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COPPER OXYCHLORIDE APPLIED ALONE TO CONTROL CITRUS BLACK SPOT[1]

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ABSTRACT – Citrus black spot (CBS) is a disease caused by the *Phyllosticta citricarpa* fungus that causes lesions in fruits and, in more severe stages, fruit drops. The use of systemic fungicides is the main control measure for CBS; however, an alternative control measure is the use of cupric fungicides applied alone with short intervals. Therefore, the objective of the present work was to evaluate the effect of applications of copper oxychloride at different rates on the control of CBS. The experiment was conducted in Bebedouro, SP, Brazil, in the 2014/2015 crop season, in a randomized block design, using a *Citrus sinensis* variety (Valencia). The treatments consisted of copper rates (zero - control; 31, 24.5, 18.5, 12.2, and 9.1 mg of metal copper per cubic meter of canopy) using copper oxychloride (concentrated suspension - CS; 588 g L^{-1} of copper oxychloride or 350 g L^{-1} of metal copper), and an additional treatment with application of a cupric fungicide (cuprous oxide) and a strobilurin fungicide. The applications were carried out with 14-day intervals, starting when 2/3 of the petals of the plant's flowers were fallen, totaling 14 applications. The incidence and severity of CBS were evaluated five times with 30-day intervals up to mid-November, when the fruits were harvested. The data were used to calculate the area under the disease progress curve (AUDPC). Applications of copper oxychloride CS at rates of 31 and 24.5 mg m^{-3} with 14-day intervals are efficient for the control of CBS, with similar efficiency to the farm standard treatment.

Keywords: *Citrus sinensis.* Chemical control. Fungicide. *Phyllosticta citricarpa.*

APLICAÇÃO ISOLADA DE OXICLORETO DE COBRE NO CONTROLE DA MANCHA PRETA DOS CITROS

RESUMO – A Mancha Preta dos Citros causada pelo fungo *Phyllosticta citricarpa* é uma doença que causa lesões em frutos e queda prematura em estágios mais severos. O uso de fungicidas sistêmicos é a principal medida de controle, porém a busca por um controle alternativo pode envolver a aplicação de fungicidas cúpricos isoladamente, em intervalos reduzidos. Sendo assim, o trabalho teve como objetivo verificar o controle de MPC mediante a aplicação de oxicloreto de cobre em diferentes concentrações. O experimento foi instalado no município de Bebedouro/SP durante a safra 2014/15, variedade 'Valência', em delineamento em blocos casualizados. Os tratamentos foram constituídos pelas concentrações: zero (testemunha), 31; 24,5; 18,5; 12,2 e 9,1 mg de cobre metálico/m^3, tendo como referência o fungicida oxicloreto de cobre (588 g L^{-1} de oxicloreto de cobre ou 350 g de cobre metálico; formulação SC) e, um tratamento adicional, constituído pela aplicação do fungicida cúprico óxido cuproso e fungicida do grupo da estrobilurina. As aplicações foram realizadas em intervalos de catorze dias, iniciando em 2/3 pétalas caídas, perfazendo um total de 14 aplicações. Foram realizadas cinco avaliações de incidência e severidade em intervalos de 30 dias, estendendo-se até meados de novembro, quando foi realizada a colheita dos frutos. A partir desses dados foi calculada a área abaixo da curva de progresso da doença (AACPD). Concluiu-se que aplicações em intervalos de catorze dias de oxicloreto de cobre SC a 31 e 24,5 mg/m^3 copa, foram eficientes no controle de MPC, cuja eficiência foi comparável ao tratamento padrão.

Palavras chave: *Citrus sinensis.* Controle químico. Oxicloreto de cobre. *Phyllosticta citricarpa*.

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INTRODUCTION

Brazil is one of the world's largest citrus producing countries and São Paulo is the Brazilian largest citrus producing state. The total citrus plants in the 2018/2019 crop season was estimated in 175.26 million, including producing and growing ones, with an estimated production of 284.88 million of 40.8-kilo boxes (FUNDECITRUS, 2018).

Citrus industry is important for the Brazilian economy because it generates millions of jobs; however, the sector have facing phytosanitary problems over the years, especially diseases, that have caused negative impacts on citrus fruit production and marketing. Citrus black spot (CBS) is a disease caused by the *Phyllosticta citricarpa* fungus (*Guignardia citricarpa* Kiely at its cytomorphic phase) that causes qualitative and quantitative damages to citrus crops (SILVA JUNIOR et al., 2016).

Qualitative damages caused by CBS can depreciate the fruit peels and make it impossible to export them to European Union countries, where this fungus is a quarantine pest (A1); quantitative damages due to early fruit drops reduce plant fruit yield (SILVA JUNIOR et al., 2016).

All citrus species of economic importance, especially sweet orange varieties, are susceptible to CBS (SILVA JUNIOR et al., 2016). Citrus fruits are susceptible from the beginning of the fruiting until the maturation stage (AGUIAR et al., 2012).

Symptoms of CBS are caused by conidia formed in dry branches and in fruits, and by ascospores from fallen leaves at initial decomposition phases (SILVA JUNIOR et al., 2016; McONIE, 1964; KOTZÉ, 2000). Both inoculum sources are present mainly between spring and early autumn, which is the essential period to control the pathogen.

CBS management is carried out through chemical control and complemented by cultural practices such as weed management (SCALOPPI et al., 2012), acceleration of decomposition of fallen leaves, intercropping (BELLOTTE et al., 2009; BELLOTTE et al., 2013), and pruning (NOZAKI, 2007).

Fungicide application is the main control measure for CBS, which is essential to maintain high fruit yields. Cupric fungicides are usually applied with 28-day intervals to control citrus scab (*Elsinoe fawcettii* and *E. australis*) and melanose (*Diaporthe citri*) (TIMMER; BROWN 2000). Strobilurin fungicides are usually applied combined with mineral or plant oils, using 42-day intervals (SILVA JUNIOR et al., 2016).

Some cupric fungicides are approved for control of *P. citricarpa* in citrus plants and are routinely used. Applications of these fungicides with 28-day intervals have been inefficient in areas with many inoculum sources, late-maturing varieties, and frequent rains (MOTTA, 2009). Therefore, studies evaluating smaller intervals and fractionated rates of cupric fungicides are necessary.

Citrus plantations are managed, in general, with biweekly insecticide applications in critical population periods of *Diaphorina citri* (Psyllidae), a vector of *Candidatus Liberibacter asiaticus* (Las) and *Candidatus Liberibacter americanus* (Lam), which cause the citrus greening disease. Moreover, cupric fungicides are used at shorter intervals in areas with history of citrus canker to minimize the incidence of *Xanthomonas citri* subsp. *citri* in leaves and fruits (BEHLAU et al., 2010).

In this context, the objective of this work was to evaluate the effect of different rates of a cupric fungicide (copper oxychloride) applied alone with 14 -day intervals on the control of citrus black spot.

MATERIAL AND METHODS

The experiment was conducted at a citrus farm in Bebedouro, SP, Brazil (21°29'41"S, 48°30'63"W), in the 2014/2015 crop season. Cuttings from 15-year-old orange trees (*Citrus sinensis*) of the Valencia variety were grafted onto lemon trees (*Citrus limonia*) planted with spacing of 7.0 by 3.0 m. A randomized block design was used, with plots consisted of 3 rows of 15 plants, totaling 45 plants per plot.

Copper oxychloride fungicide (COC) (concentrated suspension - CS; 588 g L^{-1} of copper oxychloride or 350 g L^{-1} of metal copper) were applied at different rates and compared with the farm standard treatment (FST)—cuprous oxide (CO) (wet powder - WP; 860 g kg^{-1}) applied at rate of 21 mg m^3 (mg of metal copper per cubic meter of canopy), when the plants were at the F2 stage (fruits at initial development, with diameter between 5 to 10 mm) and F3 stage (fruits with diameter between 15 and 20 mm), associated with four applications of a strobilurin fungicide (emulsifiable concentrate - EC; pyraclostrobin 250 g L^{-1}) at rate of 2.8 mg a.i. m^{-3} with 35-day intervals (Table 1), according to technical recommendation to control citrus black spot (CBS) (SILVA JUNIOR et al., 2016).

Table 1. Treatments and application intervals of chemical fungicides on citrus plants to control citrus black spot.

Treatments	Concentration (mg of metal copper per cubic meter of canopy)	Application interval	Number of applications	Quantity of metal copper (mg of metal copper per cubic meter of canopy per year)
OCO	31.0	14	14	434
OCO	24.5	14	14	343
OCO	18.5	14	14	259
OCO	12.2	14	14	170.8
OCO	9.1	14	14	127.4
FST	21 + 2.8	42	4	84
Control	-	-	-	-

COC = copper oxychloride; FST = farm standard treatment (*cuprous oxide + pyraclostrobin).*

The evaluations consisted in determining the incidence and severity of CBS in 200 fruits randomly collected from four plants in the center of each plot. Five evaluations were carried out with 30-day intervals from mid-July to mid-November when fruits were harvested. Severity of CBS was evaluated using a diagrammatic scale for estimating hard spot, considering the scores 1 = 0.5%, 2 = 1.7%, 3 = 5.0%, 4 = 11.5%, 5 = 22.5%, and 6 = 49.0% for the injured area (SPÓSITO et al., 2004). These data were used in the Wheeler's formula (1969) to determine the disease index (DI):

$$ID = \frac{1}{N}\sum_{i=0}^{m} i.n_i$$

where *ID* is the disease index; *N* is the total number of evaluated fruits; *i* is the score of the disease, *ni* is the number of fruits with score *i*; and *m* is the maximum score.

The area under the disease progress curve (AUDPC) was calculated for the incidence and severity of CBS, and the data were subjected to analysis of variance and statistically compared by the Tukey' test at 5% significance using the AgroEstat 1.0 program (BARBOSA; MALDONADO JUNIOR, 2015). The data were subjected to analysis of variance for linear regression to determine the cupric fungicide rates, according to linear response of the incidence and severity of CBS, applied to the AUDPC values, and fruit yield (kg plant^{-1}).

RESULTS AND DISCUSSION

Plants treated with application of copper oxychloride at 31 and 24.5 mg m^{-3} with 14-day intervals (14 applications) to control citrus black spot (CBS) had fruits with lower symptom scores up to the fourth evaluation (October,2015), mainly when compared to the farm standard treatment (FST) (cuprous oxide + *pyraclostrobin*), indicating the higher efficiency of these treatments over the FST (Table 2). The protection period of these treatments was higher than 180 days, consequently, they decreased fruit drop in the period with common occurrence of injuries near the plant's peduncles (AGUIAR, 2010).

The critical period of susceptibility of sweet orange fruits to the fungus *Phyllosticta citricarpa* is from the petal-fall stage (KOTZÉ, 1981) to the fruit maturation stage (AGUIAR et al., 2012), comprising more than 200 days. However, fruit susceptibility level gradually decreases with maturation (KOTZÉ, 1981).

The best response for the control of CBS in the subsequent weeks (fifth evaluation) was found with the use of cuprous oxide + pyraclostrobin (FST).

The incidence and severity of CBS were high for all treatments, increasing with the fruit maturation. It is consistent with data in the literature for late-maturing sweet oranges varieties grown in areas with many inoculum sources (SPÓSITO et al., 2004). The incidence of symptomatic fruits in the fifth and last evaluation was 89.6%, whereas in the FST it was 54.8%. Treatments with copper oxychloride (COC) presented incidence of symptomatic fruits of 65.8% to 82%, even using applications with 14-day intervals.

The severity of CBS had similar results to those of the incidence, with progress between the first and fifth evaluations (Table 3). The best control of CBS was found using the treatments with the highest COC rates (31 and 24.5 mg m^{-3}), which were similar to each other and to the FST, and better than the control. The treatments with COC at rates of 9.1 and 12.2 mg m^{-3} differed from the control in the third and fifth evaluations, respectively.

Table 2. Incidence of citrus black spot (*Phyllosticta citricarpa*) in orange plants of the Valencia variety, expressed as percentage of symptomatic fruits as a function of copper oxychloride rates and cuprous oxide + pyraclostrobin rate, in five evaluation times.

Treatment	Rate	Evaluation times				
		07/2015	08/2015	09/2015	10/2015	11/2015
		Incidence of the symptoms of citrus black spot (%)				
COC	9.1	40.7 bcC	45.5 abC	62.8 bB	66.3 bB	82.0 abA
COC	12.2	43.1 abC	41.0 abC	62.8 bB	64.5 bB	81.3 abA
COC	18.5	28.7 cdC	34.4 bcC	48.8 cB	48.4 cB	75.5 bcA
COC	24.5	22.0 dcC	27.4 cBC	34.0 dB	36.6 cdB	67.5 cdA
COC	31.0	14.0 eC	22.8 cBC	34.2 dB	33.0 dB	65.8 cA
CO + PC	21.0 + 2.8	35.7 bcBC	28.5 cC	40.8 cdB	45.0 cdAB	54.8 dA
Control	-	47.0 aC	54.2 aC	77.3 aB	80.5 aAB	89.6 aA

COC = copper oxychloride (588 g L^{-1}); CO = cuprous oxide (860 g kg^{-1}); PC = pyraclostrobin (250 g L^{-1}); Rates in mg of metal copper per cubic meter of canopy. Means followed by the same lowercase letters in the columns or same uppercase letters in the rows do not differ by the Tukey's test ($P \geq 0.05$).

The severity of CBS in these treatments was lower than those reported as crucial for fruit drop (FAGAN; GOES, 1999). High severity of CBS tends to cause lesions on the fruit surface, including near the peduncle; however, fruit drop can occur even at low severities that originate from late infections.

Cupric fungicides applied sequentially can cause darkening of injury spots resulting from the action of insects, mites, and wind (SCHUTTLE; KOTZÉ, 1997). In addition, cupric fungicides can cause injuries that, together with the fruit scars, make the fruit peel look undesirable when the fruit is intended for fresh fruit markets. Cupric fungicides based on copper hydroxide result in further damage to the fruit peel (SCHUTTLE; KOTZÉ, 1997).

No apparent phytotoxicity symptoms were found, even when using the highest COC rates with 14 applications. This is related to the formulation of the copper oxychloride product (SC) because it contains surfactants as adhesive and hydro-resistant agent that do not stain the fruits, and improve the performance of the droplets in the application by reducing their evaporation and increasing their retention time on the target (FONSECA et al., 2016).

Table 3. Severity of citrus black spot (*Phyllosticta citricarpa*) in orange plants of the Valencia variety, expressed as percentage of symptomatic fruits as a function of copper oxychloride rates and cuprous oxide + pyraclostrobin rate, in five evaluation times.

Treatments	Rates	Evaluation times				
		07/2015	08/2015	09/2015	10/2015	11/2015
		Severity of the symptoms of citrus black spot (%)				
COC	9.1	0.73 abD	0.84 aCD	1.21 bBC	1.43 aB	2.06 bA
COC	12.2	0.79 abC	0.79 abC	1.12 bcBC	1.34 aB	1.86 bA
COC	18.5	0.42 bcdB	0.56 abcB	0.75 cdB	0.69 bB	1.38 cA
COC	24.5	0.25 cdB	0.38 bcB	0.45 dB	0.51 bAB	0.90 dA
COC	31.0	0.16 dB	0.25 cB	0.43 dB	0.43 bB	0.95 dA
CO + PC	21.0 + 2.8	0.63 abcA	0.58 abcA	0.61 dA	0.69 bA	0.81 dA
Control	-	0.93 aC	0.86 aC	1.73 aB	1.76 aB	2.99 aA

COC = copper oxychloride (588 g L^{-1}); CO = cuprous oxide (860 g kg^{-1}); PC = pyraclostrobin (250 g L^{-1}); Rates in mg of metal copper per cubic meter of canopy. Means followed by the same lowercase letters in the columns or same uppercase letters in the rows do not differ by the Tukey's test ($P \geq 0.05$).

The area under the disease progress curve (AUDPC) of all treatments with fungicides were greater than that of the control (Table 4). The treatment with COC at rate of 31.0 mg m^{-3} presented efficient control, more efficient than the FST, when considering the incidence and severity of CBS. The treatment with COC at 24.5 mg m^{-3} was also efficient, presenting similar results to those of the treatments COC at 31.0 mg m^{-3} and FST.

The fungicide applications were carried out following technical criteria for uniformity, intervals between applications, volume of the solution applied, and technical details; however, a complete protection of fruits is difficult to achieve because of difficulties of reaching the target uniformly, since the conidia and ascospores are spread randomly on the fruits (ALMEIDA, 2009). Moreover, spraying devices have technical limitations that make them unable to generate uniform sprays and produce droplets that reach all the fruit surfaces; and long exposure period of the fruits to the inoculum (higher than 180 days) (AGUIAR et al., 2012) and the occurrence of rains directly and indirectly affect the efficiency of treatments.

Table 5 shows the results of the regression analysis for incidence and severity of CBS and fruit production; and Figures 1, 2, and 3 show the response curves of these variables to different copper oxychloride rates. The results of all analyzed variables were significant, fitting to the linear model, thus, it was not possible to determine the rate of maximum protective effect.

The plants treated with the lowest rates of copper oxychloride were more susceptible to the pathogen. The results showed a linear decrease in the incidence of CBS with increasing copper oxychloride rates (Figure 1).

The severity of CBS was higher in the control and in treatments with copper oxychloride at rates of 9.1 and 12.2 mg m^{-3}, which had potential for fruit drop (Figure 2, and Tables 3 and 6). The percentages of control in treatments with copper oxychloride at rates of 24.5 and 31.0 mg m^{-3}, considering the AUDPC of severity, were 69.4% and 73.3%, respectively.

Table 4. Area under the disease progress curve (AUDPC) for incidence and severity of citrus black spot (*Phyllosticta citricarpa*) in orange plants of the Valencia variety grown under conditions of natural infestation in Bebedouro, SP, Brazil, in the 2014/2015 crop season.

Treatments	Rates (mg m^{-3})	AUDPC	
		Incidence	Severity
COC	9.1	7076.2 b	146.69 b
COC	12.2	6913.1 b	137.43 b
COC	18.5	5508.7 c	87.51 c
COC	24.5	4256.2 de	57.78 de
COC	31.0	3926.2 e	50.43 e
CO + PC	21.0 + 2.8	4785.0 d	78.30 cd
Control	-	8300.6 a	189.31 a
F value		170.64**	79.62**
CV (%)		8.61	21.74

COC = copper oxychloride (588 g L^{-1}); CO = cuprous oxide (860 g kg^{-1}); PC = pyraclostrobin (250 g L^{-1}); Rates in mg of metal copper per cubic meter of canopy; CV = coefficient of variation. Means followed by the same letter in the columns do not differ by the Tukey's test ($P \geq 0.05$).

Table 5. Regression by analysis of variance of the area under the disease progress curve (AUDPC)—for citrus black spot (*Phyllosticta citricarpa*)—and yield (kg $plant^{-1}$) of orange plants (Valencia variety) subjected to different copper oxychloride rates.

Variables	Equation model	Equation	CV (%)	F Test	R^2
Incidence - AUDPC	Linear	$y = -37.829x + 8439.96$	5.64	212.32**	89.91%
Severity- AUDPC	Linear	$y = -1.2042x + 189.29$	10.77	188.48**	89.55%
Yield	Linear	$y = 0.30158x + 60.6739$	8.70	28.29**	58.49%

The treatments with COC at rates of 24.5 and 31.0 mg m^{-3} and the FST treatment had similar fruit yield. The plants in treatments with the lowest AUDPC for incidence and severity of CBS had the highest fruit yields (Table 6). The less efficient treatments for the control of *P. citricarpa* (COC at 9.1 and 12.2 mg m^{-3}) had the lowest yields (Figure 3).

The severity of CBS increased with fruit maturation, resulting in progressive fruit drops, especially between the last two evaluations (October and November) (Tables 3 and 4).

The application of cupric fungicides (protective) at early stages of fruit development (high growth rates) and with 14-day intervals hinders the contact of the pathogen with the plant tissues, suppressing the pathogen at pre-penetration stages, thus, reducing the disease progress. When the application intervals are longer (28 days), the fruits may be unprotected due to the appearance of new tissues, which can increase the infection (SILVA JUNIOR et al., 2016).

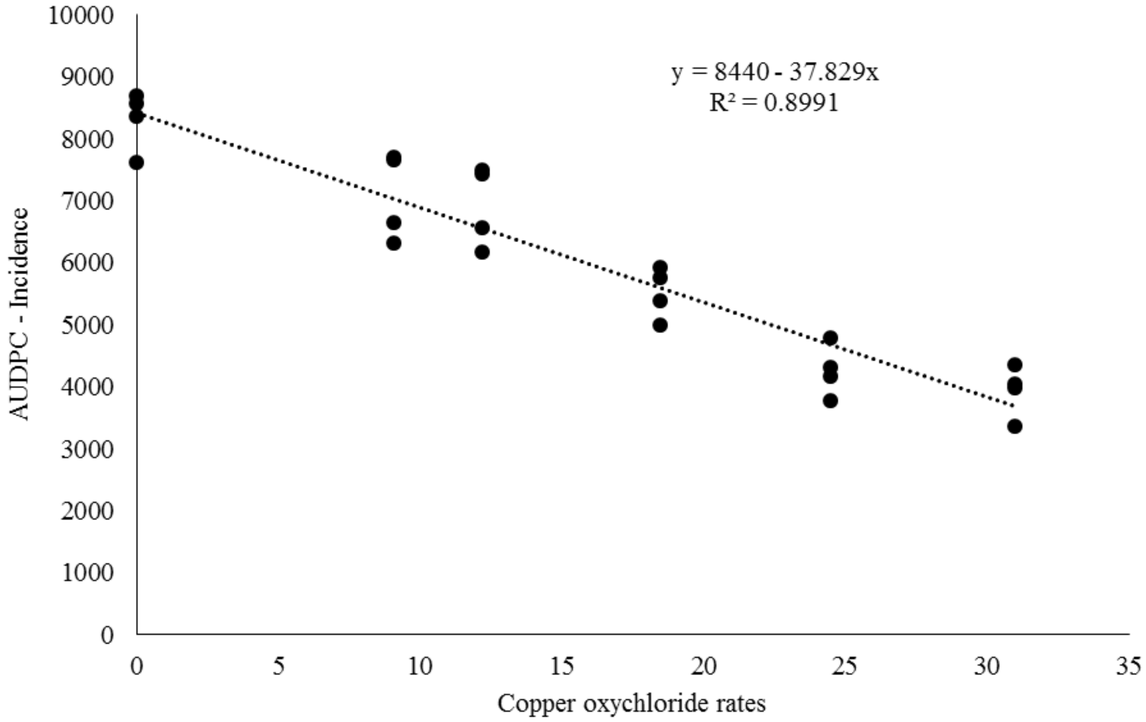

Figure 1. Graphical regression modeling by analysis of variance of the area under the disease progress curve (AUDPC) for incidence of citrus black spot (*Phyllosticta citricarpa*) in orange plants (Valencia variety) subjected to different copper oxychloride rates (mg of metal copper per cubic meter of canopy).

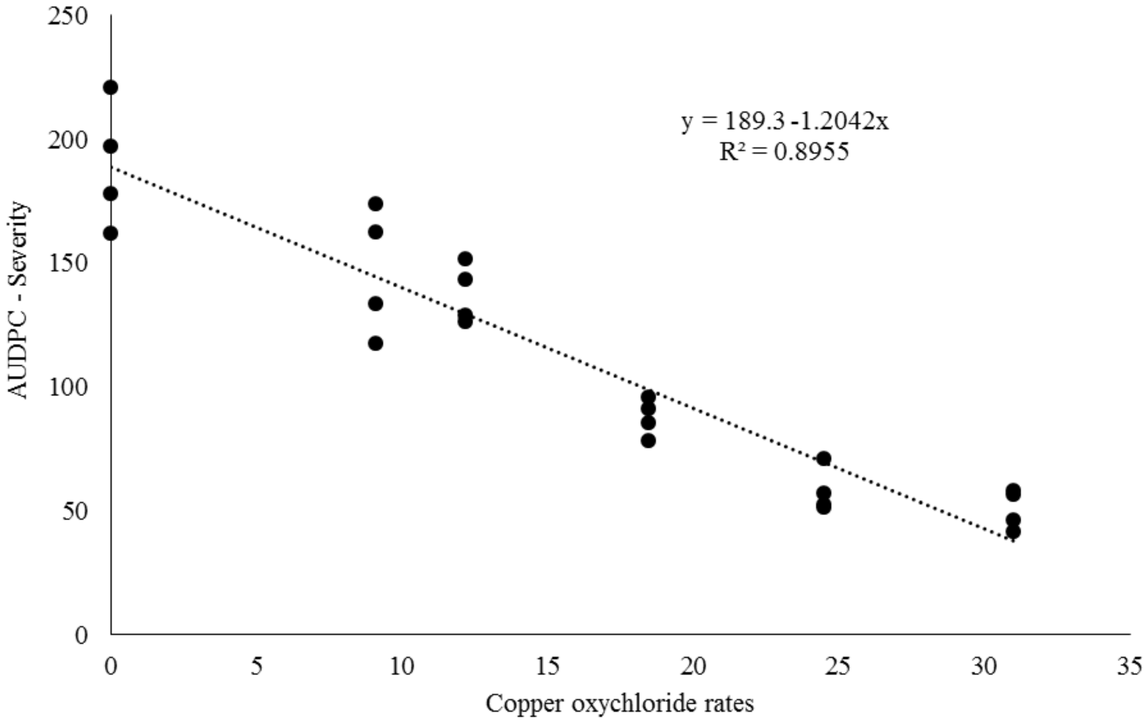

Figure 2. Graphical modeling of the regression by analysis of variance of the area under the disease progress curve (AUDPC) for severity of citrus black spot (*Phyllosticta citricarpa*) in orange plants (Valencia variety) subjected to different copper oxychloride rates (mg of metal copper per cubic meter of canopy).

According to Silva Júnior et al. (2016), reducing the application intervals of cupric fungicides from 25 days to 20 days decreases their efficiency in controlling the pathogen when the number of applications is maintained. However, their efficiency is maintained when the protection period is compensated by increasing the number of applications. Thus, managements with lower intervals between applications require a higher number of applications to maintain the ideal protection period.

Spring months in the state of São Paulo, Brazil, present significant increasing temperature; this favors the maturity of Valencia oranges, but increases the severity of CBS and fruit drop (FEICHTENBERGER, 1996).

The highest fruit yields were obtained when using COC at rates of 24.5 and 31.0 mg m^{-3} and the FST (CO + pyraclostrobin); the percentages of fruit drop of these treatments were 12, 3%, 11.6%, and 9.3%, respectively. The control treatment presented the highest accumulated percentage of fruit drop (28.1%) by the end of the evaluations, which resulted in lowest fruit yield (Table 6).

This low yield shows that the control treatment probably had early fruit drop before the fruit drop evaluations. The hypothesis of Kotzé (1996) that even with few lesions, fruit drops can occur, indicates an effect of infections in the fruit peduncles.

Table 6. Fruit yield and fruit drop in orange trees (Valencia variety) subjected to different copper oxychloride rates to control citrus black spot (*Phyllosticta citricarpa*) under conditions of natural infestation in Bebedouro, SP, Brazil.

Treatments	Rates (mg m^{-3})	Fruit yield (kg $plant^{-1}$)^X	Difference from the control^Y (%)	Fruit drop (%)
COC	9.1	67.1 cd	9.6	25.4
COC	12.2	86.7b	41.6	19.1
COC	18.5	69.1 c	12.9	20.1
COC	24.5	100.9 a	64.9	12.3
COC	31.0	95.9 a	56.7	11.6
CO + PC	21.0 + 2.8	102.3 a	67.2	9.3
Control	-	61.2 d	-	28.1
F value		111.20**	-	-
CV (%)		7.87	-	-

COC = copper oxychloride (588 g L^{-1}); CO = cuprous oxide (860 g kg^{-1}); PC = pyraclostrobin (250 g L^{-1}); Rates in mg of metal copper per cubic meter of canopy; CV = coefficient of variation. Means followed by the same letter in the columns do not differ by the Tukey's test ($P \geq 0.05$). ^{X}= data related to average fruit weight of four plants in the plots. ^{Y}= data obtained according to the ABBOTT formula (1925). Rates in mg of metal copper per cubic meter of canopy.

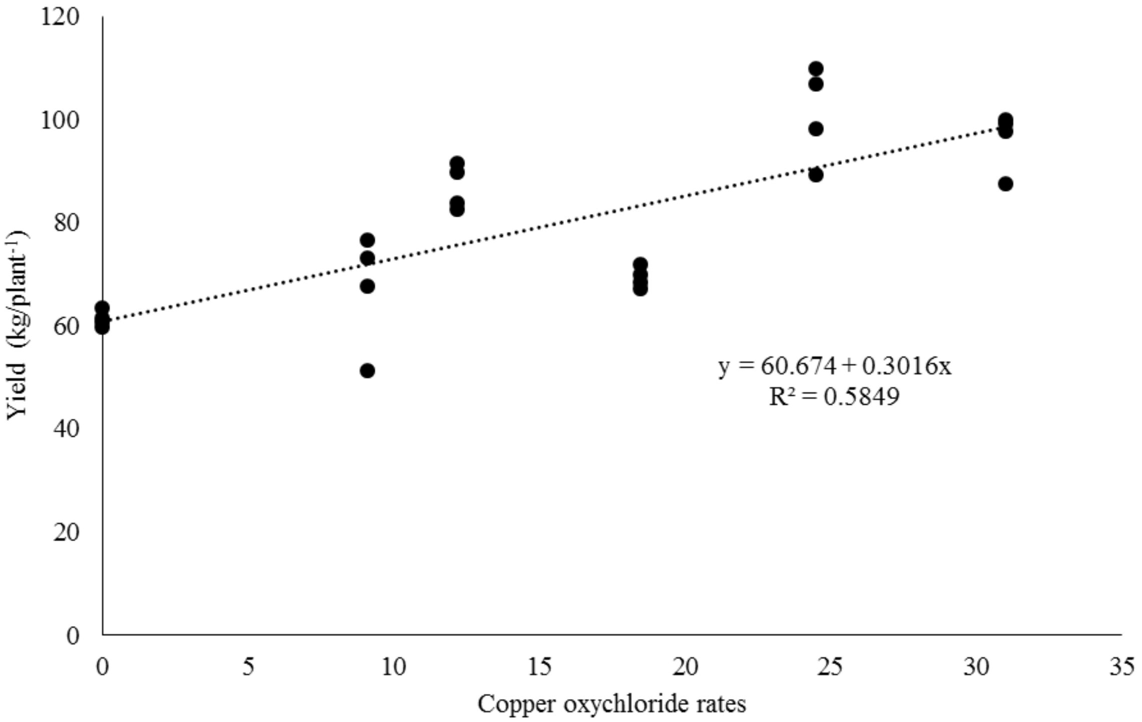

Figure 3. Graphical modeling of regression by analysis of variance of fruit yield (kg $plant^{-1}$) of orange plants (Valencia variety) subjected to different copper oxychloride rates (mg of metal copper per cubic meter of canopy).

Considering that the use of insecticides to control *Diaphorina citri* is carried out biweekly, the adoption of simultaneous use of copper oxychloride is an efficient alternative to control *P. citricarpa*.

The application of copper oxychloride alone is a practical and coherent way for the control of CBS and for the preventive control of diseases that limit the Brazilian citriculture, especially in the state of São Paulo. Thus, the protection of fruits with applications of copper oxychloride with 14-day intervals up to the end of the rainy season is important to reduce incidence and severity of CBS and fruit drop in citrus plants.

CONCLUSION

The use of copper oxychloride fungicide (588 g L^{-1} of copper oxychloride or 350 g of metal copper; concentrated solution formulation) applied alone at rates of 24.5 and 31.0 mg of metal copper per cubic meter of canopy, with 14-day intervals, is efficient to control citrus black spot.

REFERENCES

ABBOTT, W. S. A. Method of computing the effectiveness of an insecticide. **Journal of Economic Entomology**, v. 18, n. 2, p. 265-266, 1925.

AGUIAR, R. L. **Produção de anticorpo policional para caracterização de *Phyllosticta citricarpa* em tecidos lenhosos de citros**. 2010. 84 f. Tese (Doutorado em Agronomia: Área de Concentração em Produção Vegetal) – Universidade Estadual Paulista, Jaboticabal, 2010.

AGUIAR, R. L. et al. Período de incubação de *Guignardia citricarpa* em diferentes estádios fenológicos de frutos de laranjeira 'Valência'. **Tropical Plant Pathology**, v. 37, n. 2, p. 155-158, 2012.

ALMEIDA, T. F. **Mancha preta dos citros: Expressão dos sintomas em frutos pela inoculação com conídios e controle do agente causal (*Guignardia citricarpa*)**. 2009. 66 f. Tese (Doutorado em Agronomia: Área de Concentração em Produção Vegetal) – Universidade Estadual Paulista, Jaboticabal, 2009.

BARBOSA, J. C.; MALDONADO JR, W. **Experimentação Agronômica e AgroEstat - Sistema para Análises Estatísticas de Ensaios Agronômicos**. Jaboticabal: Gráfica Multipress Ltda, 2015. 396 p.

BEHLAU, F. et al. Effect of frequency of copper applications on control of citrus canker and the yield of young bearing sweet orange trees. **Crop Protection**, v. 29, n. 3, p. 300-305, 2010.

BELLOTTE, J. A. M. et al. Aceleration of the decomposition of Sicilian lemon leaves as an auxiliary measure in the control of citrus black spot. **Fitopatologia Brasileira**, v. 34, n. 2, p. 71-76, 2009.

BELLOTTE, J. A. M. et al. The effects of inter-crop cultivation Between rows of citrus crop on spreading of *Guignardia citricarpa* Ascospores and in the citrus black spot occurrence. **Revista Brasileira de Fruticultura**, v. 35, n. 1, p. 102-111, 2013.

FAGAN, C.; GOES, A. Efeito da severidade da mancha preta dos frutos cítricos causada por *Guignardia citricarpa* na queda prematura de frutos de laranja 'Natal'. **Fitopatologia Brasileira**, v. 24, n. 1, p. 282, 1999.

FEICHTENBERGER, E. Mancha Preta ou Pinta Preta dos Citros. **Laranja & Cia**, Matão, v. 43, n. 1, p. 10-11, 1996.

FONSECA, A. E. et al. Tenacity and persistence of copper fungicides in citros seedlings under simulated rainfall. **Revista Caatinga**, v. 29, n. 3, p. 677-684, 2016.

FUNDO DE DEFESA DA CITRICULTURA - FUNDECITRUS. **RESULTADOS**: Reestimativa da safra de laranja 2018-2019 do cinturão citrícola de São Paulo e triangulo/Sudoeste Mineiro – Cenário em fevereiro de 2019. Araraquara, 2019. 2 p.

KOTZÉ, J. M. Epidemiology and control of citrus black spot in South Africa. **Plant Disease**, v. 65, n. 12, p. 945-50, 1981.

KOTZÉ, J. M. History and epidemiology of citrus black spot in South Africa. **Proceedings of the International Society Citriculture**, p. 1296-1299, 1996.

KOTZÉ, J. M. Citrus black spot. In: Timmer, L. W., Garnsey, S. M., Graham, J.H. (Ed.). **Compendium of Citrus Diseases**. Saint Paul, Minnesota: APS Press, 2000. v. 2, cap. 13, p. 23-25.

McONIE, K. C. The latent occurrence in citrus and other hosts of a *Guignardia* easily confused with *G. citricarpa*, the citrus black spot pathogen. **Phytopathology**, v. 54, n. 1, p. 40-43, 1964.

MOTTA, R. R. **Determinação do período residual de fungicidas protetores e sistêmicos parao controle de *Guignardia citricarpa* em frutos cítricos**. 2009. 70 p. Dissertação (Mestrado em Agronomia: Área de Concentração em Produção

Vegetal) - Universidade Estadual Paulista, Jaboticabal, 2009.

NOZAKI, M. H. **Produção de estruturas reprodutivas e efeito do ambiente nos tipos de sintomas produzidos por *Guignardia citricarpa* em *Citrus* spp**. 2007. 68 p. Tese (Doutorado em Agronomia: Área de Concentração em Produção Vegetal) - Universidade Estadual Paulista, Jaboticabal, 2007.

SCALOPPI, E. M. T. et al. Efeito do manejo cultural e químico na incidência e severidade da mancha-preta dos citros. **Revista Brasileira de Fruticultura**, v. 34, n. 1, p. 102-108, 2012.

SCHUTTLE, G. C.; KOTZÉ, J. M. Grass mulching as part in integrated control programme for the control of citrus black spot. **Citrus journal**, v. 7, n. 3, p. 18-20, 1997.

SILVA JUNIOR, G. et al. **Pinta preta dos citros**: a doença e o seu manejo. 1. ed. Araraquara, SP: FUNDECITRUS, 2016. 208 p.

SPÓSITO, M. B. et al. Elaboração e validação de escala diagramática para avaliação da severidade da mancha preta em frutos cítricos. **Fitopatologia Brasileira**, v. 29, n. 1, p. 81-85, 2004.

TIMMER, L. W.; BROWN, G. E. Biology and control of anthracnose diseases of citrus. In: PRUSKY, S.; FREEMAN, M.; DICKMAN, B. (Ed.). **Colletotrichum Host Specificity.** Saint Paul: Pathology, and Host-Pathogen Interaction, 2000. v. 1, cap. 17, p. 300–316.