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Resistance of potato genotypes to late blight

Resistência de genótipos de batata à requeima

Helena N. Oxley[1]*, Cesar B. Gomes[2], Arione da S. Pereira[2], Fernanda Q. Azevedo[2]

[1]Department of Phytossanity, Universidade Federal de Pelotas, Pelotas, RS, Brazil. [2]Laboratory of Phytopathology, Embrapa Clima Temperado, Pelotas, RS, Brazil.

ABSTRACT - Late blight (*Phytophthora infestans*) is a serious problem in potato crops in southern Brazil due to favorable climatic conditions for the development of the pathogen and the lack of resistant cultivars available in the market. Thus, this study aimed to evaluate the reaction of eight cultivars (Asterix, Catucha, BRS Clara, BRS F63 - Camila, Cristal, BRS F183 - Potira, Markies, and BRS Pérola) and five advanced clones (F05-11-03, F21-07-09, Odone 80-02, F50-08-01, and F63-10-07) to late bight under field conditions. The Agata and the clone CIP392.617-54 were used as susceptible and resistant controls, respectively. The experiments were conducted in the municipality of Pelotas, RS, in the autumn season of 2018 and 2019. Sixty days after planting, the plants were inoculated with the pathogen; and, after one week, the genotypes were evaluated for disease severity and the area under the disease progress curve. 'Catucha' was classified as resistant to moderately resistant to *P. infestans*; 'Cristal,' F50-08-01 and 'BRS Perola', moderately susceptible to resistant; and 'BRS F63' - Camila, F63-10-07, F05-11-03, Asterix, F21-07-09, BRS F183 – Potira, and Odone 80-02, moderately susceptible to susceptible. BRS Clara and Markies showed the greatest variations in both experiments, showing to be susceptible in the autumn of 2018 experiment and moderately resistant in the autumn of 2019 experiment.

Keywords: *Solanum tuberosum*. *Phytophthora infestans*. Reaction.

RESUMO - A requeima (*Phytophthora infestans*) constitui-se em um sério problema à cultura da batata na região sul do Brasil em função das condições climáticas favoráveis ao desenvolvimento do patógeno e pela carência de cultivares resistentes disponíveis no mercado. Dessa forma, foi objetivo deste estudo, avaliar a reação de oito cultivares (Asterix, Catucha, BRS Clara, BRS F63 - Camila, Cristal, BRS F183 - Potira, Markies e BRS Pérola) e cinco clones avançados (F05-11-03, F21-07-09, Odone 80-02, F50-08-01 e F63-10-07) de batata à requeima em condições de campo. A cultivar Agata e o clone CIP392.617-54 foram utilizados como testemunhas, suscetível e resistente, respectivamente. Os experimentos foram conduzidos no município de Pelotas, RS, nos cultivos de outono de 2018 e 2019. Sessenta dias após o plantio, as plantas foram inoculadas com o patógeno e, decorrido uma semana, os genótipos foram avaliados quanto à severidade da doença e a área abaixo da curva do progresso da doença. 'Catucha' comportou-se como resistente a moderadamente resistente; 'Cristal', F50-08-01 e 'BRS Pérola', moderadamente suscetível a resistente; e 'BRS F63' - Camila, 'F63-10-07', 'F05-11-03', 'Asterix', 'F21-07-09', 'BRS F183' - Potira Odone 80-02, moderadamente suscetível a suscetível. As cultivares BRS Clara e Markies apresentaram as maiores variações em ambos experimentos, comportando-se como suscetível no outono de 2018 e moderadamente resistente no outono de 2019.

Palavras-chave: *Solanum tuberosum*. *Phytophthora infestans*. Reação.

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***Corresponding author:**
<hoxley@gmail.com>

INTRODUCTION

Potato (*Solanum tuberosum L.*) is historically one of the most important crops for human consumption, ranking fourth among the world's most-produced foods (FAO, 2022). In 2020, Brazil produced 3,767,769 potato tons with an average yield of around 32 t ha^{-1}, with the southern region responsible for 32% of national production (IBGE, 2022). However, one of the main challenges of the production system is phytosanitary management. Among the diseases, late blight, caused by the oomycete *Phytophthora infestans* (Mont.) de Bary, remains the most important in potato crop worldwide (SAVILLE; RISTAINO, 2021). Under favorable environmental conditions, the pathogen can complete its life cycle within five days in susceptible cultivars, decimating entire crops (FRY; GOODWIN, 1997). The symptoms can be observed mainly on the leaves and they are characterized by spots of variable size, light or dark green in color and moist appearance which evolve into dark brown to black, necrotic and irregular spots. A circle of sporulation can be observed on the underside of the leaves, with a velvety appearance and grayish-white color, around the lesions. As the lesions coalesce, the leaf tissue exhibits a generalized burning appearance. In the shoots, late blight causes the death of the apical buds. On the petioles and stems the lesions are dark, and elongated, and on tubercles, the lesions are deep, reddish-brown, and poorly defined (TÖFOLI; DOMINGUES, 2021).

In the southern region of the country, late blight is the main disease that affects potato cultivation, which often requires intensive fungicide applications (BOSCO et al., 2010). The use of cultivars with durable resistance (horizontal) is

one of the most desired strategies due to lower costs with fungicides, and reduced risks of contamination of the environment and to human health (PEREIRA et al., 2012). However, few cultivars have this characteristic for use in regions where late blight is a serious limiting factor for the crop. In this sense, the stability of resistance to *P. infestans* has been one of the targets of Embrapa's potato breeding program. Therefore, the objective of this work was to evaluate the reaction of commercial cultivars and advanced potato clones to *P. infestans* under field conditions.

MATERIAL AND METHODS

Eight cultivars (Asterix, Catucha, BRS Clara, Cristal, BRS F183 - Potira, Markies, BRS F63- Camila, and BRS Pérola) and five advanced clones (F05-11-03, F21-07-09, Odone 80-02, F50-08-01 and F63-10-07) from Embrapa's potato breeding program were evaluated for the reaction to *P. infestans* (Table 1), under field conditions. The Agata cultivar and the CIP392.617-54 clone were used as controls, susceptible and resistant, respectively.

Table 1. Potato genotypes evaluated for reaction to *Phytophthora infestans* under field conditions in autumn seasons of 2018 and 2019.

Genotype	Origin	Genealogy
Agata	Netherlands	Böhn 52/72 X Sirco
Asterix	Netherlands	Cardinal X SVPVe 709
Catucha	Brazil-Epagri	2CRI1149-1-78 X C999-263-70
BRS Clara	Brail-Embrapa	White Lady x Catucha
Cristal	Brazil-Embrapa	CRI420-12-60 X CRI368-8-60
CIP392.617-54	Peru- CIP	387002.11 X 387170.9
F05-11-03	Brazil-Embrapa	White Lady X C1740-11-95
F21-07-09	Brazil-Embrapa	White Lady X C1750-15-95
F50-08-01	Brazil-Embrapa	Rioja X C1316-8-82
F63-10-07	Brazil-Embrapa	Rioja X C1786-9-96
BRS F183 - Potira	Brazil-Embrapa	BRS Ana X C2372-02-02
Markies	Netherlands	Fianna X Agria
Odone 80-02	Brazil-Embrapa	Rioja X C1786-9-96
BRS Pérola	Brazil-Embrapa	2CRI1149-1-78 X Granola
BRS F63 - Camila	Brazil-Embrapa	C1750-15-95 X C1883-22-97

The experiments were carried out in the autumn seasons of 2018 and 2019, between March and June, in the municipality of Pelotas-RS (31° 32' S, 52° 24' W, 54m a.s.l.). A randomized complete block design with three replications was used. Each plot consisted of a row of eight plants spaced 30 cm within row and 0.80 m between row.

The Agata cultivar and the CIP392.617-54 clone were used as susceptible and resistant controls, respectively (GOMES et al., 2009). An isolate of *P. infestans* belonging to compatibility group A2 from the collection of phytopathogenic microorganisms of agronomic interest (COFIA) of Embrapa Clima Temperado was used as inoculum.

Sixty days after emergence, the plants were sprayed with a 10^5 sporangia/mL suspension of *P. infestans* using a manual costal sprayer. Seven days after inoculation, five assessments of disease severity (%) were carried out at intervals of two to three days, based on the Reifschneider scale (1987) adapted (0 to 100%), in which the last assessment was conducted when the susceptible control Agata reached 100% severity.

From the severity data, the area under the disease progress curve (AUDPC) was calculated for each genotype, using the GW Basic program (MAFFIA, 1986). Subsequently, the AUDPC values and the last severity assessment [transformed into arc sine root $\sqrt{(x/100)}$] of each experiment were submitted to ANOVA in a factorial scheme (15 x 2). If there was a significant interaction between the factors, the means of both variables for the genotype factor were submitted to the Scott and Knott cluster test ($P < 0.05$); and for the year factor by the t-test ($P < 0.05$). According to the results of the AUDPC and severity analyses, the genotypes were classified as resistant, moderately resistant, moderately susceptible, and susceptible (GOMES et al., 2009).

RESULTS AND DISCUSSION

The statistical analyses showed significant interaction between the genotype and year factors ($P < 0.05$), showing higher values of AUDPC and severity of *P. infestans* in 2018. Considering the results of the analyzes of both experiments, the genotypes were separated into four groups (Table 2).

CIP392.617-54 clone and Agata cultivar maintained the resistance ($0.0 < AUDPC < 9.17$) and susceptibility ($355.94 < AUDPC < 357.55$) patterns, respectively, in both experiments.

The genotypes Catucha, Cristal, and F50-08-01 were

classified as resistant to *P. infestans* (15.92<AUDPC<26.00), although their reaction varied from moderately resistant to moderately susceptible in one of the experiments. The reactions of BRS Clara, BRS Pérola, and Markies, even having shown some level of resistance, varied between moderately resistant and susceptible considering the AUDPC values (173.36 to 439.17). Although 'Asterix', 'Potira', F21-07-09, 'Camila', F63-10-07, F05-11-03, and 'Odone 80-02' behaved as the most susceptible genotypes to late blight, the last four showed a lower degree of susceptibility (moderately susceptible) in the 2019 experiment (201.08< AUDPC<359.78).

Table 2. Area under the disease progress curve (AUDPC), severity percentage (SEV%), and the reaction of 15 potato genotypes to *Phytophthora infestans* in the autumn seasons of 2018 and 2019.

Genotypes	2018			2019		
	AACPD	Reaction	Severity	AACPD	Reaction	Severity
F21-07-09	488.84a*	S	100.00a1**	359.78a	S	66.00b
BRS Clara	439.17a**	S	97.67a**	173.36c	MR	42.00b
Asterix	406.84a	S	92.67a	367.25a	S	73.00b
BRS F63 - Camila	406.5a**	S	96.00a	201.08b	MS	70.34b
F63-10-07	403.84a**	S	96.34a**	220.17b	MS	55.00b
F05-11-03	388.17a**	S	92.67a	267.94b	MS	69.34b
BRS F183 -Potira	378.17a	S	92.67a	382.67a	S	95.67b
Odone 80-02	375.67a	S	90.00a	222.00a	MS	69.00b
Markies	366.67a**	S	97.00a**	173.75c	MR	46.67b
Agata	357.55a	S	87.71a	355.94a	S	100.00a
Cristal	313.34b**	MS	78.33b**	26.00d	R	5.67c
F50-08-01	292.84b**	MS	62.67b**	15.92d	R	6.43c
BRS Pérola	282.00b**	MS	74.00b**	173.57c	MR	41.34b
Catucha Epagri	177.84c**	MR	48.00c**	17.17d	R	3.67c
CIP392.617-54	9.17d	R	5.33d	0.00d	R	0.00c
CV (%)	16.58		12.14	31.55		29.35

*Means followed by equal letters, in the column, belong to the same group by the Scott & Knott test (P <0.05); and, on the line, by the t-test ** (P <0,05); CV: coefficient of variation; 1- original values transformed into arcsine √(x/100); R= resistant, MR= moderately resistant, MS= moderately susceptible, S= susceptible.

By analyzing the final severity values (Table 2), the resistant genotype 'Cristal', 'Catucha' and F05-11-03 showed low severity values in at least one of the experiments (3.67 < sev <6.63) compared to the resistant control CIP392.617-54. However, for moderately resistant and moderately susceptible genotypes, *sev* values were higher, ranging on average from 41.34 to 70.34% in 2019, and from 46.00 to 96.34% in 2018. In susceptible genotypes (F21-07-09, 'Asterix' and 'Potira'), in both experiments, sev values ranged from 66.00 to 99% in 2019, and from 87.71 to 100% in 2018, compared to 'Agata' control (87.71-99%).

The genetic resistance of 'Cristal', 'Catucha', 'F50-08-01', and the resistant control CIP392.617-54 have been verified in other field experiment studies in southern Rio Grande do Sul (GOMES et al., 2009; CASA-COILA et al., 2019; PEREIRA et al., 2022). The stability of resistance to late blight is a highly desirable genetic trait in a potato breeding program, given the great variability of *P. infestans* isolates that normally occurs in the production environment in different regions of the planet (SAVILLE; MARTIN; RISTAINO, 2016) and our conditions (SANTANA et al., 2013; CASA-COILA et al., 2019). Due to this important characteristic, 'Cristal' and 'Catucha' have been widely used in ecological cropping systems in southern Brazil (TÖFOLI et al., 2013; PASSOS et al., 2017; EICHOLZ et al., 2021). In addition, 'Catucha', 'Cristal', as well as 'F50.08.01' show good resistance to early blight, *Alternaria grandis* Simmons (Rodrigues, 2009) (LOURENÇO JUNIOR et al., 2020). The first two genotypes are also moderately susceptible to *Potato leafroll virus* (PLRV) (Quanjer et al, 1916) (DANIELS; PEREIRA, 2004), and the first is resistant to *P. brachyurus* (Godfrey, 1929) and *M. graminicola* (Golden & Birchfield, 1965) (LIMA-MEDINA; GOMES; GONZAGA, 2014; LIMA -MEDINA et al., 2016). Furthermore, the CIP 392.617-54 clone is considered a good progenitor for crosses of *S. tuberosum*, aiming at resistance to *P. infestans,* due to its high level of stable resistance to late blight.

Among the cultivars that showed moderate resistance, the reaction of 'BRS Clara' has varied a lot since its release (PEREIRA et al., 2013), when it was shown to be resistant to *P. infestans*. Although 'BRS Clara' has 'Catucha' as one of the parents in its genealogy, its resistance pattern has oscillated

between moderately resistant and susceptible. This same oscillation performance has also been noticed for 'BRS Pérola' and Odone 80-02 (WOLTER et al., 2016), and for 'Camila', whose field reaction ranged from highly susceptible to resistant (CASA-COILA et al., 2019), being correlated with the race of *P. infestans*. According to studies conducted by Rocha (2015) specifically with 'BRS Clara', a high level of quantitative resistance to *P. infestans* associated with qualitative resistance was observed, showing that the R genes present in this cultivar did not provide full protection to the isolate under study. According to the same author, depending on the race composition of the pathogen present in a given location, the same genotype may still present an immunity reaction to *P. infestans*. Despite showing variation in reaction to late blight over the years, 'BRS Clara' has agronomic characteristics (elongated oval shape, yellow and smooth skin, with moderate resistance to greening, shallow buds, cream flesh, medium-short dormancy, and moderate resistance to early blight) which allow its maintenance in the national market as one of the most important cultivars in the organic crop system for our conditions. The late blight susceptibility of 'Agata' and 'Asterix' reported in this study has already been recorded in several studies conducted under different conditions and potato production systems (TÖFOLI; DOMINGUES; ZANOTTA, 2017; WOLTER, 2018; BUSNELLO et al., 2019). For the 'Potira' cultivar, similar results were described by Pereira et al. (2022), who reported high susceptibility under field conditions. Although 'Agata' and 'Asterix' occupy a large space in the market due to their culinary qualities or ease of seed potato production (PEREIRA, 2011), both, as well as 'Camila', require a greater number of sprays with chemical fungicides (BRASIL, 2022) or efficient alternative products for *P. infestans* management due to their high values of severity and AUDPC under favorable conditions.

CONCLUSION

Our results show that the reaction to late blight of the Catucha cultivar is moderately resistant, while 'Cristal', F50-08-01 and BRS Pérola vary from resistant to moderately susceptible; 'BRS F63' - Camila, F63-10-07, F05-11-03, 'Asterix', F21-07-09, 'BRS F183' - 'Potira' and Odone 80-02 range from moderately susceptible to susceptible; and 'BRS Clara' and 'Markies' range from moderately resistant to susceptible.

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