

## EFFECT OF VARIOUS FUNGICIDES IN THE CONTROL OF *ALTERNARIA* LEAF BLIGHT IN CARROT CROPS

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### RESUMO

#### AÇÃO DE FUNGICIDAS NO CONTROLE DA MANCHA DE *ALTERNARIA* NA CULTURA DA CENOURA.

A mancha de *Alternaria* causada pelo fungo *Alternaria dauci* está entre as mais importantes e destrutivas doenças da cultura da cenoura no Brasil e no mundo. Com objetivo de avaliar a eficácia de diferentes fungicidas no seu controle foi realizado um experimento com a cultivar Verano no município de Andradas, MG, no período de fevereiro a abril de 2017. O delineamento experimental adotado foi o de blocos ao acaso com 7 tratamentos e quatro repetições, sendo cada parcela composta por 4 m<sup>2</sup>. Foram realizadas 6 aplicações a intervalos de sete dias, e volume de 400 L/ha. O critério de avaliação utilizado foi a severidade da doença, tendo como base a porcentagem de área foliar afetada (0 a 100%). Os resultados de quatro avaliações foram utilizados para o cálculo da área abaixo da curva de progresso da doença (AACPD). Todos os fungicidas reduziram significativamente a severidade e o progresso da doença em relação à testemunha. Fluxapiraxade+piraclostrobina (0.3 L p.c./ha) destacou-se sendo superior a boscalida+cresoxim metílico (0.5 L p.c./ha), hidróxido de cobre (1.5 kg p.c./ha) e azoxistrobina (0.12 kg p.c./ha), porém semelhante ao piraclostrobina+metiram (2.0 kg p.c./ha) e boscalida (0.15 kg p.c./ha). Boscalida+cresoxim metílico (0.50 L p.c./ha) e hidróxido de cobre (1.5 kg p.c./ha) apresentaram comportamento intermediário enquanto que azoxistrobina (0.12 kg p.c./ha) foi o menos eficiente. Os fungicidas testados não foram fitotóxicos à cultura da cenoura.

Palavras chave: *Daucus carota*, *Alternaria dauci*, carboximidas, estrobilurinas.

## ABSTRACT

### EFFECT OF VARIOUS FUNGICIDES IN THE CONTROL OF *ALTERNARIA* LEAF BLIGHT IN CARROT CROPS

*Alternaria* leaf blight, caused by the fungus *Alternaria dauci*, is considered to be the most common and destructive disease in carrot crops in Brazil and worldwide. To evaluate the effectiveness of different fungicides in controlling *Alternaria* leaf blight, we conducted an experiment using the cultivar 'Verano' in Andradas, Minas Gerais, from February to April 2017. A randomized complete block design was used with seven treatment and four replicate plots of 4 m<sup>2</sup> each. Six applications of 400 L/ha were applied at 7-day intervals. The severity of the disease was determined based on the percentage of leaf area affected by the disease (0 to 100%). The results of four evaluations were used to calculate the area under the disease-progress curve. All fungicides significantly reduced the severity and progression of the disease compared to the control. Fluxapyroxad + pyraclostrobin (0.3 L c.p./ha) was more effective than boscalid + kresoxim-methyl (0.5 L c.p./ha), copper hydroxide (1.5 kg c.p./ha), and azoxystrobin (0.12 kg c.p./ha), but similar in effectiveness to pyraclostrobin + metiram (2.0 kg c.p./ha) and boscalid (0.15 kg c.p./ha). Azoxystrobin (0.12 kg c.p./ha) was the least effective fungicide. None of the tested fungicides were phytotoxic to the carrot crop.

**Keywords:** *Daucus carota*, *Alternaria dauci*, carboximides, strobilurins.

The carrot (*Daucus carota* L.) is native to Asia and has become the most cultivated and consumed Apiaceae in the world. Carrots are rich in  $\beta$ -carotene, potassium, fibre, and antioxidants, and considered to be a functional food due to them conveying health benefits, such as: lowering cholesterol levels, strengthening the immune system, and providing protection against some cancers.

*Alternaria* leaf blight, caused by the fungus *Alternaria dauci* (J.G. Kühn) J.W. Groves & Skolko, is among the most important and destructive diseases of carrot crops in Brazil and worldwide. *Alternaria* leaf blight causes small lesions in the

margins and extremities of the leaflets of the leaves and can thus drastically reduce leaf area in susceptible cultivars, causing significant reductions in yield and root quality. The lesions are of irregular size and shape, have dark brown or dun coloration and may have concentric halos, some of which are also surrounded by yellowish halos. Dark, elongated, and moist lesions may also develop on the petioles and inflorescences. In its pre- and post-emergence stages, the fungus can affect germination success, cause the tipping and death of seedlings, and thus reduce the stand in the field (PER-SLEY, 2010; TÖFOLI & DOMINGUES,

2010; EKMAN & TESORIERO, 2015). The disease prefers temperatures ranging from 23 to 30°C and periods of leaf wetting from 8 to 12 hours. The disease becomes more evident after the closing of the crop, when there is a greater accumulation of humidity inside the foliage and less air circulation between the plants (MASSOLA JR. et al., 2016).

The adoption of integrated control measures is essential for the effective management of the disease. These include: planting healthy seeds, treating seeds with fungicides, avoiding planting in humid areas, using cultivars with resistance, ensuring balanced fertilization, avoiding excessive irrigation, rotating crops, and applying registered fungicides (FARRAR et al., 2004; TÖFOLI et al., 2015; MASSOLA JR. et al. 2016). Although a program based on crop measures can minimize the occurrence of the disease, the use of fungicides is necessary when susceptible materials are planted in favorable climatic conditions. According to TÖFOLI & DOMINGUES (2010) and AGROFIT (2019), the main groups of fungicides recommended for the control of *Alternaria* leaf blight in carrot crops in Brazil are **dithiocarbamates** (mancozeb, metiram); **phthalonitrile** (chlorothalonil); **copper** (copper oxychloride, copper hydroxide, copper oxide); **strobilurins** (azoxystrobin, pyraclostrobin and trifloxystrobin); **triazoles** (tebuconazole, difenoconazole, tetraconazole, metconazole, bromuconazole); **dicarboximides** (iprodione, procymidone); **anilinopyrimidine** (pyrimethanil),

**carboxamides** (boscalid; fluxapyroxad), and **oxazolidinedione** (famoxadone).

Studies have demonstrated the effectiveness of the fungicides difenoconazole, azoxystrobin, chlorothalonil, and pyraclostrobin in controlling *Alternaria* leaf blight in carrots (FARRAR et al., 2004; DORMAN, 2009; MARINGONI et al., 2012).

The present study was conducted from February to April of 2017 using a commercial carrot cultivar (cv. Verano) in the city of Andradas, Minas Gerais, Brazil. The fungicides tested (c.p./ha) were: azoxystrobin (0.12 kg), copper hydroxide (1.5 kg), pyraclostrobin + metiram (2.0 kg), boscalid (0.15 kg), boscalid + kresoxim-methyl (0.5 L) and fluxapyroxad + pyraclostrobin (0.3 L). The treatments involved six applications at 7-day intervals that began 53 days after sowing. The treatments were applied with a pressurized backpack sprayer (CO<sub>2</sub>) equipped with a 1-meter pole with four nozzles (type 110-02), spaced 25 cm apart, and at a height of 50 cm from the plants. A pressure of 3 bar was used which yielded a treatment volume of 400 liters of mixture per treated hectare. A randomized block design was used, which was comprised of seven treatment and four replication plots of 4 m<sup>2</sup> each.

The severity of the disease was evaluated based on the percentage of leaf area affected by the disease in each plot (0 to 100%). Four evaluations were conducted at intervals of 5 to 7 days, the last of which were conducted at 5 and 12 days after the last application (DALA).

The results of the evaluations were used to calculate the area under the disease progress curve (AUDPC) according to CAMPBELL & MADDEN (1990). The mean areas under the curves were compared and statistically analyzed using the Tukey test at 5% probability.

*Alternaria* leaf blight reached considerable levels of severity and progression in the control plots, which enabled the clear differentiation of the effects of the tested treatments (Table 1, Figure 1).

At 5 DALA, the severity of *Alternaria* leaf blight was significantly reduced in all treatments compared to the control. The highest levels of control were obtained from treatments with the fungicides fluxapyroxad + pyraclostrobin, pyraclostrobin + metiram, boscalid, boscalid + kresox-

im-methyl, and copper hydroxide, which had similar effects and were more effective than azoxystrobin.

At 12 DALA, fluxapyroxad + pyraclostrobin showed the highest residual of control, which was higher than treatments with boscalid + kresoxim-methyl, copper hydroxide, and azoxystrobin, but similar to the effectiveness of pyraclostrobin + metiram and boscalid. Boscalid + kresoxim-methyl and copper hydroxide showed intermediate effects and azoxystrobin was the least effective treatment.

The fluxapyroxad + pyraclostrobin treatment presented an AUDPC lower than copper hydroxide and azoxystrobin but a similar AUDPC to the other fungicide treatments.

**Table 1. Severity (0 to 100%) and area under the disease progress curve (AUDPC) of *Alternaria* leaf blight in carrot crops (cv. Verano) treated with various fungicides in Andradas, Minas Gerais, 2017.**

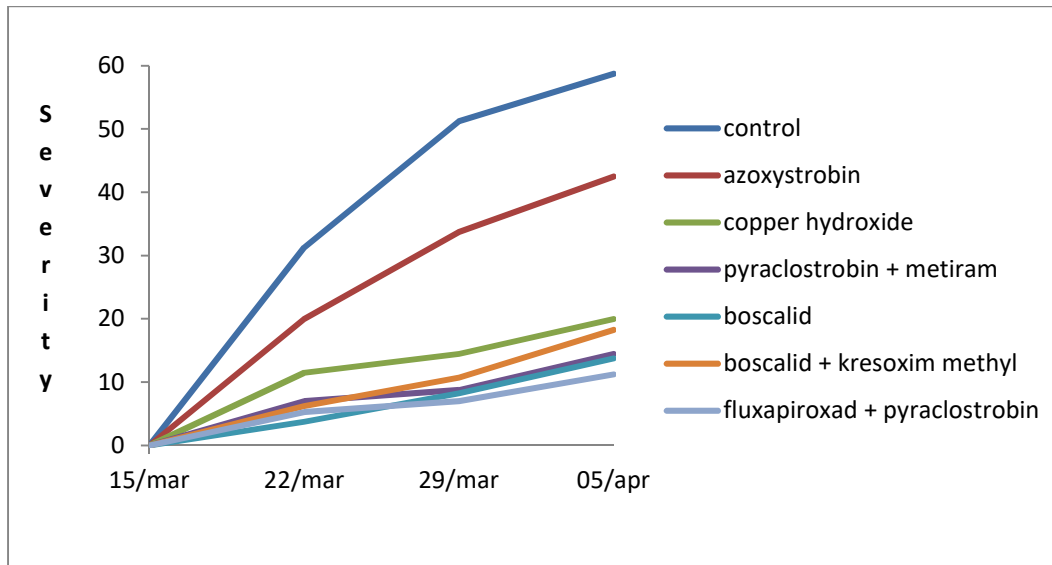
Treatments	Severity		AUDPC
	5 DALA*	12 DALA*	
Control	51.25 a	58.75 a**	783.25 a
Azoxystrobin (0.12 kg/ha)	33.75 b	42.50 b	515.25 b
Copper hydroxide (1.5 kg/ha)	14.50 c	20.00 c	252.25 c
Pyraclostrobin + metiram (2 kg/ha)	8.75 c	14.50 cd	161.50 cd
Boscalid (0.15 kg/ha)	8.25 c	13.75 cd	132.25 cd
Boscalid + kresoxim-methyl (0.5 L/ha)	10.75 c	18.25 c	183.00 cd
Fluxapyroxad + pyraclostrobin (0.3 L/ha)	7.00 c	11.25 d	121.75 d
CV (%)***	20.97	11.62	17.66

\* DALA: Days after last application.

\*\* Means followed by the same letter do not differ according to the Tukey test at 5% significance.

\*\*\* Coefficient of variation

**Figure 1. Progression of Alternaria leaf blight in carrot crops (cv. Verano) treated with various fungicides in Andradas, Minas Gerais, 2017. Severity: 0 to 100%.**



The observed effectiveness of the fluxapyroxad + pyraclostrobin treatment in the present study can be attributed to the high protective and systemic action of the mixture and by the association of two distinct mechanisms of action. Both fungicides block energy production in the fungal cells, although they act at different sites of the Krebs Cycle (TÖFOLI et al., 2016a). The carboxamide fluxapyroxad acts in the Complex II enzyme complex through the inhibition of the enzyme succinate dehydrogenase, whereas the strobilurin pyraclostrobin acts in Complex III as an inhibitor of electron transport in the mitochondria, which prevents the formation of ATP (SAUTER, 2007; FRAC, 2019). The blocking of energy production reflects directly on the germination of conidia, elongation of the germination

tube, formation of appressoria, mycelial growth, and sporulation. The simultaneous action in two metabolic steps of the same physiological process reduces the occurrence of resistance and is highly recommended for the intercalated use of fungicides with different mechanisms of action (TÖFOLI et al., 2016a).

The high efficacy of isolated or mixed boscalid fungicide in Andradas was also reported by GALENS et al. (2005). This fungicide belongs to the class of carboxamides and presents the same mechanism of action as fluxapyroxad. It is characterized by a broad spectrum of action at all stages of development of ascomycetes, basidiomycetes, and mitosporic fungi (JACOBELIS JR., 2015; FRAC, 2019).

In general, the strobilurins pyraclostrobin and azoxystrobin are considered effective in the control of the *Alternaria* leaf blight in carrot crops (FARRAR et al., 2004, DORMAN, 2009; MARINGONI et al., 2012). In the present study, the application of pyraclostrobin mixed with metiram resulted in a control similar to the carboxamides and better than azoxystrobin. This finding differed from the results obtained by SIVIERO et al. (2004), but was consistent with those of MARINGONI et al. (2012).

It is noteworthy that, in addition to reducing the severity of diseases, strobilurins and carboxamides have been reported to increase productivity and the quality of production. These positive effects on plant physiology are mainly attributed to the increase in chlorophyll content (green effect), increase in nitrate reductase enzyme activity, increase in antioxidant production, and the decrease in ethylene production. These results have been observed in several crops, such as tomato (TÖFOLI et al., 2003a; TÖFOLI et al., 2003b; RAMOS 2013, JACOBELIS JR., 2015), potato (TÖFOLI et al., 2016b), soybean (CARIJJO, 2014), Muskmelon (MACEDO, 2012), cucumber (AMARO, 2011), among others. MARINGONI et al. (2012) studied carrot crops and found that pyraclostrobin alone and in combination with metiram were not only the most effective control

substances for *Alternaria* leaf blight but were also able to produce heavier roots with increase soluble solids content. These authors also emphasized that, although azoxystrobin was less efficient in controlling the disease, it did positively influence the soluble solids content of the roots. Likewise, COLOMBARI et al. (2015) observed that the application of boscalid in areas of high fertility favored the production of longer roots and that pyraclostrobin increased the production of leaves per plant at the end of the cycle.

In the present study, copper hydroxide showed a considerable level of *Alternaria* control, which was inferior to the fluxapyroxad + pyraclostrobin treatment, similar in effectiveness to boscalid, boscalid + kresoxim-methyl, pyraclostrobin + metiram, and superior in effectiveness to azoxystrobin. Belonging to the class of copper fungicides, copper hydroxide is characterized by a good protective action and by having a considerable adherence to the leaf surface. Copper ions act by inactivating particular enzymes with sulfhydryl, hydroxyl, or carboxyl groups, thus causing a generalized disorder in the cell metabolism (TÖFOLI et al., 2013). The nonspecific action of the copper hydroxide makes it an indispensable tool in programs for the intercalated use of fungicides and to avoid the occurrence of resistant strains.

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