



Potato late blight control based on the Blitecast forecast system on the Rio Grande do Sul Plateau, Brazil

Gabriele Maito¹ Mateus Possebon Bortoluzzi^{1*}
Samuel Zottis Dal Magro¹ Laura Valentina Caus Maldaner¹

¹Escola de Ciências Agrárias, Inovação e Negócios, Universidade de Passo Fundo (UPF), 99052-900, Passo Fundo, RS, Brasil. E-mail: mateusbortoluzzi@upf.br. *Corresponding author.

ABSTRACT: Potato (*Solanum tuberosum* L.) is an increasingly important source of food, rural employment, and financial income, contributing to the social stabilization of rural areas, especially in developing countries. However, this crop is very sensitive to diseases, which drastically affect yield, in addition to increasing production costs for their control and the risk of environmental contamination. This study evaluated the control of late blight (*Phytophthora infestans*) in potato cv. Ágata based on the Blitecast disease forecast system and tuber yield in two growing seasons. The experiments were conducted in the spring of 2022 and autumn of 2023 in the municipality of Passo Fundo. Different accumulated severity values (SV) were calculated by the Blitecast model, which constituted the treatments SV 18, SV 24 and SV 30, in addition to a weekly treatment and a control without application. The experimental design consisted of randomized blocks with four replications, in which each plot had five rows of plants measuring 3 m in length. Late blight severity and the final tuber yield were evaluated. The use of the Blitecast forecast system to control potato late blight allows for a reduction in the number of fungicide applications without affecting the final tuber yield. The forecast system should be used as a tool for the integrated management of potato diseases.

Key words: *Phytophthora infestans*, *Solanum tuberosum* L., chemical control, disease forecast.

Controle da requeima da batata com base no sistema de previsão Blitecast no Planalto do Rio Grande do Sul

RESUMO: A batata (*Solanum tuberosum* L.) é uma fonte cada vez mais importante de alimento, de emprego rural e de aumento de renda, contribuindo para a estabilização social do meio rural, principalmente nos países em desenvolvimento. Entretanto, trata-se de uma cultura bastante sensível às doenças, as quais afetam drasticamente a produtividade, além da necessidade de controle elevar o custo de produção e o risco de contaminação ambiental. O objetivo do trabalho foi avaliar o controle da requeima (*Phytophthora infestans*) da batata cv. Ágata com base no sistema de previsão de doenças Blitecast e sua produtividade de tubérculos em duas safras. Os experimentos foram conduzidos na primavera de 2022 e no outono de 2023, no município de Passo Fundo. Diferentes valores de severidade (VS) acumulada, calculados pelo modelo Blitecast, constituíram os tratamentos VS 18, VS 24 e VS 30, acrescentando o tratamento semanal e a testemunha, sem aplicação. O delineamento foi em blocos casualizados com quatro repetições, sendo cada parcela composta de cinco fileiras de plantas com 3 metros de comprimento. Foram avaliadas a severidade da requeima e a produtividade final de tubérculos. A utilização do sistema de previsão Blitecast para o controle da requeima da batata, permite reduzir o número de aplicações de fungicidas sem afetar a produtividade final de tubérculos. O sistema de previsão deve ser utilizado como ferramenta para o manejo integrado de doenças da batata.

Palavras-chave: *Phytophthora infestans*, *Solanum tuberosum* L., controle químico, previsão de doença.

INTRODUCTION

Late blight is caused by the oomycete *Phytophthora infestans* (Mont.) De Bary, which can drastically compromise the yield of potato (*Solanum tuberosum* L.) tubers under favorable air temperature and humidity conditions. Brazil presents a high potato late blight severity occurrence, requiring numerous fungicide applications (HIJMANS et al., 2000). These recurring fungicide applications often have an unreasonable impact on the environment and increase production costs.

Therefore, alternatives to rationalize the chemical control of late blight, such as the use of disease occurrence forecast systems, which consider different weather elements, are necessary. Air temperature between 7.2 and 26.6 °C (KRAUSE et al., 1975) and a long period of high air humidity are the weather variables that most favor infection by *P. infestans*. Thus, a long duration of leaf wetness allows the establishment of parasitism, otherwise, the surface of the susceptible organ dries out and the spore loses viability through desiccation, as it is a structure sensitive to dehydration (TRENTIN et al., 2009).

The use of disease occurrence forecast systems, based on environmental conditions during the cultivation cycle, has stood out as an alternative to assist in decision-making, indicating periods of conditions favorable to the development of diseases, and determining the moment more suitable for fungicide applications (TAYLOR et al., 2003; BATISTA et al., 2006; TRENTIN et al., 2009; BOSCO et al., 2010; GRIMM et al., 2011). Decision Support Systems have been used in European countries, especially in the Netherlands, where at least 36% of potato producers employ the generated recommendations (COOKE et al., 2001). The main advantages of forecast systems are higher profit for the producer, decreased risk of epidemics, reduced number of sprays, and less damage to humans and the environment (BERGAMIN FILHO et al., 1995). Therefore, seeking alternatives to carry out more rational chemical control of potato late blight is of paramount importance.

The Blitecast system (KRAUSE et al., 1975) indicated the applications necessary to control late blight throughout the entire cultivation cycle and is based on the calculated severity value, which associates the duration of relative humidity higher than or equal to 90% and mean air temperature during these periods of high humidity. The hypothesis is that the use of the Blitecast system allows reducing fungicide applications in potatoes without affecting yield, reducing production costs and possible environmental impacts. This research is justified by the possibility of generating information about the efficiency of the Blitecast system, particularly in predicting the occurrence of late blight for the cv. Ágata. This cultivar is extensively utilized in the northern region of Rio Grande do Sul State, which constituted an important growing region where the Blitecast system remains untested.

This study evaluated the performance of the Blitecast forecast system in late blight control and the impact on tuber yield of potato cv. Ágata in spring and autumn cultivations on the Rio Grande do Sul Plateau.

MATERIALS AND METHODS

The experiments were carried out in the municipality of Passo Fundo, Rio Grande do Sul, Brazil, located at a latitude of 28°12'49.6" South and longitude of 52°23'37.8" West and an altitude of 654 m. The climate is characterized as humid subtropical (Cfa), with no defined dry season, according to the Köppen climate classification (ALVARES et al.,

2013). The soil in the region is an Oxisol (Latossolo Vermelho distrófico húmico) (STRECK et al., 2018).

The spring experiment was conducted from August 25 to December 16, 2022, while the autumn experiment was carried out from February 28 to June 27, 2023. In both cases, the Ágata potato cultivar was used. The experimental design consisted of randomized blocks, with four replications. Each plot was composed of five rows of plants measuring 3.0 m in length. Management followed technical recommendations for the crop. Treatments were based on different time intervals between fungicide applications. Weekly applications were performed in one of the treatments and no application was conducted in the control. The time intervals in the other treatments were calculated based on the accumulated severity values (SV), calculated by the Blitecast model, with 18, 24, and 30 SV. Severity values were calculated following table 1 (KRAUSE et al., 1975), ranging from zero to four, according to the mean air temperature in the period in which the relative humidity was higher than or equal to 90% (RH > 90) and the number of hours accumulated with RH > 90 for each day. Applications were performed at each accumulation of 18, 24, and 30 SV.

The fungicide Zetanil WG (cymoxanil + chlorothalonil) was applied at a dose of 1.5 kg ha⁻¹. The application was performed using a CO₂-pressurized sprayer at a rate of 500 L ha⁻¹. Data on rainfall, temperature, and relative humidity were obtained from an automatic weather station located 500 m from the experiment.

Late blight severity was evaluated by a single evaluator, both in spring and autumn, on three plants per plot demarcated at the beginning of the experiment and quantified using the diagrammatic scale by JAMES (1971). The final tuber yield (kg ha⁻¹) was determined by harvesting three linear meters from the three central rows of each plot. Tubers were harvested at 92 and 96 days after emergence (DAE) in the spring and autumn experiments, respectively, without differentiation between commercial and non-commercial tubers. The data were subjected to analysis of variance and, when significant, the means of the treatments were compared using the Tukey test at a 5% probability of error using the program SASM-Agri version 8.1 (CANTERI et al., 2001). The severity, expressed as a percentage, was transformed into $\arcsin \sqrt{\frac{x}{100}}$ for statistical analysis.

RESULTS AND DISCUSSION

The disease was observed 36 days after emergence (DAE) in the spring, manifesting itself

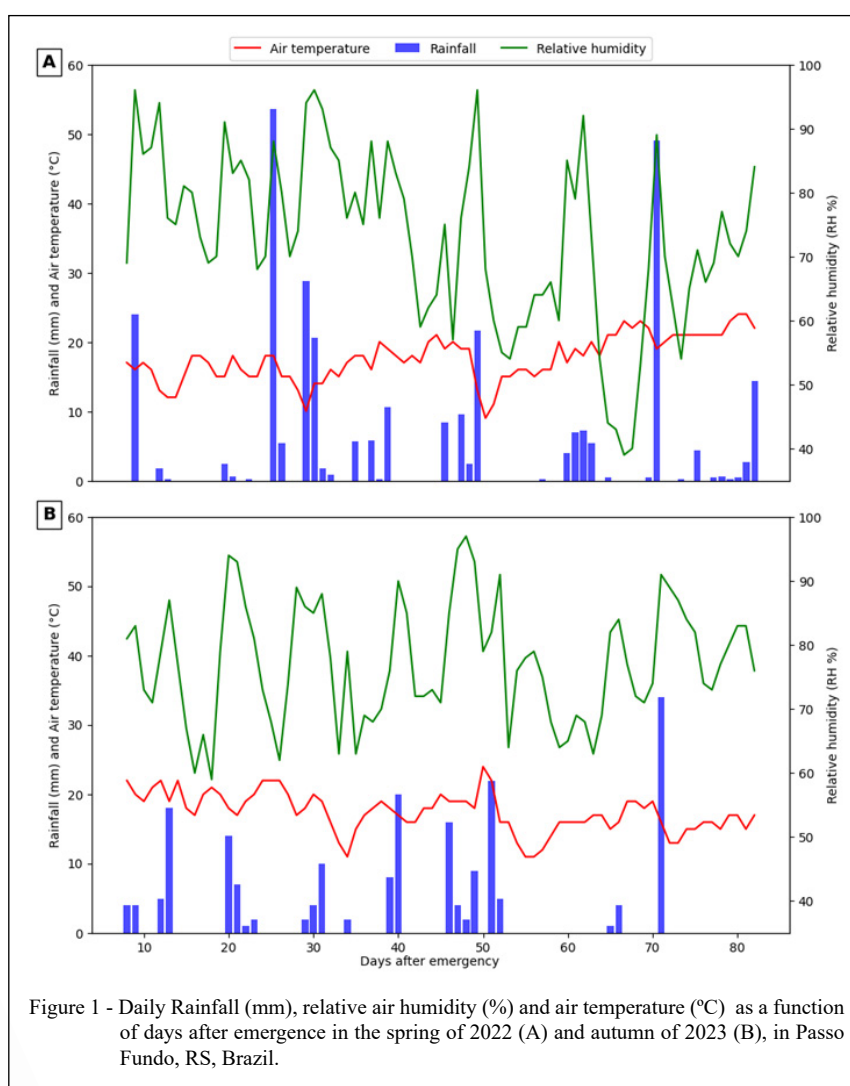
Table 1 - Mean air temperature (°C) classes during continuous periods of accumulation of hours with relative air humidity higher than 90% (HRH > 90%) and respective daily severity values (SV) for late blight control.

Air temperature classes (°C)	-----HRH > 90%-----				
7.2-11.6	≤ 15	16-18	19-21	22-24	> 24
11.7-15.0	≤ 12	13-15	16-18	19-21	> 22
15.1-26.6	≤ 9	10-12	13-15	16-18	> 19
SV	0	1	2	3	4

Source: KRAUSE et al. 1975.

after a period of rain between days 21 and 35 DAE (Figure 1A). Samples of leaves with symptoms were taken to the laboratory for confirmation. Sporangiophores and sporangia grow on the abaxial part of the leaves under high relative air humidity

conditions, giving a whitish color around the lesion, very similar to a thin white mold (TÖFOLI et al., 2013). According to HUBER & GILLESPIE (1992), the presence of free water on the leaves can be observed on dewy nights or rainy days, allowing



sporangium production. Prolonged leaf wetness leads to the germination of spores on the plant during the wetness period, potentially infesting the plant tissue again.

The Blitecast forecast system indicated chemical control for 18 severity values (SV) accumulated at 31 DAE in Passo Fundo (Figure 2A), demonstrating good prediction accuracy. GRÜNWALD et al. (2000) reported a different situation in the Toluca Valley, where the system indicated the initial fungicide application only after the disease was established.

Irregular rains were observed at the beginning of the spring experiment (Figure 1A), determining a low accumulation of severity values calculated by the Blitecast system (Figure 2A). Rains occurred more

frequently after 21 DAE and, as a result, SV accumulated (Figure 2A). No rain events were observed from 48 to 56 DAE and, consequently, there was no increase in SV, keeping the soil surface drier and hotter during the day, which disadvantages the incidence of late blight (GRIMM et al., 2011). However, late blight appeared in all treatments from 55 DAE, with the air temperature remaining above 16 °C during this period. The optimum air temperature for late blight is between 16 and 23 °C (ERWIN & RIBEIRO, 1996). Its manifestation occurs when associated with the presence of the inoculum and a host. The Ágata cultivar is considered susceptible to *P. infestans*, favoring infection and disease progression (OXLEY et al., 2023).

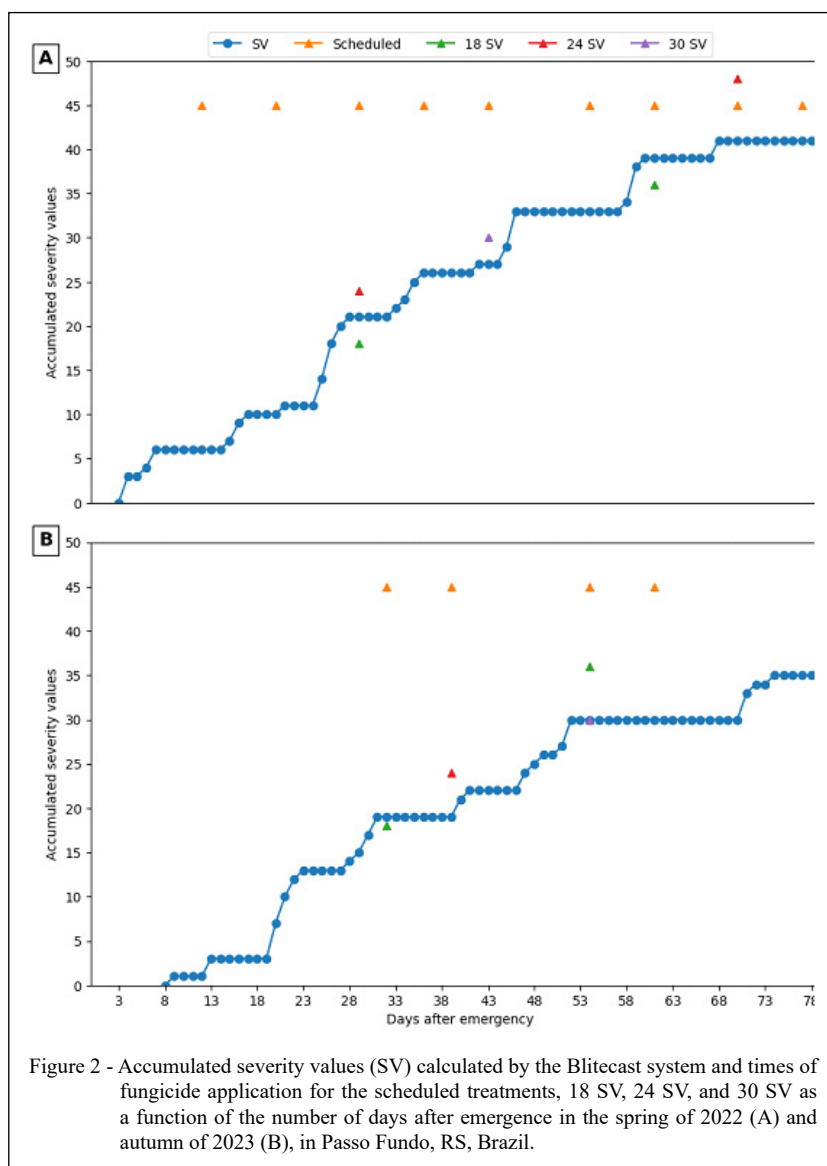


Figure 2 - Accumulated severity values (SV) calculated by the Blitecast system and times of fungicide application for the scheduled treatments, 18 SV, 24 SV, and 30 SV as a function of the number of days after emergence in the spring of 2022 (A) and autumn of 2023 (B), in Passo Fundo, RS, Brazil.

A period of continuous rain with high air temperature and humidity was observed in the autumn, from 46 DAE (Figure 1B), favoring the rapid progression of early blight, which affected all experimental units and compromised the assessments of potato late blight. Figure 2 shows the SV calculated by the Blitecast System and the moment of fungicide application for the scheduled treatments, 18 SV, 24 SV, and 30 SV. In some cases, due to rainfall forecasts, certain applications were advanced, such as the application corresponding to the 30 SV treatment, conducted when the Blitecast system had accumulated only 27 SV (Figure 2A). The scheduled treatment received one application every seven days, with nine and four application times being determined in the spring (Figure 2A) and autumn (Figure 2B), respectively.

The periods suitable for late blight development are those in which there is an increase in SV in a short space of time, indicating the likely period for the disease development (ZADOKS et al., 1979). The favorable period in the spring was observed from 23 DAE (Figure 2A) and in the autumn from 19 DAE (Figure 2B). Late blight was less pronounced in the autumn compared to the spring, with the final mean severity being 1% in the autumn and reaching 8.2% in the spring (Table 2). Furthermore, the start of scheduled applications in

the autumn was delayed by two weeks due to the occurrence of rain, justifying the carrying out of only four applications and concentrating the applications of 18 SV.

The use of weather data as a basis for the forecast system, using the 30 SV treatment, allowed only one application to be carried out in the spring and autumn (Figure 2). Spraying was conducted a maximum of two times for treatments 18 and 24 SV, both in the spring and autumn. TRENTIN et al. (2009) observed similar data for the spring period, in which three and two applications were carried out for treatments 18 and 24 SV, respectively. In contrast, the forecast system indicated six applications in the autumn (TRENTIN et al., 2009), which is in line with the results obtained by BATISTA et al. (2006), in which the number of scheduled applications was similar to those indicated by forecast systems when weather conditions are favorable to the disease. HIJMANS et al. (2000) reported the need for around eight fungicide applications in Brazil based on the Blitecast system.

The lowest final severity (2.7%) in the spring occurred in the 24 SV treatment, followed by the scheduled and 18 SV treatments, with severities lower than 3.2% (Table 2). The control showed the highest final severity (18%), but did not statistically differ from the others treatments, probably due to the high

Table 2 - Observed final severity (%), potato tuber yield (kg ha⁻¹), and number of fungicide applications for the spring 2022 and autumn 2023 cultivation. Passo Fundo, RS, Brazil.

Spring 2022			
Treatment	-----Severity (%)-----	-----Yield (kg ha ⁻¹)-----	----Number of applications----
Control	18.0 a	47048 a	-
Scheduled	3.2 a	48090 a	9
18 SV	4.6 a	46875 a	2
24 SV	2.7 a	48958 a	2
30 SV	12.3 a	48784 a	1
Mean	8.2	48177	
CV (%) ¹	55.4	12.2	
Autumn 2023			
Control	2.3 b	10885 a	-
Scheduled	0.7 a	13437 a	4
18 SV	0.9 ab	11380 a	2
24 SV	0.5 a	11224 a	1
30 SV	0.6 a	13385 a	1
Mean	1	12356	
CV (%)	24.4	23.9	

Means followed by the same letter in the column do not differ from each other by the Tukey test ($P \leq 0.05$).

¹CV: coefficient of variation.

coefficient of variation (54%). The 24 SV treatment also had the lowest severity in the autumn (0.5%), not differing from the control. Severity was below 1.0% for the other treatments (Table 2). Conversely, there was no significant difference in tuber yield during autumn across treatments. The autumn yield was notably lower compared to spring mainly due to excessive rainfall and the occurrence of early blight. The tuber yield obtained align closely with those reported by BATISTA et al. (2006) and BOSCO et al. (2010).

In addition to the control, treatments 18, 24, and 30 SV showed tuber yield similar to the scheduled treatment in the spring, despite receiving none, one, or only two fungicide applications and the same level of accumulated severity (Table 2). These findings demonstrate that depending on the disease inoculum availability and meteorological conditions during the development cycle, chemical control may be unnecessary. Regarding the Blitecast system, considering that nine applications were carried out for the scheduled treatment, the number of chemical treatments used to control late blight can be reduced without significantly affecting tuber yield, corroborating with the results obtained by TRENTIN et al. (2009) and BOSCO et al. (2010). Therefore, in addition to the different integrated control methods, such as the use of healthy seed potatoes, less susceptible cultivars, removal and destruction of volunteer plants, and chemical control (TAYLOR et al., 2003), monitoring all diseases that may occur in the crop is essential.

CONCLUSION

The use of the Blitecast forecast system for potato late blight, with an accumulation of 18, 24, and 30 severity values, allowed reducing the number of fungicide applications without significantly affecting the final tuber yield.

The forecast system should be used as a tool for the integrated management of potato diseases. Further studies should be conducted to enhance the utilization of Blitecast in conjunction with other systems, aiming to predict the occurrence of additional potato diseases.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES).

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors critically revised the manuscript and approved the final version.

REFERENCES

- ALVARES, C. A. et al. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, v.22, n.6, p.711-728, 2013. Available from: <http://143.107.18.37/material/mftandra2/ACA0225/Alvares_et_al_Koppen_climate_classBrazil_MeteoZei_2014.pdf>. Accessed: Dec. 01, 2023. doi: 10.1127/0941-2948/2013/0507.
- BATISTA, D. C. et al. Validation of decision support systems for tomato early blight and potato late blight, under Brazilian conditions. *Crop Protection*, v.25, n.7, p.664-670, 2006. Available from: <<https://doi.org/10.1016/j.cropro.2005.09.009>>. Accessed: Dec. 04, 2023. doi: 10.1016/j.cropro.2005.09.009.
- BERGAMIN FILHO, A. et al. **Manual de Fitopatologia: princípios e conceitos**. São Paulo: Agronômica Ceres, 1995. 919 p.
- BOSCO, L. C. et al. Sistemas de previsão de requeima em cultivos de batata em Santa Maria, RS. *Bragantia*, v.69, p.649-660, 2010. Available from: <<https://doi.org/10.1590/S0006-87052010000300017>>. Accessed: Dec. 01, 2023. doi: 10.1590/S0006-87052010000300017.
- CANTERI, M. G. et al. SASM - Agri: Sistema para análise e separação de médias em experimentos agrícolas pelos métodos Scoft - Knott, Tukey e Duncan. *Revista Brasileira de Agrocomputação*, v.1, n.2, p.18-24, 2001. Available from: <https://agrocomputacao.deinfo.uepg.br/dezembro_2001/Arquivos/RBAC_01_02.pdf>. Accessed: Dec. 04, 2023.
- ERWIN, D. C.; RIBEIRO, O. K. **Phytophthora: Diseases Worldwide**. St. Paul, Minnesota: APS Press, 1996. 592p.
- GRIMM, E. L. et al. Potato productivity as a function of irrigation and chemical control of Late Blight. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.15, n.2, p.125-130, 2011. Available from: <<https://doi.org/10.1590/S1415-43662011000200003>>. Accessed: Sept. 24, 2023. doi: 10.1590/S1415-43662011000200003.
- GRÜNWARD, N. J. et al. Potato late-blight management in the Toluca Valley: Forecasts and resistant cultivars. *Plant Disease*, v.84, n.4, p.410-416, 2000. Available from: <<https://doi.org/10.1094/PDIS.2000.84.4.410>>. Accessed: Dec. 04, 2023. doi: 10.1094/PDIS.2000.84.4.410.
- HIJMANS, R. J. et al. Estimating the global severity of potato late blight with GIS-linked disease forecast models. *Plant Pathology*, v.49, n.6, p.697-705, 2000. Available from: <<https://doi.org/10.1046/j.1365-3059.2000.00511.x>>. Accessed: Dec. 01, 2023. doi: 10.1046/j.1365-3059.2000.00511.x.
- HUBER, L.; GILLESPIE, T. J. Modeling leaf wetness in relation to plant disease epidemiology. *Annual Review of Phytopathology*, v.30, p.553-577, 1992. Available from: <<https://www.annualreviews.org/doi/pdf/10.1146/annurev.py.30.090192.003005>>. Accessed: Dec. 01, 2023.
- JAMES, W. C. An illustrated series of assessment keys for plant diseases. Their preparation and usage. **Canadian Plant Disease**

- Survey, v.51, n.2, p.39-65, 1971. Available from: <[https://phytopath.ca/wp-content/uploads/2014/10/cpds-archive/vol51/CPDS_Vol_51_No_2_\(39-65\)1971.pdf](https://phytopath.ca/wp-content/uploads/2014/10/cpds-archive/vol51/CPDS_Vol_51_No_2_(39-65)1971.pdf)>. Accessed: Dec. 04, 2023.
- KRAUSE, R. A. et al. BLITECAST a computerized forecast of potato late blight. **Plant Disease Reporter**, v.59, p.95-98, 1975. Available from: <<https://books.google.com/books?hl=pt-BR&lr=&id=ow9BD6P2KZ4C&oi=fnd&pg=PA95&ots=gWWGZByO4k&sig=OdT2HmVCvcNiiNI7LJN4btvcNT0>>. Accessed: Sept. 27, 2024.
- OXLEY, H. N. et al. Resistance of potato genotypes to late blight. **Revista Caatinga**, v.36, n.3, p.585-589, 2023. Available from: <<https://doi.org/10.1590/1983-21252023v36n311rc>>. Accessed: Nov. 12, 2023. doi: 10.1590/1983-21252023v36n311rc.
- STRECK, E. V. et al. **Solos do RS**. 3. ed., rev. e ampl. Porto Alegre: Emater/RS, 2018. 252p.
- TAYLOR, M. C. et al. Relative performance of five forecasting schemes for potato late blight (*Phytophthora infestans*) I. Accuracy of infection warnings and reduction of unnecessary, theoretical, fungicide applications. **Crop Protection**, v.22, n.2, p.275-283, 2003. Available from: <[https://doi.org/10.1016/S0261-2194\(02\)00148-5](https://doi.org/10.1016/S0261-2194(02)00148-5)>. Accessed: Nov. 21, 2023. doi: 10.1016/S0261-2194(02)00148-5.
- TÓFOLI, J. G. et al. Potato late blight and early blight: importance, characteristics and sustainable management. **Biológico**, v.75, n.1, p.33-40, 2013. Available from: <https://www.academia.edu/download/52512138/Requeima_e_pinta_preta_na_cultura_da_bat20170406-4048-1h5q8tm.pdf>. Accessed: Sept. 27, 2024.
- TRENTIN, G. et al. Controlling potato cv. 'Asterix' late blight base on forecast systems. **Ciência Rural**, v.39, n.2, p.393-399, 2009. Available from: <<https://doi.org/10.1590/S0103-84782009000200012>>. Accessed: Oct. 10, 2023. doi: 10.1590/S0103-84782009000200012.
- ZADOKS, J. C. et al. **Epidemiology and plant disease management**. New York: Oxford University, 1979. 427p.