

Levels of Resistance to Late Blight Available in Latin America

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Abstract

Potato late blight is a disease where the most common practice for disease control is fungicide use. When applications are excessive, damage to the environment may occur. Genetic breeding is one of the fundamental tools in disease management and the one with the least negative impact on the environment. A broad genetic variability exists in Latin American breeding programs and there is a good degree of utilization. As a consequence, advanced materials and cultivars exist that permit the prediction of a drastic reduction in the use of fungicides once these materials are adopted by farmers. It can be assured that in the not too distant future — five years — adapted materials with good commercial and culinary, as well as resistance to late blight characteristics will be available and in a solid process of dissemination among growers. These materials will be a fundamental component for the integrated management of late blight.

Resumen

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El tizón tardío de la papa es una de esas enfermedades en que el uso de fungicidas constituye la práctica más utilizada para su control. Esta puede ser dañina al medio ambiente cuando se realizan aplicaciones excesivas de fungicidas. El mejoramiento genético es una de las herramientas fundamentales en el manejo integrado de plagas y quizás la que menos “externalidades” negativas tiene, considerando principalmente su impacto ambiental. En los programas de mejoramiento de América Latina existe una amplia variabilidad genética la que se encuentra en buen grado de utilización. Como consecuencia de ello, existen materiales avanzados y cultivares que permiten prever una drástica reducción del uso de fungicidas una vez adoptados por los productores. Se puede asegurar que en un plazo no muy lejano — cinco años —, se dispondrá de materiales adaptados, con buenas características culinarias y comerciales y resistentes al tizón tardío en franco proceso de difusión entre los productores. Dichos materiales serán un componente fundamental en el manejo integrado de esta enfermedad.

Introduction

Late blight of potato is one of those diseases for which fungicide treatment constitutes the main control practice. If this disease is not treated in time, its effects can be devastating, but it can also be damaging to the environment if excessive fungicide is applied to control it. New variants of the pathogen, *Phytophthora infestans*, are spreading in developing countries and it is clear that if no action is taken there will be a dramatic increase in fungicide use and even stronger chemicals will be developed. Both these effects imply serious consequences for the environment, farmer's health and production costs. The late blight problem is more acute in countries where high humidity and poverty limit the farmers' capacities to respond even to the older variants of the pathogen. The rapid spread of new more aggressive and fungicide resistant variants of the pathogen has resulted in this disease becoming the most costly limiting biotic factor in global food production (Collins et al., 1999).

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Plant breeding is a fundamental tool of Integrated Pest Management and perhaps the one with the least negative impact on the environment. Products of plant breeding aimed at reducing pest damage lead to decreased pesticide use, and therefore reduce environmental contamination and its effect on people.

For plant breeding to fulfill its mission of providing cultivars that require less fungicide, it must be carried out in an integral manner, i.e. starting from the design and execution of the initial crosses and continuing right up to the production of seed of the most promising materials. If for economic reasons it is impossible to carry out the whole process in one place, programs must turn to reliable sources of materials. Costs of diverse nature can be accrued (according to activity: crosses, transplanting, selection and evaluation; or cultivar released or obtained, or plantlet produced; etc) and the impact of these costs on the efficiency of the process varies from country to country. This is where each national breeding program must decide whether it should carry out all, or only some of the stages of the breeding program, including ploidy manipulation and marker assisted selection to ensure that that a large number of genotypes will be submitted for selection each year. Given the polygenic nature of the character and the variability inherent to autotetraploidy, large populations are necessary.

Situation of the plant breeding programs in Latin America

Given the complexity of the activities undertaken and the limits imposed by immense distances and communication difficulties, any attempt at making a panorama of the plant breeding programs of Latin America situation of runs the risk of falling into the trap of oversimplification and misconception.. Nonetheless, the situation can be analyzed from the end point of the breeding process, i.e. by studying the national cultivars released in each country and tracing a deeper analysis back from them.

National cultivars produced by plant breeding programs of varied duration, have been released from the Latin American countries of Argentina, Bolivia, Brazil, Chile, Ecuador, Colombia, Mexico, Peru and Uruguay. Recent programs, such as that in Uruguay, are working alongside long established programs such as those in Argentina and Brazil, not to mention the historical selection undertaken by pre-Colombian Andean communities in Bolivia, Colombia, Ecuador and Peru, countries where governmental and private plant breeding are also longstanding.

Changes in the plant breeding programs in Latin America have been strongly influenced by the action of Cooperative Research and Technology Transfers Programs (PROCIs), such as PROCIPA (CIP [International Potato Center] network in Southern Cone [of South America]), PRECODEPA (CIP network in Central America and the Caribbean) and PRACIPA (CIP network [in the Andean region]). In these networks, the role of the CIP as an enabler, facilitating the exchange of materials present in the country programs, and as a generator of its own worthwhile materials is another factor that has had a profound impact on the successful spread of new cultivars in Latin America.

The creation of improved cultivars in Latin America has taken place in four stages:

1. Prehistoric: traditional, not scientific, only in Andean countries. Substantial exchange between different communities.
2. From the early XX century to the 1980s with the application of Mendelian concepts, independent efforts in some countries such as Argentina, Brazil, Colombia and Mexico. Little exchange between programs. Abundant official national and international resources.
3. The 1980s: implementation of the PROCIS, the action of CIP, much exchange of material and technology, synergism between programs, many varieties released. Resources from multilateral resources highly important.
4. From 1990 onwards: maturity of the programs, advances towards the application of molecular methods to assist selection, concentration on global problems such as late blight, much complementation with seed production programs, many programs self-financing through the implementation of property rights of the breeders. Governmental and international funds scarce.

It can be stated with certainty that searching for durable resistance to late blight is the current principal priority of most, if not all, the breeding programs of Latin America, along with obtaining independent funding due to the scarcity of governmental funding. At the same time, the development of cultivars has become clearly demand-driven, with clear guidelines emerging from the participatory mechanisms put in place by programs like those in Bolivia, Peru, Ecuador and Columbia. In countries where farms are larger, such as in Argentina, Brazil, Chile, Mexico, and Uruguay, cultivar diffusion is more business oriented. Intermediate approaches are found in Colombia and Costa Rica.

Objectives common to all programs include improving yield stability (related to more durable resistance for viruses and late blight) and obtaining specific qualities for processing and an external appearance more appealing to local taste. To achieve these objectives, selection and evaluation procedures have been made more efficient. Certain countries, such as Argentina, have found it necessary to mechanize the breeding program to carry out a selection process that resembles as closely as possible the production environment of the end-user. The same applies to other techniques such as irrigation and fertilization.

It must be emphasized that this last stage of the breeding process has greatly benefited from the widespread use of rapid multiplication techniques — a factor that has considerably helped to disseminate new cultivars in all the countries. In addition, molecular-assisted techniques are being used in selection, for genetic transformation and for the characterization of cultivars, although this is proceeding at a slower pace. Argentina now has a system of characterization based on microsatellites that has been used to detect cultivar mixtures in field seed lots and to establish systems by which pure lines and cultivars can be identified by companies producing prebasic seed. Argentina, Bolivia and Uruguay are working in cooperation with Scotland, the Netherlands and France to develop molecular markers for the identification of QTLs for durable resistance to late blight in a segregating population of *Solanum chacoense* created and evaluated in Argentina (Feingold et al, 2000).

Genetic variability in the breeding programs of Latin America

Genetic variation is quite frequently talked about in various scientific and agro-political circles. It is usually referred to as a global heritage that must be preserved and not eroded. Few people talk about its real use and its practical value, which, without diminishing the importance of its strategic value, should be considered at least as important.

Latin American breeding programs are characterized by the wide use of both native wild species and cultivated species to produce popular local cultivars. Certainly, interspecific hybrids, such as *Solanum x chaucha*, have arisen naturally and are used for direct consumption in several Andean regions. The widespread use of up to six species in the Argentinean program has already been mentioned (Huarte et al., 1993). Micheletto et al. (1999; 2000) studied three wild diploid species from Argentina and found R genes and variability for partial or quantitative resistance (Tables 1 and 2).

Table 1. Compatibility (susceptibility) reactions and frequency of resistant genotypes per species after inoculation with *P. infestans* Race 0 in greenhouse tests.

Species	N° of genotypes	N° of plants tested	N° of resistant genotypes	Frequency of resistant genotypes
<i>S. chacoense</i>	17	35	1	0.06
<i>S. microdontum</i>	4	10	4	1.00
<i>S. commersonii</i>	11	22	4	0.18

Micheletto et al, (1999).

Table 2. Variability within and between species and Duncan's multiple range test for AUDPC (area under disease progress curve) under field conditions in 1996–1997.

Species and controls	Mean squares	Pr > F	Mean	Duncan ¹ Group
Serrana, Bintje ²			1977.49	A
<i>S. commersonii</i>	37171	0.0017	1513.98	B
<i>S. chacoense</i>	3490124	0.0001	723.98	C
<i>S. microdontum</i>	1507517	0.0001	204.60	D

¹ Means with the same letter do not differ significantly.

² Susceptible controls.
Micheletto et al, (1999).

A large group of species has been evaluated in Columbia (Estrada and Ñustez, 2000). Many of the species studied showed high levels of resistance with values between 1 and 3 on the scale used by these authors (Table 3).

Table 3. Species and clones of tuberiferous *Solanum* or of the NRSP-6 project of the USDA – University of Wisconsin and evaluated for resistance to blight in Columbia in 1986.

Species	# of accessions	Level of resistance	Species	# of accessions	Level of resistance
<i>S. acaule</i>	3	3	<i>S. lignicaule</i>	1	3
<i>S. boliviense</i>	1	1	<i>S. megistacrolobum</i>	1	1
<i>S. bulbocastanum</i>	2	1 to 6	<i>S. microdontum</i>	5	3 to 9
<i>S. bukasovii</i>	2	3 to 6	<i>S. morelliforme</i>	2	1
<i>S. cardiophyllum</i>	3	3 to 6	<i>S. pinnatisectum</i>	2	1
<i>S. sanctae rosae</i>	1	3	<i>S. polyadenium</i>	4	1
<i>S. hougasii</i>	1	1	<i>S. iopetalum</i>	2	1
<i>S. jamesii</i>	2	3			

Level of resistance: 1 very high; 3 average; 6 susceptible; 9 very susceptible
Estrada and Ñustez, (2000)

Working with segregating populations better adapted to the local Peruvian conditions, Chavez (unpublished) reported a high level of resistance in material from CIP that were not treated with fungicides during cultivation (Table 4).

Table 4. Families of botanical seed highly resistant to *P. infestans* with frequencies of resistant genotypes of over 90% in two different environments (Comas and Arequipa).

ID No.	Cross	Reaction to Late Blight ¹
1	C95 C-16.1 x TPS-13	VR.**
2	C95 C-16.9 x TPS-13	VR.**
3	C95 C-17.1 x TPS-13	VR.*
4	C95- C-17.6 x TPS-13	VR.***
5	C95 C-48.1 x TPS-13	VR.**
6	C95 C-54.11 x TPS-13	VR..**
7	C95 C-16.9 x TPS-67	VR.***
8	C95 C-17.1 x TPS-67	VR.**
9	C95 C-17.6 x TPS-67	VR.***
10	C95 C-54.9 x TPS-67	VR.**
11	C95 C-16.5 x CCOMPIS	VR.**
12	C95 L-127.4 x TPS-67	VR.**
13	C95 C-16.5 x TPS-13	VR.***
14	TPS-25 x C94H-08.2	VR.**

¹ VR = very resistant, of these *** is the most resistant and * is the least. Chavez (unpublished)

In Bolivia, González et al. (2000) determined the general and specific combining abilities in a diallele cross with eight parents and observed important epistatic effects for the expression of late blight resistance.

These four examples in Argentina, Bolivia, Columbia and Peru confirm that a great amount of variation is available for breeding for durable late blight resistance in Latin America with sources ranging from wild species to *Solanum tuberosum*. We shall now examine how much of this variability has been introduced into commercial cultivars.

Cultivars with late blight resistance in Latin America

The Latin America Linkage Group of the Global Initiative on Late Blight (GILB) met in February 2000 in Havana, Cuba and agreed to make an inventory of the blight resistant cultivars that had been released in the region. The information from several countries is presented in Tables 5 to 7.

The Peruvian material presented in Table 5 by Chavez (unpublished) includes material from CIP and consists of high yielding germplasm with earliness and good cooking qualities in addition to resistance to late blight. Only part of the material available is presented here (some 175 promising clones with more than 10,000 first-year tubers). While the work of CIP should be considered as being international, the program of J. Landeo, CIP Breeder, is based in the Andean region and has been one of the most important contributors of late blight resistant germplasm submitted for selection in Latin American countries (Landeo et al., 2000). Details of these resistant materials are beyond the scope of this report. Likewise, Peru has a network for the evaluation and selection for advanced blight resistant clones (Gonzalez et al., 2000).

Table 5. Peruvian and CIP germplasm with late blight resistance.

A. Commercial cultivars			C. Families of botanical seed for the coastal plains	
N°	Cultivar		1	Achirana X TPS.67
1	Amarilis		2	Atzimba X TPS.13
2	Chaglina		3	HPS.I.67
3	Atahualpa		4	HPS.II.13
4	INIA.301		5	MF.II. X TPS.67
5	Chata Roja		6	C95.16.1 X TPS.67
6	INIA-305		7	C95.16.1 X TPS.13
			8	C95.16.9 X TPS.13
			9	C95.17.1 X TPS.13
			10	C95.17.6 X TPS.13
			11	C95.28.2 X TPS.67
B. Advanced clones			D. Other clones	
From the program of Juan Landeo (CIP)			From the CIP Genetic resources department	
N°	Clone	Population		
1	384298.56	A	1	C91.640
2	385524.9	A	2	TPS.07
3	386039.17	A	3	TPS.13
4	387096.2	A	4	TPS.25
5	387164.4	B3C0		
6	387170.16	B3C0		
7	389746.2	B3C0		
8	392047.19	A		
9	393079.4	B3C1		
10	385556.44	A		
11	392637.10	B3C1		
12	393280.57	B3C1		
13	391580.30	B3C1		
14	393073.197	B3C1		
15	393073.179	B3C1		

(R. Chavez, unpublished)

Nineteen cultivars with good late blight resistance from six Latin American countries are presented in Table 6. In Argentina, Pampeana INTA showed high resistance and no evidence of possessing major genes.

However, possibly due to the absence of R genes, it was not one of the most highly resistant varieties in SIFT (Standard International Field Trials). In collaboration with CIP, 23 advanced clones have been obtained (Population B3), which are available for international distribution. These clones have been crossed with virus resistant progenitors without major resistance genes that are adapted to long days (Serrana INTA and Pampeana INTA), producing about 3500 clones at the first stage of selection with artificial infection in the field over two clonal generations.

The value of the Ecuadorian Potato Collection from which six clones are available after participatory selection with the producers should also be emphasized (Cuesta et al., 2000).

Table 6. Cultivars with high resistance to late blight in six Latin American countries (information source in brackets).

Uruguay –	(F. Vilaró) Iporá	Colombia –	(C. Ñustez) ICA Unica ICA Purace ICA Morita	Brasil –	(A. Buso) Chiquita Mantiqueira Mineira Liza IAC Aracy Ruiva EPAGRI 361 – Catucha
Argentina –	(M. Huarte) Pampeana INTA	Ecuador –	(H. Andrade) INIAP-Fripapa INIAP-Margarita INIAP-Rosita INIAP-Santa-Isabel(a) Santa Catalina		
Bolivia –	(J. Gabriel) Chota Ñawi* Perla* India* Jaspe* Robusta* Cordillera*				

* Highly resistant

Twenty-seven cultivars with varying degrees and types of resistance to late blight are reported for Mexico (Table 7). These cultivars are very valuable considering where the selection took place and the antiquity of many of them. The contributors consider seven of these cultivars as highly resistant: Rosita (Sangema), San José, Norteña, Modesta Blanca, Zafiro, Malinche and Montserrat. PICTIPAPA (International Cooperative Program for Potato Late Blight) report that 853 clones in nine families have been evaluated in the program run by D. Corsini (USA), among which the family J103-K7 x B0718-3, with four promising clones, is outstanding (Hernández Vilchis and Lozoya Saldaña, 2000). This material is being distributed to producers and institutes in Mexico.

Table 7. Mexican cultivars with late blight resistance.

Mexican cultivars with blight resistance	
Bertita	Mexiquense
Greta	Puebla
Conchita	Tollocan
Elenita	Michoacán
Erendira	Marciana
Dorita	Rosita (Sangema)*
Florita	San José *
Gabriela	Ileri Norteña *
Montsama	Montserrat *
Murca	Lupita
Anita	Zafiro*
Juanita	Malinche*
Atzimba	Modesta Blanca*

Highly resistant
Flores F. and Rubio O., (personal communication)

Genotype x Environment interactions and late blight resistance

Genotype x Environment interactions (G x E) for late blight resistance have not yet been fully studied. The global study undertaken by several institutes and reported on by Forbes and Tolstrup (1999) suggests that there is an interaction, but that it is no greater than the variation due to genotype and locality.

Studies on 12 segregating families from CIP Population B appear to indicate important interactions between genotypes and environments with different day lengths (Table 8) (Huarte, 1999).

For a long time other programs have been directing their efforts towards producing cultivars with high levels of horizontal resistance to late blight adapted to tuberize in conditions of long days and high disease pressure. They have not been exempt from problems. More so, when one considers that many available sources of resistance, including those generated by CIP, are very late varieties for the conditions of the MERCOSUR (Argentina Chile, Paraguay and Uruguay) countries. The study of possible linkage or pleiotropy between these characters is of utmost importance for the management of the G x E interaction and for improving selection efficiency. Similarly, if the new cultivars are to be widely adopted, it is imperative that blight resistance be combined with other characters of economic interest, such as virus resistance and cooking quality. This is the aim of the FONTAGRO (Regional Fund for Agricultural Technology) Project between FONAIAP (Venezuela), FORTIPAPA (Ecuador), INIA (Peru), INIFAP (Mexico), INTA (Argentina), University National de Colombia and CORPOICA (Colombia), IBTA (Bolivia) and CIP.

Table 8: Mean AUDPC values and relative order of B3 population progenies in 1995 for blight resistance in Balcarce (Argentina), Rionegro (Colombia) and Toluca (Mexico).

Progeny	AUDPC*			Order		
	Mexico	Colombia	Argentina	Mexico	Colombia	Argentina
391585	490	557	180	22	3	1
393312	436	1026	266	20	16	2
393464	675	1233	269	40	34	3
393468	783	1211	319	51	32	4
393071	525	1295	389	26	35	15
393235	286	1026	407	4	16	17
393462	1286	1633	459	59	52	26
393380	152	425	473	1	1	30
393460	1276	1585	633	58	48	42
393076	647	1314	779	38	38	49
393466	1272	1564	898	57	47	52
393439	698	1230	1576	43	33	60

* Data for Mexico and Colombia were submitted by J. Landeo and data for Argentina collected by M. van Damme and M. Huarte.

Conclusions

Ample resources of genetic variation are available and being widely used in the plant breeding programs of Latin America. In consequence, advanced materials and clones have been produced that make it possible to contemplate a dramatic reduction fungicide use once they have been adopted by farmers. These materials consist of around 250 promising clones, a high number considering their advanced stage in the selection process.

The existence of both promising materials and great genetic variability underlines the need of directing the use of molecular markers towards more efficient selection and the identification of naturally occurring genes in the species to transform valuable, but susceptible, cultivars.

Finally, the positive effect of collaboration efforts should be emphasized, including the networks of cooperation between countries, as well as collaboration with CIP, and the importance of working together with farmers, which in many cases has assured the spread of these resistant cultivars.

It is clear that in the near future – five years perhaps – adapted materials, with good cooking and commercial qualities combined with resistance to late blight will be available and in the process of being widely

distributed among farmers. Such materials will form a fundamental component in the integrated management of this disease.

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