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RESEARCH PAPER

Crown and root rot of highbush blueberry caused by *Phytophthora cinnamomi* and *P. citrophthora* and cultivar susceptibility

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Abstract

A. Larach, X. Besoain, and E. Salgado. 2009. Crown and root rot of highbush blueberry caused by *Phytophthora cinnamomi* and *P. citrophthora* and cultivar sensitivity. Cien. Inv. Agr. 36(3):433-442. Chile is the largest producer and exporter of blueberries in the southern hemisphere. During the 2006-2007 growing season, blueberry production increased in Chile as a result of an expansion of the planted area, reaching around 10,762 ha in 2007. Fungal diseases are of great importance in blueberry production; among them, *Phytophthora* root rot is a disease known worldwide as a major cause of death for highbush blueberry plants in the USA. Symptoms of *Phytophthora* root rot have been detected over the last four years in Chile. Nevertheless, the causal agents have not been previously described in Chile. This study aims to determine the pathogenicity of *Phytophthora* spp. isolated from highbush blueberry and to study cultivar susceptibility. The pathogenicity tests show that the species *P. cinnamomi* and *P. citrophthora* were the cause of crown and root rot of highbush blueberry. Significant differences in plant height, shoot growth stem diameter, and fresh weights of roots and aerial parts between inoculated and non-inoculated plants were observed. Blueberry cv. 'Toro' was the only cultivar resistant to *P. cinnamomi*, while both 'Elliot' and 'Toro' were resistant to *P. citrophthora.* Regardless of the *Phytophthora* species, cv. 'Biloxi' was the most affected. This is the first report of *Phytophthora* root rot in Chile and, to our knowledge, the first report of *P. citrophthora* affecting blueberry plants worldwide.

Key words: Blueberry diseases, highbush blueberry, blueberry cultivars, *Phytophthora*, *Vaccinium corymbosum*.

Introduction

Most of the countries producing highbush blueberry (*Vaccinium corymbosum* L.) are located in the northern hemisphere, and the USA is the main producer and consumer at world level. Blueberry production has increased in several countries in the southern hemisphere, of which Chile is the main blueberry-producing and -exporting country. Blueberries were introduced around 1979, and the planted blueberry area reached 10,762 ha in 2007 (CORFO, 1993; USDA, 2005; ODEPA, 2007; INE, 2008). In Chile, the main cultivars are 'Elliot', 'Briggitta', 'Duke', 'Bluecrop', 'O'Neal, 'Blue Ray', and 'Berkeley' (ODEPA, 2007).

Phytophthora root rot was observed in blueberry bushes more than 40 years ago (Royle and Hickman, 1963). Previously, Raniere (1961), when studying blueberry plants showing yellowish leaves and early defoliation, roots necrosis, and

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vascular discoloration on the crown and stems, associated *Phytophthora* sp. with this syndrome. However, Royle and Hickman (1963) identified *P. cinnamomi* associated to root rot of highbush blueberry. Recently, the same pathogen was isolated from blueberries in North Carolina, and the obtained isolates of *Phytophthora* were pathogenic in all the highbush blueberry cultivars (Clayton and Haasis, 1964; Milholland and Galleta, 1967). Currently, only *P. cinnamomi* has been described as a very important pathogen causing root rot in highbush blueberry; it has also been reported in Italy (Tamietti, 2003; Brannen *et al*., 2007).

Symptoms include yellowing or reddening leaves, growth cessation, defoliation, marginal leaves necrosis, and death of smaller terminal leaves and canes. Likewise, the root system of an affected bush is small, dark, and necrotic (Royle and Hickman, 1963; Clayton and Haasis, 1964; Milholland and Galleta 1967; Draper *et al*., 1971; Milholland 1975; Sterne, 1982; Clark *et al*., 1986; De Silva *et al*., 1999; Smith, 2002, 2006, 2007; Bryla and Linderman, 2007).

During the past four years, highbush blueberry plants with lower growth, foliar chlorosis, and reddish foliage have been detected and associated with crown and root rot. *Phytophthora* spp. colonies have been consistently recovered from diseased plants. Therefore, the objective of this study is to isolate and identify the causal agent of crown and root rot of blueberry and to evaluate the susceptibility of the main highbush blueberry cultivars currently produced in Chile.

Materials and methods

Phytophthora isolates

Isolates of *Phytophthora* were obtained from roots of highbush blueberry 'Jewel', 'Misty', 'O´Neal', and 'Star' collected in commercial orchards located in Hijuelas and Villa Alemana (Valparaíso Region), Chile. The diseased plants were characterized by dieback, leaf chlorosis, foliage reddening, rootlets rot, and necrotic cortical lesions in the crown. The isolations were performed from roots and crowns washed thoroughly with abundant tap water, after which small pieces (1 cm long) of root and crown tissues from the edges of the necrotic lesions was extracted. Each sample was washed in sterile distilled water (SDW), dried on a sterile paper towel, and left aseptically for 40 min next to a burner. Each sample was plated immediately in MSP agar medium containing 18 g corn meal agar per liter, 10 mg pimaricine, and 100 mL pentachloronitrobenzene (PCNB) (modified medium P_{10}PV, Tsao and Ocana, 1969). Plates were incubated at 24°C for 5 days in darkness. Hyphal tips obtained from colonies tentatively identified as *Phytophthora* spp. were sub-cultivated in MSP. Isolates were maintained in 10 mL SDW in tubes at 15-20ºC.

Additionally, four *Phytophthora* isolates obtained from diseased blueberries in October 2005 were included in this study.

Characterization and identification

Sporangia were obtained from mycelium pieces taken from actively growing colonies that were incubated in sterile carrot juice (500 g carrots boiled for 15 min 1 L SDW) on glass plates under continuous light for 48 h at 24°C. Then, the mycelial colonies were washed with SDW and treated for 3 min at 5°C with saline solution containing 2.36 g $CaNO_3$, 0.5 g KNO_3, and 1.0 g $MgSO_4$ per liter, as well as 1 mL of chelated iron solution (13.0 gL^{-1} EDTA, 7.5 gL^{-1} KOH, and 24.5 gL^{-1} $FeSO_4$). Subsequently, the mycelium was washed with SDW, after which it was incubated in soil extract at 1% w/v for 48 h at 24°C under light. The presence of sporangia was determined under a light microscope. The shape, width, length, length/width ratio, presence or absence of papillae, number of papillae, internal and external proliferations, and caducity or persistence of 30 sporangia per each isolate were determined.

Gametangia were studied in triplicate in single cultures or by pairing each isolate with known

sexual compatibility types A1 or A2 of *P. cinnamomi* in an MSP. Plates were incubated for 30 days at 21°C in darkness. The presence of oogonia and antheridia was determined under a light microscope after 5 days, and the formation of oospores was determined after 30 days of incubation.

The colony morphology and color was determined after incubation for 6 days at 24°C on potato dextrose agar acidulated with 1 mLL^{-1} 1 N lactic acid (APDA). The effect of temperature on the mycelial growth was studied by observing the colony diameter after incubating in MSP at 5, 10, 20, 25, 30, and 35°C for 5 days. Three replicates were used for each temperature.

The identification of *Phytophthora* species was based on the taxonomic keys and on the description of each *Phytophthora* species (Stamps *et al*., 1990; Erwin and Ribeiro, 1996).

Pathogenicity tests

The pathogenicities of eight isolates (Par1 - Par8) identified as *Phytophthora* spp. were studied in 18-month old blueberries. Highbush blueberries cv. 'Misty' were transplanted to 4-L pots with sterile soil substrate (1/3 organic soil and 2/3 pine leaves) and arranged on a 60-cm-high counter in a greenhouse with 24°C mean day temperature. In early winter (July), the soil substrate was infested with 100 mL per pot of a mycelial suspension (10^5 propagules mL^{-1}) obtained from APDA cultures. An equal number of control plants were treated with 100 mL of sterile water. Immediately after inoculation, as well as 30 and 60 days thereafter, all the plants were subjected to a 24-hour soil flooding.

The plants were fertilized weekly with a nutritive solution (nitrogen:phosphorus:potassium,1: 1:1). The soil substrate was maintained at pH 5.7 by adding 0.5 mLL^{-1} of phosphoric acid to an electrical conductivity of 0.6 dS m^{-1}. The irrigation frequency was determined using a 15-cm tensiometer (Irrometer Company, California, USA) located in a control plant. Each plant was irrigated using 200 mL of water when the soil tension reached -0.04 MPa, restoring the soil humidity to field capacity (-0.033 MPa).

The presence of leaf chlorosis and reddening, root rot, and crown rot was recorded after 120 days of the inoculation. Plant height, sprout growth, stem diameter, fresh aerial weight, and root weight were also determined. To reisolate the pathogen from inoculated plants, small pieces of diseased tissues taken from roots and crowns were extracted from each experimental unit and plated in an MSP medium. The re-identification was made on the basis of the sporangia (Stamps *et al*., 1990; Erwin and Ribeiro, 1996).

Susceptibility of blueberries cultivars

The susceptibility of 12-month old blueberries 'Biloxi', 'Bluecrop', 'Brigitta', 'Duke', 'Elliott', 'Misty', 'O´Neal', and 'Toro' to *P. cinnamomi* and *P. citrophthora* was studied. Plants were obtained from *in vitro* propagation and transplanted to 4-L pots containing sterile soil substrate (1/5 organic soil, 2/5 pine leaves, 2/5 sawdust). The test was performed between November and February in a greenhouse with an average day temperature between 20 and 30°C. Isolates Par-3 and Par-6, identified respectively as *P. cinnamomi* and *P. citrophthora*, were used. These *Phytophthora* isolates were the most virulent in pathogenicity tests previously performed. Each plant was inoculated with 100 mL of a mycelial suspension (10^5 propagule mL^{-1}) obtained from isolates on APDA. The control plants were treated with 100 mL of SDW. After the inoculation, all the plants were subjected immediately and after 30 days to 24 h of flooding.

The plants were fertilized as indicated before. Irrigations were performed only to restore the 10% soil humidity and maintained the soil at field capacity.

The symptoms were determined in inoculated plants, and the effect of the inoculations and re-identification of the pathogen were evaluated, as described above, 90 days after inoculation.

Design and statistical analysis

The treatments in the pathogenicity test and cultivar susceptibility were distributed according to a completely randomized design with four and three replicates of one plant each, respectively. The results were analyzed for variance, and means were compared according to Tukey's test ($p = 0.05$).

Results

Isolation and identification

Based on the colony morphology and the morphology of the reproductive structures obtained, *P. cinnamomi* and *P. citrophthora* were identified (Table 1). The identification of the isolation Par-6 was corroborated molecularly by CABI Bioscience (IMI 396018).

Table 1. Isolates of *Phytophthora* spp. obtained from highbush blueberry (*Vaccinium* sp) orchards in the Region of Valparaíso, Chile.

Blueberry cultivars	Source	Locality	Species of *Phytophthora*	Isolates
O´Neal	Roots	Villa Alemana	*P. cinnamomi*	Par-1
Star	Roots	Villa Alemana	*P. cinnamomi*	Par-2
Misty	Roots	Villa Alemana	*P. cinnamomi*	Par-3
Misty	Crown	Villa Alemana	*P. cinnamomi*	Par-4
Misty	Crown	Villa Alemana	*P. cinnamomi*	Par-5
Marimba	Crown	Cabildo	*P. citrophthora*	Par-6
Marimba	Crown	Cabildo	*P. citrophthora*	Par-7
Misty	Roots	Quillota	*P. cinnamomi*	Par-8

The colonies developed by *P. cinnamomi* (isolates Par-1, Par-2, Par-3, Par-4, Par-5, and Par-8) were white in MSP. Mycelial growth was obtained between 20 and 30°C, but optimal temperature for mycelial was 25°C. A white cotton-like colony with a rosette aspect developed in APDA medium (Figure 1a). The mycelium was characterized by the presence of abundant coralloid to botryose hyphal swellings (Figure 1b) and the presence of terminal chlamydospores of 30 µm in diameter. Persistent, ellipsoid to ovoid non-papillate sporangia of 61.2 µm x 37.0 µm on average were obtained in a liquid medium. Sporangia had a length:width ratio of 1.7, and internal proliferations were observed (Figure 1c). Finally, the crossings made with *P. cinnamomi* reference strains (type A1 and A2) evidenced the formation of smooth walls and hyaline oogonia, with an average diameter of 40.5 µm, and oospores were produced in the presence of the compatibility type A1 of *P. cinnamomi.* Therefore, a heterothallic compatibility and the compatibility type A2 were determined. The Antheridia were amphygenous (Figure 1d).

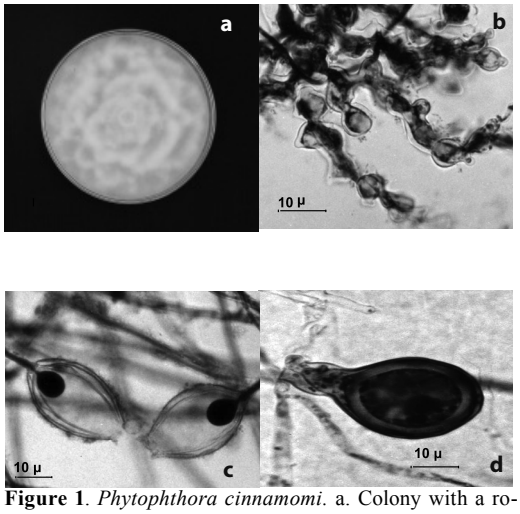

Figure 1. *Phytophthora cinnamomi*. a. Colony with a rosette pattern in APDA media. b. Coraloides hyphae. *c.* Ellipsoids sporangia with internal proliferation. d. Oospore with amphigynous antherium.

P. citrophthora (isolates Par-6 and Par-7) was characterized by the development of white and bare colonies in MSP. Mycelial growth was obtained between 20 and 30°C, but the optimal temperature for mycelial growth was at 25°C. In APDA, the colonies were white and cotton-like (Figure 2a). Hyphal swellings or presence of chlamydospores were not obtained. Papillate and deciduous sporangia were obtained in liquid medium, with a medium peduncle (higher than

20 µm and lower than 50 µm). Sporangia were ovoid (Figure 2b), obpyriform, obturbinate, or distorted (Figure 2c-d), presenting one or two apices, 50.1 µm x 48.0 µm in average, with a length:width ratio of 1.8. No oospores were obtained in single cultures or in cultures that paired each isolate with A1 or A2 of *P. cinnamomi*.

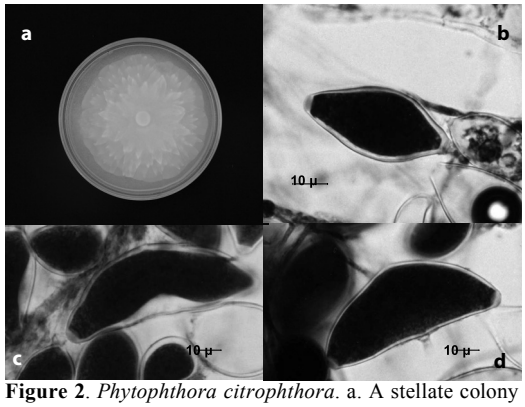

Figure 2. *Phytophthora citrophthora*. a. A stellate colony in APDA media. b. Ovoid papillate sporangium. c-d. Distorted sporangia.

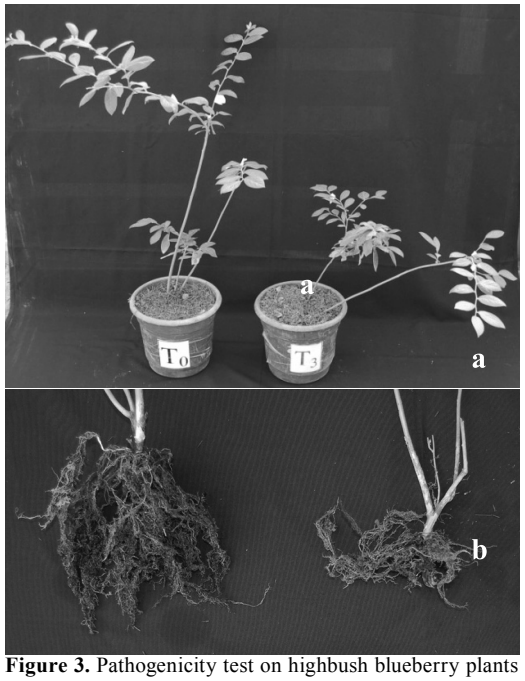

Figure 3. Pathogenicity test on highbush blueberry plants cv. 'Misty'. a. Growth of non-inoculated (left) and inoculated with *Phytophthora cinnamomi* (right). b. Non-inoculated roots (left) and inoculated (right) with *P. cinnamomi*.

Pathogenicity

All the *P. cinnamomi* and *P. citrophthora* isolates caused cortical rot lesions on the crown and root rots. Foliar symptoms consisted of leaf chlorosis and partial reddening of the foliage. A dark brown discoloration of the xylem tissue was observed. The height, shoot growth, diameter of main stem, foliage fresh weight and root fresh weight were significantly lower in plants inoculated with either *P. cinnamomi* or *P. citrophthor*a than in non-inoculated plants. For *P. cinnamomi* and *P. citrophthora,* isolations Par-3 and Par-6, respectively, were the most virulent isolates (Table 2). Isolates of *P. citrophthora* (Par-6 and Par-7) induced the same level of crown damage, while isolates of *P. cinnamomi* varied in symptom expression (Table 2).

P. cinnamomi and *P. citrophthora* were reisolated from inoculated plants. Non-inoculated plants yielded no *Phytophthora* after reisolation.

Cultivar susceptibility

Regardless of the cultivar, the plants inoculated with *P. cinnamomi* and *P. citrophthora* showed vascular discoloration, cortical rot in roots, leaf chlorosis, and foliar reddening. Independently of the species of *Phytophthora*, blueberry cvs. 'Biloxi' and 'Duke' showed the most damage. Non-inoculated plants were without symptoms.

The blueberries 'Biloxi' and 'Elliot' inoculated with *P. cinnamomi* showed a significant decrease in plant height compared to non-inoculated plants. The blueberries 'Biloxi' and 'Bluecrop' showed a significant decrease in the diameter of main stem, cvs. 'Bluecrop', 'Briggita', and 'Duke' had a significantly decreased weight of fresh roots, and cv. 'Duke' showed a significant decrease in fresh aerial weight when compared to non-inoculated plants.

The blueberry cv. 'Biloxi' inoculated with *P. citrophthora* showed a significant decrease in the

Table 2. Pathogenicity of *Phytophthora cinnamomi* and *P. citrophthora* isolates on highbush blueberry plants cv. 'Misty'.

	Averaging effects of the treatments in[1]				
Treatments	Plant height cm	Shoot growth cm	Stem diameter cm	Fresh foliage weight g	Fresh root weight g
Non- inoculated	86.70 a	34.84 a	1.80 a	80,50 a	80.50 a
P. cinnamomi					
Par-1	62.80 bcd	14.23 b	0.85 b	48.70 b	44.30 b
Par-2	70.35 bc	13.97 b	0.84 b	34.30 e	38.39 d
Par-3	49.03 e	11.23 c	0.50 c	29.10 f	29.40 e
Par-4	73.95 b	14.51 b	0.83 b	47.50 b	36.40 d
Par-5	51.55 e	12.97 c	0.83 b	44.50 c	37.13 d
Par-8	67.65 c	11.72 c	0.83 b	36.00 e	40.76 c
P. citrophthora					
Par-6	58.50 de	12.79 c	0.50 c	39.90 d	37.50 d
Par-7	65.13 bc	12.95 c	0.84 b	48.60 b	44.80 b

[1]Means followed by different letters in the same column are significantly different according to Tukey's test ($p < 0.05$).

plant height, and the diameter of the main stems was significantly decreased in the cvs. 'Bluecrop' and 'Briggita'. The weight of fresh foliage was significantly decreased in cvs. 'Biloxi', 'Briggita', and 'Duke', and the fresh root weight decreased significantly in cvs. 'Biloxi', and 'Duke' compared to non-inoculated plants (Table 3).

Phytophthora colonies were reisolated from diseased tissues of inoculated blueberry plants, after which *P. cinnamomi* or *P. citrophthora* were identified. There was no evidence of *Phytophthora* spp. in non-inoculated plants.

Discussion

The morphological features of the *Phytophthora* isolates allowed the identification of *P. cinnamomi* and *P. citrophthora* in Chilean blueberries for the first time.

All isolates of *P. cinnamomi* obtained were heterothallic of compatibility type A2, which is in agreement with works previously reported (Clayton and Haasis, 1964; Sterne, 1982). The *P. citrophthora* isolations were sexually sterile, which is characteristic of most *P. citrophthora* isolates (Stamps *et al.*, 1990; Erwin and Ribeiro, 1996).

All the isolates of *P. cinnamomi* and *P. citrophthora* were found to be pathogenic in highbush blueberry, and the reisolation from diseased tissues was successful, which allowed the fulfillment of Koch's postulates. However, differences in virulence were found among isolates. Similar differences have been reported in blueberries (Milholland, 1975) and other species (Zentmyer, 1980; Dudzinski *et al.,* 1993; Robin and Desprez-Loustau, 1998; Linde *et al*., 1999). Among isolates of *P. cinnamomi* and *P. citrophthora*, Par-3 and Par-6 were the most virulent isolates. The isolates Par-3 and Par-6 showed, respectively, a decrease of 67.8 and 63.3% in stem growth, 39.1 and 32.1% in main stem diameter, 43.4 and 32.5% in plant height, 63.9 and 46.1% in fresh foliage weight, and 36.5 and 53.4% in fresh root weight, compared to non-inoculated control plants.

The symptoms developed by inoculated plants coincide with field symptoms commonly observed under field conditions in Chile, as well as with symptoms described for *Phytophthora* root rot elsewhere (Royle and Hickman, 1963; Clayton and Haasis, 1964; Milholland and Galleta, 1967; Milholland 1975; Erb *et al.,* 1986; Tamietti, 2003; Smith, 2002, 2006, 2007; Bryla and Linderman, 2007). However, crown damage is uncommon and only reported in a few instances (Raniere, 1961; Milholland, 1995; Tamietti, 2003).

Based on the results obtained, blueberry cv. 'Toro' was seen to be highly resistant to *P. cinnamomi,* and the cvs. 'Elliot' and 'Toro' were highly resistant to *P. citrophthora*. However, additional evaluations using zoospores under

Table 3. Cultivar susceptibility assay in highbush blueberry inoculated with *Phytophthora cinnamomi* (Par-3) and *P. citrophthora* (Par-6).

Cultivars	Treatments		
	Non-inoculated	*P. cinnamomi*	*P. citrophthora*
		Plant height[1], cm	
Biloxi	111.00 a	79.67 bc	51.67 def
Bluecrop	82.33 bc	81.67 bc	79.67 bc
Briggita	64.67 bcdef	59.67 cdef	62.33 bcdef
Duke	75.67 bcd	53.67 def	57.00 cdef
Elliot	86.00 ab	48.67 ef	72.67 bcde
Misty	72.33 bcde	61.00 bcdef	69.33 bcdef
O´Neal	75.67 bcd	52.33 def	60.00 cdef
Toro	52.33 def	45.67 f	50.67 def
		Shoot diameter[1], cm	
Biloxi	1.90 abcd	1.23 efg	1.83 abcd
Bluecrop	2.00 abc	1.20 efg	1.30 efg
Briggita	1.57 cdef	1.47 defg	1.10 g
Duke	1.93 abc	1.83 abcd	1.90 abcd
Elliot	2.03 ab	1.83 abcd	1.80 abcd
Misty	1.33 efg	1.13 fg	1.13 fg
O´Neal	2.10 a	2.03 ab	1.97 abc
Toro	1.90 abcd	1.80 abcd	1.93 abc
		Fresh weight of roots[1], g	
Biloxi	91.67 cde	71.33 cdefghi	47.67 fghij
Bluecrop	106.67 cd	50.67 fghij	67.67 defghi
Briggita	256.00 a	155.00 b	195.67 b
Duke	110.67 c	37.00 hij	38.00 hij
Elliot	91.67 cde	52.67 efghij	82.67 cdefg
Misty	42.00 ghij	20.33 j	34.00 ij
O´Neal	110.67 c	76.67 cdefghij	87.00 cdef
Toro	68.67 defghi	40.00 hij	67.00 defghi
		Fresh weight of aerial[1], g	
Biloxi	64.00 ab	56.33 abc	31.00 de
Bluecrop	70.67 a	64.00 ab	71.00 a
Briggita	65.67 a	54.00 abcd	52.33 abcde
Duke	77.00 a	37.33 cde	31.00 de
Elliot	52.67 abcde	33.67 cde	41.00 bcde
Misty	44.00 bcde	28.33 e	36.33 cde
O´Neal	45.33 bcde	33.33 cde	38.33 cde
Toro	33.67 cde	31.00 de	41.00 bcde

[1]Average of three plants per treatment. Means followed by different letters in the row were significant different according to Tukey's test ($p < 0.05$).

field conditions are required before drawing a conclusion about the resistance to *P. cinnamomi* and *P. citrophthora* observed in blueberries.

To the best of our knowledge, only *P. cinnamomi* has been previously reported in highbush blueberry. Therefore, this work represents the first report on *P. citrophthora* as a pathogen in highbush blueberry on a global scale. Previously, *P. citrophthora* has been reported to affect citrus crops (Besoain *et al.,* 1998; Vial *et al*., 2006), raspberry (Latorre and Muñoz, 1993), and kiwi (Latorre *et al.,* 1991) in Chile.

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Resumen

A. Larach, X. Besoain y E. Salgado. 2009. Pudrición del cuello y raíces en arándano alto causado por *Phytophthora cinnamomi* y *P. citrophthora*, y susceptibilidad de cultivares. Cien. Inv. Agr. 36(3):433-442. Chile es el principal productor y exportador de arándanos del hemisferio sur. Durante 2006-2007, la producción de arándanos (*Vaccinium* spp.) aumentó en Chile, como resultado de una expansión de la superficie plantada, alcanzando 10.762 ha en 2007. Las enfermedades fungosas tienen gran importancia en esta especie frutal siendo la pudrición radical producida por *Phytophthora* una de las principales causas de muerte de plantas de arándano alto en EUA. Durante los últimos cuatro años, se han detectado arándanos con pudrición radical en huertos de la región de Valparaíso, Chile, aislándose en todas ellas *Phytophthora* spp. Este trabajo tuvo como objetivos determinar la patogenicidad en arándano alto de aislamientos de *Phytophthora spp.,* y evaluar la susceptibilidad de cultivares de arándanos actualmente plantados en Chile. De este modo, se demostró la patogenicidad de aislamientos de *P. cinnamomi* y *P. citrophthora* , los que causaron pudrición al cuello y raíces en arándano alto. Existió una diferencia significativa entre las plantas inoculadas y las plantas testigo, para las variables altura de planta, crecimiento de brotes, diámetro del tallo, peso fresco de raíces y de parte aérea. En relación con *P. cinnamomi* sólo el cultivar 'Toro' fue resistente, mientras que los cultivares 'Elliot' y 'Toro' mostraron resistencia a *P. citrophthora*, siendo cv. 'Biloxi' el cultivar más afectado por *P. citrophthora*. De acuerdo con nuestro conocimiento, este es el primer reporte de *P. citrophthora* como causante de pudrición al cuello y raíces en arándano a nivel mundial y el primer trabajo que describe la pudrición del cuello y de las raíces por *Phytophthora* en Chile.

Palabras claves: Arándanos, arándanos altos, cultivares de arándanos, enfermedades, *Phytophthora, Vaccinium corymbosum.*

References

Besoain, X., E. Briceño, and E. Piontelli. 1998. Enfermedades de postcosecha en limones y su incidencia en la temporada 1997. Fitopatología 33:84-85.

Besoain, X., C. Arenas, E. Salgado, and B.A. Latorre. 2005. **Effect of soil flooding period on the development of avocado (*Persea americana*) root rot caused by** *Phytophthora cinnamomi.* Cien. Inv. Agr. 32:97-103.

Brannen, P.M., S. Nesmith, and P. Harmon. 2007 Use of phosphonates for control of *Phytophthora* root rot of blueberry. Phytopathology 97:S13.

Bryla, D., and R. Linderman. 2007. Implications of irrigation method and amount of water application on *Phytophthora* y *Pythium* infection and severity of root rot in highbush blueberry. HortScience 42:1463-1467.

Clark, J.R., J.N. Moore, and A.D. Draper. 1986. Inheritance of resistance to *Phytophthora* root rot in highbush blueberry. J. Amer. Soc. Hort. Sci. 111:106-109.

Clayton, C.M., and F.A. Haasis. 1964. Blueberry root rot caused by *Phytophthora cinnamomi* in North Carolina. Plant. Dis. Reptr. 48:460-461.

CORFO.1993. Berries, situación actual y perspectivas. Corporación de fomento de la producción, CORFO, Santiago, Chile. 118 pp.

De Silva, A., K. Patterson, C. Rothrock, and R. McNew. 1999. *Phytophthora* root rot of blueberry increases with frequency of flooding. HortScience 34:693-695.

Draper, A.D., S.M. Mircetich, and D.H. Scott. 1971. *Vaccinium* clones resistant to *Phytophthora cinnamomi* Rands. HortScience 6:167-169.

Dudzinski, MJ., K.M. Old, and R.J. Gibbs. 1993. Pathogenic variability in Australian isolates of *Phytophthora cinnamomi*. Australian Journal of

Botany 41:721-732.

Erb, W.A., J.N. Moore, and R.E. Sterne. 1986. Attraction of *Phytophthora cinnamomi* zoospores to blueberry roots. HortScience 21:1361-1363.

Erwin, D.C., and O.K. Ribeiro. 1996. *Phytophthora* diseases worldwide. APS Press, St. Paul, MN., USA. 562 pp.

INE. 2008. Chile estadístico, Censo Agropecuario 2007.

http://www.ine.cl/canales/chile_estadistico/censos_agropecuarios/censo_agropecuario_07.php. (Accessed: April, 2008).

Latorre, B.A., C.A. Alvarez, and O.K. Ribeiro. 1991. *Phytophthora* root rot of kiwifruit in Chile. Plant Disease 75:949-952.

Latorre, B.A., and R. Muñoz. 1993. Root rot of red raspberry caused by *Phytophthora citricola* and *Phytophthora citrophthora* in Chile. Plant Disease 77:715-718.

Linde, C., G. Kemp, and M.J. Wingfield. 1999. Variation in pathogenicity among South African isolates of *Phytophthora cinnamomi*. **European Journal of Plant Pathology 105:231-239.**

Milholland, R.D., and G.J. Galleta. 1967. Relative susceptibility of blueberry cultivar to *Phytophthora cinnamomi* Rands. Plant Dis. Reptr. 51:998-1001.

Milholland, R.D. 1975. Pathogenicity and histopathology of *Phytophthora cinnamomi* on highbush and rabbiteye blueberry. Phytopathology 65:789-793.

Milholland, R.D.1995. Diseases caused by fungi, blueberries, *Phytophthora* root rot. Pages 7-23. In: F. Caruso and D. Ramsdell (eds.). Compendium of Blueberry and Cranberry Disease. APS Press, St Paul, MN., USA.

ODEPA.. 2007. Agricultura y Mercados, Frutales y Viñas: Situación de los mercados de exportación de tres frutas en expansión: paltas, arándanos y cerezas. Oficina de Estudios y Políticas Agrarias, ODEPA.

http://www.odepa.gob.cl/odepaweb/servlet/contenidos.ServletResumenesScr?idcla=2&idcat=5. (Accessed: March, 2008).

Raniere, L.C. 1961. Observations on new or unusual diseases of highbush blueberry. Plant. Dis. Reptr. 45:844.

Robin, C. and M.L, Desprez-Loustau. 1998. Testing variability in pathogenicity of *Phytophthora cinnamomi.* European Journal of plant pathology 104:465-475.

Royle, D.J., and C.J. Hickman. 1963. *Phytophthora cinnamomi* on highbush blueberry. Plant. Dis. Reptr. 47:266-268.

Smith, B. 2002. Susceptibility of southern highbush blueberry cultivars to *Phytophthora* root rot. Acta Hort. 574:75-79.

Smith, B. 2006. *Phytophthora* root rot and *Botryosphaeria* stem blight: Important disease of southern blueberries in the southern United States. Acta Hort .715: 473-479.

Smith, B. 2007. Cultural practices and chemical treatments affect *Phytophthora* root rot of blueberries grown in South Mississipi. Phytopathology 97:S183.

Stamps, D.J., G.M. Waterhouse, F.J. Newhook, and G.S. Hall. 1990. Revised tabular key to the species of *Phytophthora*. Segunda edición. CAB International, Wallingford, UK. 28 p.

Sterne, R.E.1982. *Phytophthora* root rot of blueberry in Arkansas. Plant Disease 66:604-605.

Tamietti, G. 2003. First report of *Phytophthora cinnamomi* on high-bush blueberry in Italy. Plant Disease 87:451.

Tsao, P., and Ocana, G. 1969. Selective isolation of species of *Phytophthora* from natural soils on an improved antibiotic medium. Nature (London) 223:636-638.

USDA. 2005. The U.S and World Situation: Blueberries. Foreign Agricultural Service. Horticultural and Tropical Products Division. United States Departament of Agricultura, USDA, Foreign Agricultural Service. http://www.fas.usda.gov/htp/HortCircular/2005/Charts%20Circular/2006%20Blueberries.pdf. (Accessed: March 2008).

Vial, A., B.A. Latorre, and J. Ortúzar. 2006. Characterization of *Phytophthora citrophthora* and *P. inundata* associated to foot and root rot of citrus trees in Chile. Cien. Inv. Agr. 33:205-216.

Zentmyer, G.A. 1980. *P. cinnamomi* and the disease it causes. APS. MN., USA. 96 pp.