isolates from tomato did not attack any of the potato differentials (Table 1). In addition, isolates that formed sporulating lesions on both hosts were more aggressive on their original host. These findings support the conclusion that in Ecuador the epidemics on tomato and potato are caused by two physiologically different populations (Oyarzun et al., 1998).

Table 1. Virulence of isolates of *Phytophthora infestans* from tomato or potato and inoculated onto both hosts.

Isolates from potato			Isolates from tomato		
Race determined on potato differentials [a]	**Race determined on tomato differentials[b]**	**N° of isolates**	**Race determined on potato differentials**	**Race determined on tomato differentials**	**N° of isolates**
0,1,3,4,7,8,10,11	0,1	23	0,3,7	0,1,2,3	15
0,1,3,4,7,8,10,11	0,1,3	11	0,3	0,1,2,3	12
0,1,3,4,7,8,10,11	0	8	0	0,1,2,3	8
0,1,3,4,7,10,11	0,3	3	0,2,3	0,1,2,3	6
0,1,2,3,4,6,7,10,11	0,1	2	NI	0,1,2,3	5
0,1,2,3,4,6,7,8,10,11	0,3	2	3	0,1,2,3	3
0,1,3,4,7,8,11	NI	1	0,2,3,7	0,1,2,3	2
0,1,3,4,7,8,11	0	1	NI	2	1
0,1,3,4,7,8,11	0,3	1	NI	0,1,2	1
0,1,3,4,7,11	0,1	1	0,4	0,1,2,3	1
0,1,3,4,7,10,11	0	1	0,11	0,1,2,3	1
0,1,3,4,7,8,10,11	NI	1	0,3,7	0,1,2,3	1
0,1,3,4,6,7,10,11	0,1	1	0,10,11	0,1,3	1
0,1,2,3,4,6,7,10,11	0,1,3	1	0,1,3,7	0,1,3	1
0,1,2,3,4,6,7,8,10,11	0	1	0,1,3,7	0,1,2,3	1
0,1,2,3,4,6,7,8,9,10,11	0,3	1	0,1,3,4,7,8,10,11*	0,3	1
0,1,2,3,4,6,7,8,9,10,11	0,1,3	1			

[a] Numbers representing major genes that were overcome by this race, NI = No infection on any differential. The tomato race marked with an asterisk is the isolate no. 1916, which is clonal lineage EC-1 (potato lineage).

[b] Numbers represent 4 tomato cultivars: 0 = FMX-93, 1 = Pieralbo, 2 = New Yorker y 3 = Pieraline. New Yorker has the major gene for resistance Ph1, and Pieraline has Ph2. FMX-93 and Pieralbo were not thought to possess major genes for resistance Ph at the start of this study.

Source: Oyarzun, P. J., Pozo, A., Ordonez, M. E., Doucett, K. and Forbes, G. A., 1998.

Over a hundred wild and/or cultivated species of Solanaceae grow in Ecuador. Many of these present foliar lesions, which are similar to those caused by *P.infestans*. When further study was undertaken on these, a population of compatibility type A2 was found on the species *S. tetrapetalum* and *S. brevifolium* (Oyarzun et al., 1998). This population is distinct for several genetic markers, and is known at present as EC-2. Another genotype, EC-3 has been described recently on *S. betaceum* (Table 2). The discovery of these *Phytophthora* populations has provided additional stimulus for the study of the phylogeny of the pathogen, its ecology and adaptation (Erselius et al., 1999).

<u>Sexual compatibility.</u> Excluding a few self-fertile isolates, the A2 compatibility type has not been found on potato. Beside paired culture of isolates in vitro to determine their compatibility type, hundreds of leaves with two lesions have been examined, and to date none have contained oospores.

<u>Tuber infections.</u> In general the frequency of tuber infection is very low in Ecuador (Garzón, 1998). Tubers do not appear to be an important source of inoculum. Ten percent of the samples of seed potatoes examined in 1998 in Carchi, province on the northern border with Columbia, had latent *P.infestans* infections, but this appears to be an exception (Bulletin CRSP 2000). Soil suppressivity, probably due to high aluminum content and low pH, and high hilling practices that cover the developing tubers have been proposed as explanations of this phenomenon (Garzón, 1998).

Table 2. *Phytophthora infestans* lineages found in Ecuador and host species from which they were isolated.

Clonal Lineage	Gpi[a]	Pep[a]	MtDNA[a]	Hosts
US-1	86/100	92/100	IB	Tomato, *S. muricatum, S. caripense, S. ochrantum, S. andreanum*
EC-1	90/100	96/100	IIA	Potato, *S. colombianum, S. tuquerrense, S. andreanum, S. ochrantum, S. phureja, S.spp.*
EC-2	100/100	76/100	New	Potato[b] *S. phureja* [b], *S. brevifolium, S. tetrapetalum*
EC-3	86/100	76/100	IA	*S. betaceum*

[a] Gpi = Glucose-6-phosphate isomerase, Pep = Peptidase, mtDNA = mitochondrial DNA.
[b] Only one isolate of this genotype found on this host.
Source: Erselius, L. J., Hohl, H. R., Ordoñez, M. E., Jarrín, F., Velasco, A., Ramon, M. P. y Forbes, G. A. 1999.

Resistance and Breeding

Over the last 30 years there have been several changes in the composition of cultivars grown in the country (Table 3). Up to the mid-twentieth century the vast majority of cultivars grown belonged to the *S. andigena* group, selected by farmers over centuries. They were late or very late cultivars adapted to short days, hardy and extremely susceptible to *Phytophthora infestans* (Turkensteen, 1993). In the 1960s new cultivars that were produced by INIAP or private individuals were introduced. During 1966–1986, seven of these steadily increased in production, gaining prominence across the country. Around 1990, the FORTIPAPA project gave a new impetus to potato breeding, and five cultivars were released in 1995 (Programa Nacional de Raíces y Tubérculos-Papa-FORTIPAPA-INIAP, 1996), and three more in 2000 (Table 4). Some of these gained increasing popularity in the regions during 1990–2000, although an official estimation of the total area planted to them has not yet been made.

Table 3. Potato cultivars in Ecuador grown at different periods.

Before 1966	1966-1983	1990-1995	1996-2000
Uvilla	Violeta	I-Fripapa (1995) (1995)	I-Raymipapa
Bolona	Superchola	I-Margarita (1995)	I-Suprema
Jubaleña	450	I-Rosita (1995)	I-Papa Pan
Chola	I-Santa Catalina (1966)	I-Santa Isabela (1995)	Ecopapa Shayari
	I-Cecilia (1976)	I-Soledad Cañari	
	I-Maria (1980)	Ormus (1995?)	
	I-Esperanza (1983)	Crespa (1995?)	

Source: Forbes, G. 2000 (Personal communication).

Table 4. Cultivars with major gene resistance released in the past five years, their earliness and present level of resistance. Ecuador 2001.

Cultivar	Released (year)	Earliness (days)	LB resistance
I-Fripapa	1995	120/180	Resistant
I-Margarita	1995	120/150	Resistant
I-Rosita	1995	180/210	Susceptible
I-Sta Isabela	1995	180/210	Susceptible
I-Soledad Cañari	1998	180/210	Susceptible
I-Raymipapa	2000	120/150	Resistant
I-Suprema	2000	120/150	Resistant
I-Papa Pan	2000	120/150	Resistant

The relative frequencies of different cultivars have changed substantially since 1966, when native cultivars were very important. Ever since improved cultivars were first introduced during 1966–1983, they have been increasingly planted and today represent most of the area planted to potato (Figure 2). Most cultivars released until now were selected for resistance based on one or more major genes. The National Potato Breeding Program is now aiming at producing new cultivars with a good level of durable resistance based on minor genes. New genotypes under selection come from the "B" population of the International Potato Center. These have few major genes, which makes it easier to select for durable resistance.

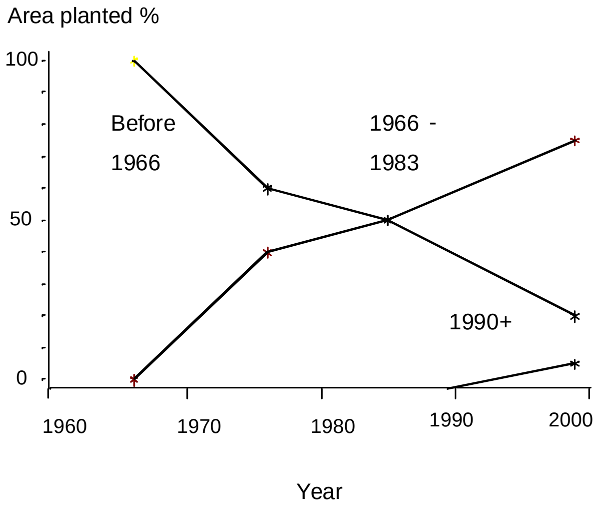


Figure 2. Percentage of the area planted to cultivars of different origin in different periods**.**

Using a participatory approach to plant breeding, a network of farmers, technicians and consumers to evaluate clones has been established. This has accelerated considerably the work of assessment and there are about ten clones with general late blight resistance and good quality, both for fresh consumption and processing (Figure 3).

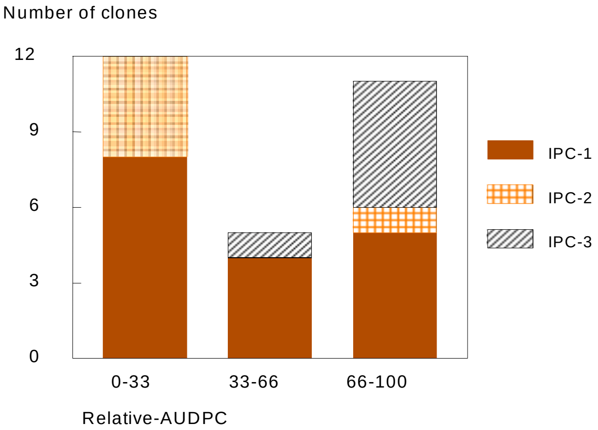


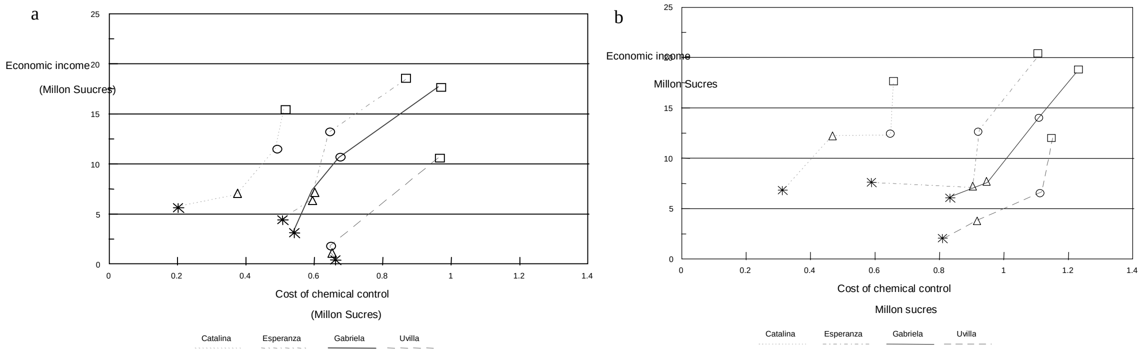
Figure 3. Relative level of infection (AUDPC, area under the disease process curve) of advanced clones, selected during three cycles of participatory research compared to the moderately resistant clone I-Catalina. Relative AUDPC calculated with I-Catalina as 100%.

Resistance in native clones. The level of quantitative resistance in the germplasm banks of *S.tuberosum* today does not appear sufficient to enable a significant reduction in fungicide use in the future (Turkensteen, 1993). The development of new improved tetraploid cultivars aimed at commercial production has caused farmers to abandon growing native species. *Solanaum phureja* is one of these native diploid species, which has been grown for a very long time on the humid lower valley slopes throughout the Ecuadorian and Colombian mountains. This species is known to be a reservoir of genetic variation for many characteristics such as earliness, quality and resistance to many potato diseases. It also has a short growth cycle that enables breeding and selection to progress rapidly, giving it clear advantages over the late *S. andigena* cultivars. Many *Solanum* species have been described recently as hosts of *P.infestans*; and the resistance shown by *S.phureja* to *P. infestans* is well established (Cañizares and Forbes, 1995). This source of resistance has recently been included in the National Breeding Program.

Chemical control of LB in Ecuador

For several decades fungicides have been the principal means of controlling LB in Ecuador. In the past decade, several studies have been undertaken on different fungicides and spraying regimes. Losses due to the disease and economic losses have been determined for cultivars with different types of resistance, as well as the efficacy and space-temporal dynamics of the most effective fungicides.

The study of two control strategies (only protectants and alternate applications of protectants and systemics) in resistant and susceptible cultivars (Catalina and Uvilla, respectively) demonstrated that a strategy based on the use of both protectants and systemics results in better yields and profits (Figure 4). The analysis suggests that the control provided by alternating protectants and systemics is improved when combined with genetic resistance (Andrade Piedra y Revelo, 1997).



□ = 0% ; ○ = 5% ; △ = 10% y ✳ = 20 % of the leaf area infected.

Figure 4. Economic yield and chemical control costs (in millions of sucres) of potato cultivars with different levels of resistance; "a" application of protectant fungicides only; "b" with alternate applications of protectants and systemics. EESC, 1997.

Within a range of 2 to 4% infection, there is no evidence that significant crop losses are caused. With higher infection incidence, losses in the order of 1.1 t/ha are incurred for each 1% increment of the leaf area infected. The action threshold for susceptible cultivars in rainy conditions is 0% of the leaf surface infected (Andrade Piedra and Revelo, 1997; Jaramillo et al., 1998). As a result, a disease management strategy has been worked out based on preventive applications backed up by interspersed applications of systemics (Jaramillo et al., 1998).

Efficiency Assessment. The most effective preventive fungicides tested were triphenyl tin acetate, chlorothalonil, mancozeb, and propineb. The best systemics were phosetyl-Al, cymoxanil, oxadicyl and metalaxyl. The lower efficiency shown by the phenylamides (metalaxyl, ofurace, benaxyl and oxadicyl) (Figure 5) in these studies could be due to the presence of P.infestans races resistant to metalaxyl (Andrade Piedra et al., 1997). Among the fungicides recently introduced onto the national market, the systemics are most efficient, these being: dimetomorph, propamocarb and azoxistrobin, providing better control than the fungicides conventionally used in the country (Taipe et al., 2000).

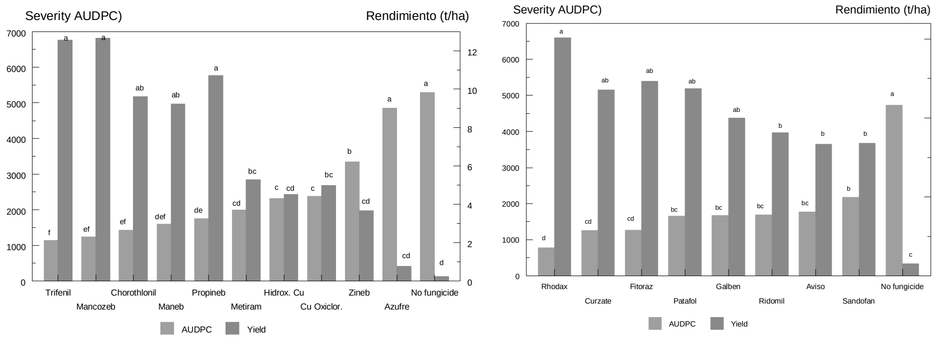


Figure 5. Efficacy of preventive and systemic fungicides in controlling LB on susceptible cultivars (AUDPC) and corresponding yields. EESC, Ecuador, 1997**.**

Fungicide Persistence. The temporal dynamics of fungicide efficacy in controlling LB was determined as the time during which the fungicide significantly inhibited infection. A group of protectants and systemics were tested. A narrow range of persistence was found among the protectant fungicides, from 5.8 days with tin triphenyl acetate to 6.6 days for Mancozeb. The persistence of systemic fungicides ranged from 2.8 days for phosetyl-Al to 7.7 days for cimoxanyl (Taipe, 1999). Recent studies of protectant fungicides found the range in persistence as 5.1 days and 7.2 days for tin triphenyl acetate and chlorothalonil, respectively (Calero, 2000).

Integrated Disease Management of Late Blight

Fungicides are very expensive in Ecuador and this leads to inefficient use. Apart from the economic cost that fungicide use implies, the incorrect use of fungicides directly affects the health of the farmer and his environment (Crissman et al., 1998a).

The lack of seasonality means that the IPM-Late Blight (Integrated Pest Management of Late Blight) programs must be based on integrating ways to reduce the rate of epidemic development. The strategy used recognizes the need for genetic resistance and for applications adapted to climatic conditions (Table 5). However, recent experiments indicate that this is not efficient enough and other parameters, the quantity and intensity of rainfall, are being incorporated as decision-making criteria.

Table 5. Reaction of potato cultivars to LB attack and recommended planting conditions**.**

Rainy season or in zones of high LB pressure		**Dry season or in zones of lower LB pressure**	
Cultivars that remain healthy (Highly resistant)	**Cultivars with little disease (Resistant)**	**Cultivars that are easliy infected (Susceptible)**	**Cultivars that are very easily infected (Highly susceptible)**
I-Fripapa	I-Catalina	I-María	Superchola
I-Margarita	Suscaleña	I-Esperanza	I-Gabriela
I-Rosita			I-Santa Isabela
I-Soledad Cañari			Bolona
			Uvilla
			Carrizo
			Cecilia
			Yema de huevo
			Capiro

Source: Revelo J., Andrade Piedra J. and Garcés S., 1995.

Limitations to the IPM-Late Blight. The implementation of IPM–Late Blight in Ecuador is particularly difficult due to the socio-economic structure of production. First, much of the crop is produced on smallholdings with scattered, small fields. Second, a single farmer may have plots in locations that have very different characteristics.

Table 6. Some of the fungicide mixtures and quantities per 200 liters water used by farmers. Carchi province, Ecuador. August, 1998.

Vegetative stage		**Flowering**		**Maturation**	
Product	**Quantity**	**Product**	**Quantity**	**Product**	**Quantity**
Mixture 1:		**Mixture 1:**		**Mixture 1:**	
Dithane	1 kg	Manzate	1 kg	Manzate	1 kg
Fitoraz	0.5 kg	Curatane	0.5 kg	Curatane	0.5 kg
Brestanid	40 cc	Brestanid	40 cc	Sandofan	0.15 kg
Fijador	100 cc	Cosan	0.25 kg	Cosan	0.5 kg
Mixture 2:		**Mixture 2:**		**Mixture 2:**	
Manzate	1 kg	Triziman-D	1 kg	Triziman-D	1 kg
Curatane	0.5 kg	Curatane	0.5 kg	Curatane	1 kg
		Sandofan	0.25 kg	Ridomil	0.25 kg
Mixture 3:		**Mixture 3:**		**Mixture 3:**	
Dithane	1.5 kg	Manzate	1.5 kg	Dithane	1.5 kg
Curatane	0.5 kg	Curatane	0.5 kg	Cosan	0.5 kg
Cosan	0.25 kg	Brestan	0.25 kg	Ridomil	0.1 kg
Stimufol	0.5 kg	Decis	250 cc	Furadan	250 cc
Decis	250 cc	Vitafol	250 cc		
Mixture 4:		**Mixture 4:**		**Mixture 4:**	
Dithane	1 kg	Dithane	1 kg	Dithane	1 kg
Brestan	0.1 kg	Curatane	0.5 kg	Fitoraz	0.5 kg
Cosan	0.5 kg	Cosan	0.5 kg	Sulfur	0.5 kg
Mixture 5:		**Mixture 5:**		**Mixture 5:**	
Dithane	1 kg	Fitoraz	0.25 kg	Manzate	1 kg
Curatane	0.5 kg	Manzate	1 kg	Curzate	0.5 kg
Cosan	0.5 kg			Cosan	0.5 kg
Ridomil	0.1 kg			Cobre	0.5 kg
Mixture 6:		**Mixture 6:**		**Mixture 6:**	
Dithane	1 kg	Manzate	1 kg	Dithane	1 kg
Curatane	1 kg	Curatane	1 kg	Fitoraz	0.5 kg
Monitor	250 cc	Ridomil	0.1 kg	Furadan	100 cc
Cosán	0.5 kg	Eviset	1 kg	Foliar	0.5 kg
Mixture 7:		**Mixture 7:**		**Mixture 7:**	
Triziman-D	1 kg	Dithane	1 kg	Curatane	0.25 kg
Curatane	0.5 kg	Curzate	0.25 kg	Dithane	1 kg
Ridomil	0.1 kg	Sandofan	0.25 kg	Cosan	1 kg
				Ridomil	0.1 kg

Source: Barrera V. and Norton G., 1998.

This complicates considerably the logistics and the use of objective criteria for decision-making for fungicide applications. The farmer does not intend to manage the disease, but rather to cure the crop of every damaging factor. For this reason, he mixes fungicides, insecticides and any fertilizers in a single operation (Table 6). Another relevant point is the farmers' poor level of technical knowledge about plant pathology. The main source of technical assistance available to farmers is the agrochemical supply houses, which are generally run by people with no scientific training (Barrera and Norton, 1998).

Institutions. Various programs and international institutions are involved in breeding. Links with private companies to develop blight-resistant clones with good processing qualities should be mentioned. The INCO-PAPA project has generated ways of transfering resistance from wild species in several Andean countries, including Ecuador. The Participatory Plant Breeding Program and Gender Analysis are contributing methods for incorporating improvement criteria outside the technical sphere. The International Potato Center has made an important contribution to the group of late blight-resistant cultivars grown in the country.

Organization. The implementation of the IPM-Late Blight in Ecuador depends on the collaboration of scientific, public and commercial institutions and the producers' organizations. The way ahead for IPM-Late Blight may be through the potato production and processing chain and regional forums on IPM-Late BLight. With all the stakeholders working together the small-scale farmer can be brought to a more objective understanding of LB and its management.

Literature cited

Andrade, H. y Oyarzun, P. 1999. Programa Nacional de Raíces y Tubérculos Rubro Papa: Plan Estratégico. Programa Nacional de Raíces y Tubérculos-Papa-INIAP, Quito, Ecuador.

Andrade Piedra, J., Jaramillo, R. y Revelo, J. 1997 Evaluación de la eficiencia de fungicidas protectantes y sistémicos y su interacción con el fertilizante foliar Stimufol, en el control de *Phytophthora infestans* en papa. Informe Ampliado. INIAP, PNRT-Papa-FORTIPAPA.

Andrade Piedra, J. y Revelo, J. 1997. Determinación preliminar de umbrales de daño de *Phytophthora infestans* en cuatro cultivares de papa con diferente tipo de resistencia. Informe Ampliado. INIAP, PNRT-Papa-FORTIPAPA.

Barrera, V. y Norton, G. 1998. Manejo de las principales plagas y enfermedades de la papa por los agricultores en la provincia del Carchi, Ecuador. Informe Final de Proyecto. INIAP-Proyecto IPM-CRSP Virginia Tech.

Calero, D. L. 2000. Dinámica de la eficiencia de cinco fungicidas protectantes para el control de *Phytophthora infestans* en dos cultivares de papa. Tesis Ing. Agr., Universidad Central del Ecuador, Quito-Ecuador.

Cañadas, L. 1984. Mapa Bioclimático y Agroecológico del Ecuador, Quito.

Cañizares, C. A., and Forbes, G. A. 1995. Foliage resistance to *Phytophthora infestans* (Mont.) de Bary in the Ecuadorian national collection of Solanum phureja ssp phureja Juz & Buk. Potato Research 38:3–10.

Crissman, C., Cole, D. y Carpio, F. 1998a. Pesticide use and farm worker health in Ecuadorian potato production. pp. 593–597 in: Crissman C., Antle J. and Capalbo, S. (eds.), Economic, environmental, and health tradeoffs in agriculture: Pesticides and the sustainability of Andean potato production. Kluwer Academic Publishers in cooperation with the International Potato Center, Massachusetts, USA..

Crissman, C., Espinosa, P., Ducrot, C., Cole, D., and Carpio, F. 1998b. The case study site: the physical, health and potato farming systems in Carchi province. pp. 85–117 in: Crissman C., Antle J. and Capalbo, S. (eds.), Economic, environmental, and health tradeoffs in agriculture: Pesticides and the sustainability of Andean potato production. Kluwer Academic Publishers in cooperation with the International Potato Center, Massachusetts, USA.

Crissman, C. C., Antle, J. M., and Capalbo, S. M., (eds.). 1998c.Economic, environmental and health tradeoffs in agriculture: Pesticides and sustainability of Andean potato production. Kluwer Academic Publishers in cooperation with the International Potato Center, Massachusetts, USA.

Ducrot, C., Hutson, J. y Wagenet, R. 1998. Describing pesticide movement in potato production on Carchi Soils. pp. 181–207 in: Crissman, C. C. Antle J. M. and Capalbo, S. M. (eds.), Economic, environmental and health tradeoffs in agriculture: Pesticides and sustainability of Andean potato production. Kluwer Academic Publishers in cooperation with the International Potato Center, Massachusetts, USA.

Erselius, L. J., Hohl, H. R., Ordoñez, M. E., Jarrín, F., Velasco, A., Ramon, M. P. y Forbes, G. A. 1999. Genetic diversity among isolates of *Phytophthora infestans* from various hosts in Ecuador. pp. 39—48 in: Impact on a Changing World. Program Report 1997–1998. Intenational Potato Center, Lima, Peru.

Escobar, M. 1994. Estudio de la población de *Phytophthora infestans* en las provincias de Carchi, Chimborazo y Loja. Tesis Ing. Agr., Universidad Central del Ecuador, Quito-Ecuador.

Forbes, G. A., Escobar, X. C., Ayala, C. C., Revelo, J., Ordoñez, M. E., Fry, B. A., Doucett, K. and Fry, W. E. 1997. Population genetic structure of *Phytophthora infestans* in Ecuador. Phytopathology 87: 375–380.

Garzón, C. D. 1998. Supresión de *Phytophthora infestans* (Mont.) de Bary en suelos de seis localidades de la Sierra Ecuatoriana. Tesis Lic. Ciencias Biologicas, Universidad Católica del Ecuador, Quito-Ecuador.

Herrera, M., Carpio, H. y Chávez, G. 1999. Estudio Sobre el Subsector de la Papa en Ecuador, Programa Nacional de Raíces y Tubérculos-Papa, Quito.

Jaramillo, R., Oyarzún, P. y Revelo, J. 1998. Determinación de umbrales de daño en el control químico de *Phytophthora infestans* en cuatro cultivares de papa con diferente tipo de resistencia. Informe Ampliado. INIAP, PNRT-Papa-FORTIPAPA.

Knapp, G. 1991. Andean ecology: Adaptive dynamics in Ecuador. In Dellplain Latin American Studies Series, Vol. No. 27. Westview Press, Boulder, Co.

Oyarzun, P. J., Pozo, A., Ordonez, M. E., Doucett, K., and Forbes, G. A. 1998. Host specificity of *Phytophthora infestans* on tomato and potato in Ecuador. Phytopathology 88:265–271.

Oyarzun,,P.J., Andrade, I., León, D , Ellis, M. y Forbes, G.A. 2001. Screening Potato diseases in Central and South Ecuador. IPM-CRSP Report 2001. INIAP PNRT-Papa. Quito, Ecuador.

Programa Nacional de Raíces y Tubérculos-Papa-FORTIPAPA-INIAP 1996. Informe Anual 1995. Page 68 in: Compendio 1995.

Revelo, J., Andrade Piedra, J. y Garcés, S. 1995. Caracterización de variedades comerciales de papa al ataque de *Phytophthora infestans*: tipo de resistencia, y relación entre la epidemia, el ambiente y el rendimiento. Informe Anual. INIAP, PNRT-Papa-FORTIPAPA, Octubre 1995.

Taipe, A., Chacón, G., Oyarzún, P. y Forbes, G. 2000. Evaluación de la eficiencia de nuevos fungicidas protectantes y sistémicos para el control de *Phytophthora infestans*. Informe Ampliado. INIAP, PNRT-Papa-FORTIPAPA.

Taipe, J. A. 1999. Estudio de la persistencia de fungicidas protectantes y sistémicos para el control de *Phytophthora infestans* (Mont.) de Bary en papa. Tesis Ing. Agr., Universidad Central del Ecuador, Quito-Ecuador.

Turkensteen, L. J. 1993. Durable resistance of potatoes against *Phytophthora infestans*. pp. 115–124 in: Jocobs, T. and Parlevliet, J. E. (eds.), Durability of Disease Resistance. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Uquillas, J., Crissman, C., Warren, P. y Dewalt, K. 1992. La papa en los sistemas de producción agropecuaria de la sierra ecuatoriana. Documento Técnico N° 2.