PHYTOSANITARY TREATMENT PROGRAM FOR TOMATO *late blight* CONTROL

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ABSTRACT: Tomato (*Solanum lycopersicum)* is one of the most expressive crops in the world agricultural scenario, constituting an important product for fresh and processed trade. The tomato crop is highly susceptible to diseases that cause reduced fruit yield and quality. Among these, Late blight stands out, which occurs in almost all tomato producing regions. To study the efficiency of the control of tomato late blight (*Phytophthora infestans*) and to test the effect of different programs of combination and alternation of fungicides, an experiment was carried out in the field during the 2015/2016 harvest. Treatments for experiments were: 1 - metiram + pyraclostrobin 400 g / 100 L; 2 - mancozeb 3.0 Kg / ha; 3 - cuprous oxide 240g / 100 L; 4 - iprodione 150 mL / 100 L; 5 - metalaxyl 300 g / 100 L; 6 - azoxystrobin 80 g / ha; 7 - diphenoconazole 50 mL / 100 L. The variables evaluated were severity of tomato blight on leaves, disease control in fruits and total commercial productivity. Based on severity data, the area under the disease progress curve was calculated. In this experiment, all treatment programs were effective in controlling the disease and the treatment program with alternating successions of metalaxyl (300 g / 100 L), metalaxyl + mancozeb (300 g / 100 L + 3.0 kg / ha), mancozeb (3.0 kg / ha), metalaxyl + cuprous oxide (300 g / 100 L + 240g / 100 L), mancozeb (3.0 kg / ha). On leaves, fungicides metalaxyl and ipyridone controlled the disease by 66 and 62% respectively. In fruits, fungicide difenoconazole controlled the disease by 87%. Thus, treatment programs using mixtures and/or alternations of chemicals proved to be efficient for controlling tomato late blight.

KEYWORDS: *Solanum lycopersicum, Phytophthora infestans*, disease control, fungicides.

PROGRAMA DE TRATAMENTO FITOSSANITÁRIO PARA CONTROLE DA REQUEIMA DO TOMATEIRO

RESUMO: O tomateiro (*Solanum lycopersicum* Mill) representa uma das mais expressivas culturas no cenário agrícola mundial, constituindo importante produto para o comércio *in natura* e de processados. A cultura do tomate é altamente suscetível a doenças causadoras de redução de rendimento e da qualidade dos frutos. Dentre estas, destaca-se a Requeima, que ocorre em quase todas as regiões onde a cultura é conduzida. Para estudar a eficiência do controle da Requeima do tomateiro (*Phytophthora infestans*) e testar o efeito de diferentes programas de combinação e alternância de fungicidas foi realizado um experimento a campo durante a safra 2015/2016. Os tratamentos para os experimentos foram: 1 – metiram + piraclostrobina 400 g /100 L; 2 - mancozeb 3,0 Kg/ha; 3 - óxido cuproso 240g/100 L; 4 - iprodione 150 mL/100 L; 5 - metalaxyl 300 g/100 L; 6 - azoxystrobin 80 g /ha; 7 - difenoconazole 50 mL/100 L. As variáveis avaliadas foram a severidade da Requeima do tomateiro nas folhas, o controle da doença nos frutos e a produtividade comercial total. Com base nos dados de severidade, foi calculada a área abaixo da curva de progresso da doença. Neste experimento, todos os programas de tratamento foram eficientes no controle da doença e o programa de tratamento com as sucessões alternadas de: metalaxyl (300 g /100 L), metalaxyl + mancozeb (300 g /100 L+ 3,0 kg/ha), mancozeb (3,0 kg/ha), metalaxyl +óxido cuproso (300 g/100 L + 240g/100 L), mancozeb (3,0 kg/ha). Nas folhas, os fungicidas metalaxyl e ipiridone controlaram a doença em 66 e 62% respectivamente. Nos frutos, o fungicida difenoconazol controlou a doença em 87%. Desta forma, os programas de tratamento usando misturas e/ou alternâncias de defensivos agrícolas mostraram-se eficientes para o controle da requeima do tomateiro.

PALAVRAS CHAVE: *Solanum lycopersicum, Phytophthora infestans*; controle de doenças; fungicidas.

INTRODUCTION

Tomato is native to South America, has spread to all continents and to almost all countries in the world (Nagai, 2018). The Brazilian tomato cultivation activity is widespread throughout the national territory, with the Southeastern and Midwestern regions being the main production regions. It has great economic importance, due to the production volume and value, to its flexibility in use as food, for its organoleptic qualities and high content of vitamin C, being well accepted by most consumers (Nassur, 2015). In Brazil, the introduction of the tomato crop started to present a very regular growth both in area and in productivity only during the 1950's and 1960's. Of Latin American countries, Brazil stands out as the largest producer of this solanaceae, being the state of São Paulo the main consumer market (Carvalho, 2014).

However, this culture is one of the most difficult to manage, as it is sensitive to numerous diseases, requiring special care. One of the main diseases that economically affect the tomato culture is the Late Blight, which is known to cause reduction in fruit yield and quality (Laurindo, 2016). The causal agent of this disease is the fungus *Phytophthora infestans*, which under favorable climatic conditions, that is, mild temperatures (between 15 and 20ºC) and relative humidity above 85%, can affect all aerial organs of tomato plants such as leaves, stems, inflorescences and unripe and ripe fruits (Tofoli, 2012; Santos, 2017). Depending on weather conditions and if control measures are not correctly adopted, there is total production loss (Tunes, 2019).

The pathogen survives mainly on crop residues and is spread by rain, strong winds and contaminated agricultural implements (Souza, 2014). Late-stage tomato crops can also, eventually, host the pathogen, serving as inoculum source for later tomato crops or nearby crops. Fungal sporulation is more frequent at the edges of the lesions, where the affected tissue is found, but not yet dead (Mulugeta, 2019).

According to Rosa (2015), it is very important to rotate crops for 2 or 3 years and it is recommended not to use seeds from diseased fruits, as the fungus is transmissible through the seed. Planting should be avoided in humid lowlands, margin of rivers and dams, poorly ventilated places and subject to fog due to the accumulation of cold and humid air and adopt wide spacing to favor ventilation and reduce the environment humidity.

Commercially grown tomato hybrids are susceptible to late blight and, therefore, the most efficient method of control is chemical (Du, 2020). Periodic preventive sprays with mancozeb, chlorothalonil or cuprous are recommended and preventive sprays with systemic agents should only be used in climatic conditions favorable to the disease (low temperatures, 12 to 20º C and frequent rains or fogs for more than two days) (Nowicki et al., 2013).

To ensure the efficiency of chemical control, it is necessary to carry out daily monitoring of the crop in order to check for the first symptoms of the disease (Chen, 2018). The right time to apply the fungicide is key to controlling the disease. Thus, the aim of the present study was to evaluate the effect of the application of mixtures and alternations of different fungicides on tomato crops for the control of late blight.

MATERIAL AND METHODS

The experiment was carried out on a private property in the location of Caravaggio da 3ª Légua, municipality of Caxias do Sul RS, under geographic coordinates 29°16'9.15"S 51°12'59.42"W, altitude of 346 meters a.s.l., in the 2015/2016 harvest.

Tomato seedlings 'Paronset` cultivar were used, being transplanted at 30 days and conducted in an inverted "V" planting system, with spacing of 0.8 m between rows and 0.6 m between plants, with 1.0 m between double rows.

A randomized block design was carried out with six treatments and four replicates, with each plot consisting of four plants, where the two central plants were considered as useful area and the others as borders.

Nitrogen fertilization was carried out with 120 kg/ha of N, with 40 to 60 kg/ha being applied at planting, along with phosphorus and potassium, and the remainder in the form of nitrocalcium, in topdressing, 25 to 30 days after planting.

Treatments were carried out with a 20-L backpack sprayer, equipped with universal conical nozzle, at intervals of 3 to 5 days, starting 10 days after transplanting. The treatment programs used are shown in Table 1. Fungicide doses used were: 1 - methiram + pyraclostrobin (cabrio top) 400 g/100 L; 2 - mancozeb (Dithane) 3.0 kg/ha; 3 - cuprous oxide (Kocide) 240 g/100 L; 4 - iprodione (Rovral) 150 ml/100 L; 5 - metalaxyl (Ridomil) 300 g/100 L; 6 - azoxystrobin (Amistar WG) 80 g/ha; 7 - difenoconazole (Score) 50 mL/100 L.

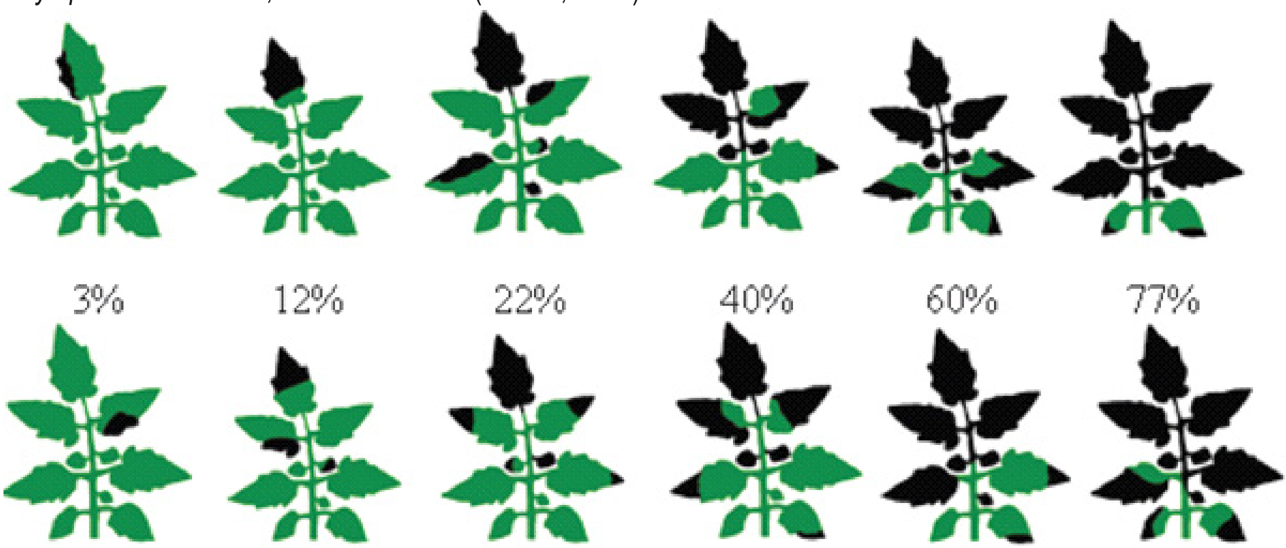
Table 1. Combination and alternation of fungicides and the sequence of sprays on tomato plants to control late blight. Caxias do Sul, RS. 2015/2016 harvest.

Treatment	Sprays (a.)				
	1st	2nd	3rd	4th	5th
1	metiram + piraclostrobin	(metiram + piraclostrobin) + mancozeb	mancozeb	(metiram + piraclostrobin) + cuprous oxide	mancozeb
2	iprodione	iprodione + mancozeb	mancozeb	iprodione + cuprous oxide	mancozeb
3	metalaxyl	metalaxyl + mancozeb	mancozeb	metalaxyl + cuprous oxide	mancozeb
4	azoxystrobin	azoxystrobin + mancozeb	mancozeb	azoxystrobin + cuprous oxide	mancozeb
5	difenoconazol	difenoconazol + mancozeb	mancozeb	difenoconazol + cuprous oxide	mancozeb
6	Control	---	---	---	---

a. If more than 5 sprays are needed, repeat the spray from the 1st spray.

To assess the late blight severity in tomato leaves, the diagrammatic scale of Côrrea et al. (2009) was used, as shown in Figure 1. Evaluations started from the appearance of the first symptoms of the disease in leaves, which occurred 72 days after transplanting.

Figure 1. Illustration of the simplified diagrammatic classification key considering six levels of late blight severity, *Phytophthora infestans*, in tomato leaves (Corrêa, 2008).



The percentage of the disease incidence in fruits was also evaluated. Commercial production and the control percentage were evaluated through the equation of Abbot (1925): Control (%) = [(control - treatment) / control] *100

The results of the disease severity on leaves were used to calculate the area under the disease progress curve (AUDPC), through the following equation, as proposed by Shaner & Finney (1977): $AUDPC = \sum^{n} i+1 [(Yi+1 + Yi) /2] *[Ti+1 - Ti)]$, where n – number of observations; Yi – disease severity in the "i" th observation; Ti – time in days in the "i" th observation.

Data on severity, incidence in fruits and production were submitted to analysis of variance and the means were compared using the Scott-Knott test at 1% probability.

The disease incidence in fruits occurred 75 days after transplanting. The time from planting to the first harvest was 90 days, and fruits were harvested at advanced maturation stage and the crop cycle lasted 120 days.

RESULTS AND DISCUSSION

Leaf late blight

The incidence of late blight was observed in all treatments. There were significant differences between them, and metalaxyl stood out for presenting 66% of control in relation to the other treatments (according to data in Table 2), corroborating Conhen, (2018) and Souza (2014), who obtained high potential to control late blight using metalaxyl-M + mancozeb. According to Kurozawa & Pavan (2005), late blight needs high humidity and temperature around 20°C to develop. In addition, the direction of plant rows was east-west, which allows for greater insolation in the canopy of plants throughout the day, reducing the period of leaf wetness caused by rain and dew, a factor that favors the development of the disease (Becker, 2005).

Table 2. Evaluation of late blight in tomato crops through leaf severity, control percentage on leaves and fruits, area under the disease progress curve of leaf infections and fruit production. Caxias do Sul, RS. 2015/2016 harvest.

Treatments	Leaves			Fruits	
	Severity (%)	Control (%)	AUDPC	Control (%)	Production (kg)
1.metiram+piraclostrobina	12.0 c	58.5 c	122.8	79.6 a	19.2 a
2. iprodione	10.6 d	62.9 b	108.3	80.4 a	17.7 a
3. metalaxyl	9.8 e	66.4 a	91.5	67.7 a	19.0 a
4. azoxystrobin	11.9 c	57.6 c	128.7	61.6 a	13.5 a
5. difenoconazole	13.0 b	55.1d	154.7	87.3 a	19.5 a
6. testemunha	29.7 a	0.0 e	473.3	0.0 b	10.7 a
F p/ Treat.	2217.7**	595.43**	---	7.63**	2.78^{NS}
C.V. (%)	3.11	5.75	---	37.04	26.54

Means followed by the same letter, in the column, do not differ from each other by the Scott-Knott 1% probability test. AUDPC: Area Under the Disease Progress Curve.

Regarding leaves, it was observed that AUDPC presented the smallest area affected by the disease in the metalaxyl spray program (91.5), unlike control that presented the largest area (473.3) of disease infestation. The natural occurrence of late blight and the favorable conditions of humidity and temperature for the development of the disease, combined with the `Paronset` cultivar and the local conditions, which is wet lowland near a river, allowed high levels of late blight infestation. Matson et al. (2015) & Kumbar, (2019) found that the Brazilian *Phytopththora infestans* populations, in addition to continuing to be clonal and with high host specificity, showed high percentages of isolates resistant and moderately resistant to metalaxyl and mefenoxam (metalaxyl-m), important fungicides that act to control late blight, especially when conditions are broadly favorable to the disease.

Fruit late blight - the percentage of diseased fruits was higher in the control treatment, but in the case of fungicides, azoxystrobin presented 61% of control, while fungicide difenoconazole showed control of 87%. Such superiority can be justified by the fact that the chemical fungicide difenoconazole has positive characteristics with immunizing action and good persistence in tissues (Du, 2017). Curative fungicides (immunizing) act directly on the infected plant, reducing symptoms or damage caused by phytopathogens. These fungicides have action directed against the pathogen after its establishment (Rodrigues, 2000). Gunacti (2019) reported that mixed formulations with protective fungicides, as in the case of difenoconazole, are applied via spray on simple formulations for the control of *P. infestans* in tomato.

Fruit productivity

Regarding fruit productivity, there were no significant differences between spraying programs, 10 kg in the control treatment and 19 kg with fungicide difenoconazole. It is clearly noted that fungicide difenoconazole stood out significantly in relation to the control of late blight in leaves and also in fruits, but it was inefficient compared to control in the final fruit production. The superiority of difenoconazole and metalaxyl in single or mixed formulations for the control of *P. infestans* in tomato has been reported several times (Rodrigues, 2000; Rekad, 2017), being attributed to several factors related to the composition of products, application and the characteristics of pathosystems in which they were used. Their lower efficiency may be due to the high solubility and mobility of the active product (Chen, 2018). Thus, despite the easy absorption and acropetal transport through tomato roots, stem and leaves, leaching probably occurred very quickly. As a consequence, it was presented at insufficient levels to provide the necessary protection during the critical period of the disease (20 to 70 days after transplanting seedlings to the field).

The treatment program based on metalaxyl and difenoconazole, with their mixtures and alternations, had the lowest severity, the highest percentage of disease control in leaves, and the lowest area under the disease progress curve (AUDPC).

The differential effectiveness of fungicides commonly used in treatment programs, mixed and/or in alternation and recently introduced, together with their economic returns, provided important information for the control of tomato late blight.

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