

1 **SOURCES AND CONCENTRATIONS OF CUPRIC FUNGICIDES FOR THE**
2 **CONTROL OF CITRUS BLACK SPOT¹**

[RC1] Comentário: Título no máximo 15 palavras.

[RC2] Comentário: Na primeira versão do artigo submetido, os nomes dos autores e a nota de rodapé com os endereços deverão ser omitidos.

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6 **ABSTRACT** – Citrus black spot (CBS) is a severe disease for citriculture in the São Paulo
7 State, Brazil. Part of its management is focused on chemical control using cupric fungicides
8 and strobilurins. The objective of the present work was to evaluate the efficacy of three
9 sources and three concentrations of cupric fungicides (copper hydroxide, copper oxychloride
10 and cuprous oxide). Orange fruits of the Pera cultivar were bagged in the plants and the
11 treatment with cupric fungicide was applied. The fruits were inoculated (by spray) with
12 *Phyllosticta citricarpa* (1×10^4 conidia mL⁻¹) after 0, 7, 14, 21, and 28 days, and bagged again.
13 The evaluation of incidence and severity was did at the harvest time of fruits. A second
14 experiment was conducted under natural infection with the same treatments, consisting of
15 application of fungicides at the stages F1 (petal fall) and F2 (fruits with diameter of 1 cm),
16 using mechanized sprayer with mean flow of 7.35 L solution plant⁻¹. Subsequently, all
17 treatments received four applications of azoxystrobin (30 g ha⁻¹), plus mineral oil at 0.25%.
18 Four monthly evaluations were done to determine the CBS incidence and severity. The initial
19 applications with cupric fungicides are essential for the control of CBS; the fungicide copper
20 hydroxide showed the best control of CBS with the lowest rate of metallic copper (43.7 g of
21 Cu⁺⁺ 100 L⁻¹) in both experiments, regardless of the conduction conditions.

[RC3] Comentário: Abstract no máximo 250 palavras.

22
23 **Keywords:** *Citrus sinensis*. *Phyllosticta citricarpa*. Metallic copper.

[RC4] Comentário: A primeira letra maiúscula. Devem ter, no mínimo, três e, no máximo, cinco palavras, não constantes no Título/Title e separadas por ponto.

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26 **FONTES E CONCENTRAÇÕES DE FUNGICIDAS CÚPRICOS NO CONTROLE DA**
27 **MANCHA PRETA DOS CITROS**

[RC5] Comentário: Título no máximo 15 palavras.

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30 **RESUMO** – A mancha preta dos citros é uma doença severa para a citricultura do Estado de
31 São Paulo. Parte do seu manejo é focado no controle químico usando fungicidas cúpricos e
32 estrobilurinas. Este trabalho teve o objetivo de avaliar a eficácia de três fontes e três
33 concentrações de fungicidas cúpricos (hidróxido de cobre, oxiclureto de cobre e óxido
34 cuproso). Frutos de laranja 'Pera' foram ensacados nas plantas seguido de tratamento com

35 fungicida cúprico. Posteriormente, após zero; sete; 14; 21 e 28 dias tais frutos foram
36 inoculados com *Phyllosticta citricarpa* (1x10⁴ conídios mL⁻¹), por pulverização, seguido de
37 novo ensacamento. A avaliação da incidência e severidade da doença ocorreu na colheita dos
38 frutos. Um segundo experimento, sob infecção natural, foi constituído pelos mesmos
39 tratamentos, sendo os fungicidas aplicados nos estádios F1 (queda de pétalas) e F2 (frutos
40 com 1cm de diâmetro) mediante pulverização tratorizada e vazão média 7,35 L calda planta⁻¹.
41 Subsequentemente, e de forma semelhante para todos os tratamentos, foram realizadas quatro
42 aplicações de azoxistrobina (30 g de i.a./ha) acrescida de óleo mineral a 0,25%. Foram
43 realizadas quatro avaliações mensais para determinação da incidência e severidade dos
44 sintomas. Concluiu-se que: as pulverizações iniciais com fungicidas cúpricos são
45 fundamentais para o controle da mancha preta dos citros; independente das condições de
46 condução, para ambos os ensaios o fungicida hidróxido de cobre propiciou a melhor resposta
47 de controle da mancha preta dos citros com a menor dosagem de cobre metálico (43,7 g de
48 Cu⁺⁺100L⁻¹).

[RC6] Comentário: Resumo no máximo 250 palavras.

49
50 **Palavras-chave:** *Citrus sinensis*. *Phyllosticta citricarpa*. Cobre metálico.

[RC7] Comentário: A primeira letra maiúscula. Devem ter, no mínimo, três e, no máximo, cinco palavras, não constantes no Título/Title e separadas por ponto.

53 INTRODUCTION

54
55 **Citrus** black spot (CBS) is caused by the fungus *Phyllosticta citricarpa* McAlp.
56 (teleomorph: *Guignardia citricarpa* Kiely) (BALDASSARI; WICKERT; GOES, 2008), and
57 is associated with citrus plants in several countries in Africa, Asia, Oceania (KOTZÉ, 2000;
58 EPPO, 2017), South America and North America, and in Caribe (TIMMER et al., 2000;
59 SCHUBERT et al., 2010; HIDALGO and PÉREZ, 2010). All citrus varieties of economic
60 importance are susceptible to this fungus, with losses that can reach 40% of the production
61 (SILVA JÚNIOR et al., 2016).

[RC8] Comentário: Parágrafos: primeira linha 1 cm.

Especial: Por:
Primeira linha 1 cm

62 The control of CBS is done usually by using fungicides; in Brazil, it is controlled
63 mainly with use of cupric and strobilurin fungicides (MOTTA, 2009; VINHAS, 2011; SILVA
64 JÚNIOR et al., 2016). Cupric fungicides are commonly applied after petal fall, corresponding
65 to the stages F1 and F2, until the fruits reach diameter of 1 cm (STOLLER, 2010;), followed
66 by two to five applications of strobilurin fungicides (SCALLOPPI et al., 2012), covering the
67 more susceptible period for fruits (AGUIAR et al., 2012), from petal fall until the end of the
68 summer, when rainfall periods of more than 8 hours still occur. Ikeda (2011) reported

[RC9] Comentário: Veja as normas de citações em: <https://periodicos.ufersa.edu.br/index.php/caatinga/preparadosmanuscritos>.

Com 1(um) autor, usar Torres (2008) ou (TORRES, 2008); com 2 (dois) autores, usar Torres e Marcos Filho (2002) ou (TORRES; MARCOS FILHO, 2002); com 3 (três) autores, usar França, Del Grossi e Marques (2009) ou (FRANÇA; DEL GROSSI; MARQUES, 2009); com mais de três autores, usar Torres et al. (2002) ou (TORRES et al., 2002).

69 satisfactory responses of control of CBS to the use of five or six applications of cupric
70 fungicides combined or alternated with strobilurins.

71 Cupric fungicides are approved, for citrus plants, only for the control of citrus scab and
72 melanosis, except copper hydroxide (Kocide WDG Bioactive, Mitsui & Co. Brasil, S.A.)
73 (MAPA, 2017); however, they are used isolate or in combination with strobilurins for the
74 control of *P. citricarpa* (VINHAS, 2011). These fungicides are applied with four-week
75 intervals, beginning after $\frac{3}{4}$ of petals felled, and subsequently with 28-day intervals,
76 combined with application of strobilurins at 35-day to 42-day intervals (MOTTA, 2009). The
77 recommended rates of cupric fungicides are 0.75 to 1.25 g L⁻¹ for copper hydroxide, 2.5 g L⁻¹
78 for copper oxychloride, and 1.0 g L⁻¹ for cuprous oxide (MAPA, 2017). However, the rates
79 used at the stages F1 and F2, and in subsequent applications in combination with strobilurins
80 for the control of CBS under field conditions vary, and are usually based on the fungicide
81 metallic copper contents. These recommendations are from studies with copper oxychloride;
82 no studies comparing sources and concentrations of cupric fungicides are found.

83 In this context, the objective of the present work was to evaluate the efficacy of three
84 sources and three concentrations of cupric fungicides under artificial conditions of inoculation
85 with *P. citricarpa*, and under natural conditions, to determine the equivalence between the
86 different compounds in relation to metallic copper concentration in the solution.

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88

89 MATERIAL AND METHODS

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91 Experiment I – Protector effect for different sources and rates of cupric fungicides 92 against *Phyllosticta citricarpa* infection in orange fruits of the Pera cultivar

93

94 The experiment was conducted in 2012 in an orchard with orange plants of the Pera
95 cultivar (plant spacing of 5.5 × 2 m), at a private property in Olímpia, state of São Paulo (SP),
96 Brazil (20°41'57.23"S and 48°59'35.33"W).

97 The isolated pathogen was from Conchal, SP, Brazil. It was multiplied in Petri dishes
98 containing BDA medium and maintained in BOD at temperature of 25°C.

99 The fungicides evaluated were copper hydroxide (Kocide WDG Bioactive[®] 462 g of
100 copper hydroxide, Mitsui & Co. Brasil, S.A.), copper oxychloride (Recop[®] 840 g of copper
101 oxychloride, Atanor do Brasil), and cuprous oxide (Redshield 750[®] 750 g of cuprous oxide,

102 Agrovant Comércio de Produtos Agrícolas Ltda). The treatments and rates used are shown in
 103 Table 1.

104 Approximately 5,000 fruits at stage F2 (STOLLER, 2010) of 100 plants were bagged on
 105 02/23/2015 to avoid infections by *P. citricarpa* naturally presents in the area. When the plants
 106 were at stage F4, they were treated with cupric fungicide on 05/13/2016. Subsequently, the
 107 fruits were inoculated with *P. citricarpa* (1×10^4 conidia mL⁻¹) in intervals of 0, 7, 14, 21, and
 108 28 days. The inoculum was prepared and the inoculation was done according to the
 109 methodology described by Almeida et al. (2008). After inoculation, the fruits were bagged
 110 again, using double layer bags (crystal paper), according to the methodology adopted by
 111 Motta (2009). The fruits were kept in the bag until the harvest (10/31/2016).

112
 113 **Table 1.** Description of the cupric fungicide treatments for the control of citrus black spot in
 114 orange plants of the Pera cultivar, and their active ingredient concentrations, formulated
 115 product rates, and metallic copper equivalent rates.

[RC10] Comentário: Não é aceito tabela e/ou figura com ORIENTAÇÃO na forma “paisagem”, ou que apresentem mais de 17 cm de largura.

Treatments	Concentration g kg ⁻¹	Rate per 100 liters of solution	
		Formulated Product	Metallic Copper
Copper hydroxide (538 g kg ⁻¹)	538	125.0	43.7
Copper hydroxide (538 g kg ⁻¹)	538	100.0	35.0
Copper hydroxide (538 g kg ⁻¹)	538	75.0	26.2
Copper oxychloride (840 g kg ⁻¹)	840	200.0	100.8
Copper oxychloride (840 g kg ⁻¹)	840	180.0	90.7
Copper oxychloride (840 g kg ⁻¹)	840	135.0	68.0
Cuprous oxide (860 g kg ⁻¹)	860	120.0	90.0
Cuprous oxide (860 g kg ⁻¹)	860	75.0	56.3
Cuprous oxide (860 g kg ⁻¹)	860	56.3	42.2
Control			

116 Copper hydroxide = Kocide WDG Bioactive[®], Mitsui & Co. Brasil, S.A.; Copper oxychloride
 117 = Recop[®], Atanor do Brasil; and Cuprous oxide = Redshield 750[®], Agrovant Comércio de
 118 Produtos Agrícolas Ltda.

119

120 The fungicides were applied according to an adaption of the method of Motta (2009);
121 fruits with diameter of 40 to 50 mm were individually sprayed with fungicide, plus mineral oil
122 at 0.20% (v v⁻¹).

123 A completely randomized experimental design was used, with a 3×3×5 factorial
124 arrangement consisted of three fungicides, three rates, and 5 inoculation times, with four
125 replications. The plots consisted of 20 fruits. The control treatment consisted of fruits without
126 application of cupric fungicide and with artificial inoculation with *P. citricarpa*.

127 The evaluations consisted of determination of the incidence (%) of symptomatic fruits
128 for citrus black spot (CBS), and the disease severity. The CBS severity was estimated using a
129 scale of grades, according to visual symptoms in percentage of lesion area—0 = fruits without
130 visual symptoms, 1= up to 0.8%, 2 = 0.8% to 1.6%, 3 = 1.6% to 3.1%, 4 = 3.1% to 6.2%, 5 =
131 6.2% to 12.5%, 6 = more than 6.2% (SPÓSITO et al., 2004).

132 The grades attributed to fruits were used to determine the disease index (DI), according
133 to Wheeler (1969):

$$DI = \frac{1}{N} \sum_{i=0}^m i \cdot n_i$$

134 where N is the number of total fruits evaluated, i is the grade of the fruit, n_i is the number of
135 fruits with grade I , and m is the maximum grade.

136 The grades attributed, disease index, and the other parameters were subjected to
137 analysis of variance, and the means were compared by the Scott-Knott test at 5% probability
138 of error.

139

140 **Experiment II - Evaluation of rates of cupric fungicides for the control of citrus black** 141 **spot**

142

143 The experiment was conducted in 2007, under natural conditions of infection by *P.*
144 *citricarpa*, in an orchard with orange plants of the Pera cultivar (plant spacing of 7 × 3.5 m),
145 at a private property of commercial production in Olímpia, SP, Brazil (20°47'59.17"S,
146 49°2'34.94"W).

147 The treatments evaluated in this experiment, representing the cupric fungicide
148 variations, were the same used in Experiment I (Table 1).

149 The fungicides were applied using a mechanized sprayer (FM Copling) with 54 nozzles
150 MagnoJet-DDC4, diffusers 25 with 758.42 kPa at 540 RPM, power takeoff with 1900 RPM,

151 and tractor speed of 3.4 km h⁻¹. The mean flowrate was 7.35 L plant⁻¹, equivalent to 134 mL
152 m⁻³ on the plants' canopies. The cupric fungicides were sprayed when the plants were at the
153 stages F1 and F2 (STOLLER, 2010), on 12/02/2015 and 12/23/2015. The spraying of
154 fungicides were resumed on 01/13/2016 with foliar applications of 500 g of azoxystrobin
155 (Vantigo[®], Syngenta Proteção de Cultivos Ltda, São Paulo) at concentration of 16 g per 100 L
156 of water plus mineral oil (Agefix[®], Packblend Indústria e Comércio de Lubrificantes Ltda) at
157 0.25% (v v⁻¹) until 05/19/2016, totaling four applications with 42-day intervals.

158 A randomized block experimental design was used, consisting of 10 treatments and four
159 replications. The plots consisted of three rows of 11 plants, totaling 33 plants or 808.5 m².

160 The evaluations were carried out on 08/10/2016, 09/08/2016, 10/06/2016, and
161 11/14/2016 to determine the CBS incidence and severity in 100 random fruits collected from
162 the five central plants of each plot. The CBS severity was estimated using a scale of grades
163 (SPÓSITO et al., 2004), and the data were used to determine the disease index (DI),
164 according to the same equation used in Experiment I.

165 The DI data were used to determine the area under the disease progress curve (AUDPC)
166 by the trapezoidal method $(DI1 + DI2)/2 * (Day2 - Day1)$. The fruits were harvested on
167 11/30/2016, when the fruit yield per plant (kg) was determined. The data were subjected to
168 analysis of variance and the means were compared by the Scott-Knott test at 5% probability
169 of error. The data were also subjected to regression analysis to determine the rates of each
170 fungicide based on linear and quadratic responses of the AUDPC.

171

172

173 **RESULTS AND DISCUSSION**

174

175 **Experiment I**

176

177 All treatments with the highest rates of cupric fungicides presented on average lower
178 incidence and severity of citrus black spot (CBS) (Table 2). The results showed direct and
179 significant responses between fungicide rates and CBS incidence and severity, except for the
180 treatment with copper oxychloride at 90.7 g 100 L⁻¹. However, high rates on equivalent
181 metallic copper do not necessarily mean high concentrations of fungicide (SILVA JÚNIOR et
182 al., 2016).

183 The number of days after the application of fungicides had a significant and negative
184 effect, with lower CBS incidence and severity when the inoculation with *Phyllosticta*

185 *citricarpa* and the treatment was carried out on the same day. The inoculations between 7 and
 186 28 days after the fungicide application resulted in similar protections. This result is related to
 187 those reported by Motta (2009), who found incidence of 30% and 80% when the inoculation
 188 was at 1 and 28 days after application of copper oxychloride, respectively. Thus, the
 189 methodology used is efficient to evaluate and replicate results, and can be used to evaluate
 190 new formulations or fungicides.

191 The interaction between the fungicide rates, fungicide sources, and days after treatment
 192 of fruits was not significant, denoting that the protection tends to decrease over time at the
 193 same proportion for all the treatments, even when using different fungicide rates and sources.
 194 These results showed that the best interval between applications of cupric fungicides depends
 195 on the control level desired, in terms of CBS incidence and severity. Thus, it can be weekly
 196 for production of fruits with lower incidence, and up to 28 days for production of fruits with
 197 incidence and severity within limits that avoid the fall of fruits. Motta (2009) found similar
 198 results, with increases in CBS incidence and severity as a function of increases in the intervals
 199 between the application of copper oxychloride and artificial inoculation with *P. citricarpa*;
 200 they reported satisfactory protection up to 21 days after the application.

201
 202 **Table 2.** Incidence and disease index of citrus black spot (*Phyllosticta citricarpa*) in orange
 203 fruits of the Pera cultivar as a function of cupric fungicides rates and sources and days after
 204 the application, in the 2015/2016 crop season.

Sources of variation		Incidence (%)		Disease index	
Treatments	Rate (g of metallic copper 100 L ⁻¹)				
1. Copper hydroxide (538 g kg ⁻¹)	43.7	16.9	A	0.22	a
2. Copper hydroxide (538 g kg ⁻¹)	35.0	24.5	b	0.31	b
3. Copper hydroxide (538 g kg ⁻¹)	26.2	26.5	b	0.34	b
4. Copper oxychloride (840 g kg ⁻¹)	100.8	14.7	a	0.19	a
5. Copper oxychloride (840 g kg ⁻¹)	90.7	13.0	a	0.17	a
6. Copper oxychloride (840 g kg ⁻¹)	68.0	32.5	c	0.41	c
7. Cuprous oxide (860 g kg ⁻¹)	90.0	17.9	a	0.24	a
8. Cuprous oxide (860 g kg ⁻¹)	56.3	20.8	b	0.27	b

9. Cuprous oxide (860 g kg ⁻¹)	42.2	38.9	c	0.49	c
10. Control		54.0	d	0.68	d
F Test		13.612	**	18.058	**
Days after application					
0		18.7	a	0.25	a
7		25.7	b	0.33	b
14		26.5	b	0.34	b
21		31.2	b	0.40	b
28		27.8	b	0.35	b
F Test		5.047	**	4.996	**
Interaction (Treatment × Days after application)					
F Test		1.052	ns	1.103	ns
CV (%)		32.88		10.87	

205 The data of incidence and severity of citrus black spot were transformed according to the
206 equations $x' = \arcsen\sqrt{x/100}$, and $x' = \sqrt{x + 0.5}$, respectively. Means followed by the
207 same letter in the columns do not differ by the Scott-Knott test at 5% probability of error. **
208 = significant by the analysis of variance at 1% probability of error; ns = not significant by the
209 analysis of variance at 5% probability of error.

210

211 Experiment II

212

213 According to the first evaluations, in August, the highest cupric fungicide rates were
214 significantly more efficient to reduce the CBS incidence (Table 3). However, they did not
215 necessarily represent the same metallic copper rate (Table 1), contradicting the
216 recommendation by equivalence (SILVA JÚNIOR et al., 2016b). These data showed that the
217 rate should be specific for each cupric fungicide source, and cannot be generalized or
218 equalized by the equivalent metallic copper. These differences were less pronounced over the
219 evaluations, although a high effectiveness had been maintained. The CBS incidence in the
220 control treatment varied from 44% to 94% from the first (10/08) to the last evaluation (14/11),
221 while in the most efficient chemical treatment it varied from 28% to 77%. These are similar
222 results to those found by Scaloppi et al. (2012), who found that better responses are
223 dependent on the simultaneous use of different alternatives, including fungicide with different

224 properties from protectors and cultural practices that reduce the inoculum, thus, reducing the
 225 CBS incidence and severity.

226

227 **Table 3.** Incidence of citrus black spot (*Phyllosticta citricarpa*) in orange fruits of the Pera
 228 cultivar treated with different cupric fungicides rates and sources in the 2015/2016 crop
 229 season.

Treatments	Rate g 100 L ⁻¹	Incidence			
		Evaluation 1	Evaluatio n 2	Evaluation 3	Evaluation 4
		08/10/2016	09/08/201 6	10/06/2016	11/14/2016
Copper hydroxide (538 g kg ⁻¹)	125.0	22.0 a	33.1 a	46.0 a	67.3 a
Copper hydroxide (538 g kg ⁻¹)	100.0	32.8 b	42.0 a	52.3 a	81.5 b
Copper hydroxide (538 g kg ⁻¹)	75.0	42.3 b	43.8 a	46.3 a	77.0 a
Copper oxychloride (840 g kg ⁻¹)	200.0	23.0 a	36.5 a	51.0 a	73.0 a
Copper oxychloride (840 g kg ⁻¹)	180.0	22.0 a	36.7 a	52.8 a	73.0 a
Copper oxychloride (840 g kg ⁻¹)	135.0	40.3 b	48.0 b	56.5 a	88.8 b
Cuprous oxide (860 g kg ⁻¹)	120.0	33.3 b	36.5 a	40.8 a	72.5 a
Cuprous oxide (860 g kg ⁻¹)	75.0	38.8 b	41.3 a	44.5 a	74.5 a
Cuprous oxide (860 g kg ⁻¹)	56.3	46.6 b	49.6 b	53.3 a	87.0 b
Control		44.4 b	58.4 c	72.8 b	94.3 b
F Test		6.563 **	8.11 **	3.964 **	2.92 *
CV (%)		8.40	6.40	12.31	39.10

230 The data of incidence of citrus black spot were transformed according to the equation
 231 $x' = \arcsen\sqrt{x/100}$. Means followed by the same letter in the columns do not differ by the
 232 Scott-Knott test at 5% probability of error. ** = significant by the analysis of variance at 1%
 233 probability of error; * = significant by the analysis of variance at 5% probability of error.

234
 235 The treatments had no effect on the CBS severity (Table 4); the CBS severity increased
 236 even in plots treated with fungicide. No treatment completely controlled the CBS. The
 237 fungicides and rates presented no differences for the control of CBS; they were different only
 238 from the control treatment.

239
 240 **Table 4.** Severity of citrus black spot (*Phyllosticta citricarpa*) in orange fruits of the Pera
 241 cultivar treated with different cupric fungicides rates and sources in the 2015/2016 crop
 242 season.

Treatments	Rate g 100 L ⁻¹	Severity			
		Evaluation	Evaluation	Evaluation	Evaluation
		1 08/10/2016	2 09/08/2016	3 10/06/2016	4 11/14/2016
1. Copper hydroxide (538 g kg ⁻¹)	125.0	0.3 a	0.4 a	0.6 a	0.9 a
2. Copper hydroxide (538 g kg ⁻¹)	100.0	0.4 b	0.6 b	0.8 a	1.1 a
3. Copper hydroxide (538 g kg ⁻¹)	75.0	0.6 d	0.6 b	0.7 a	1.2 a
4. Copper oxychloride (840 g kg ⁻¹)	200.0	0.2 a	0.4 a	0.6 a	0.9 a
5. Copper oxychloride (840 g kg ⁻¹)	180.0	0.3 a	0.5 a	0.7 a	1.0 a
6. Copper oxychloride (840 g kg ⁻¹)	135.0	0.4 b	0.6 b	0.8 a	1.1 a
7. Cuprous oxide (860 g kg ⁻¹)	120.0	0.4 b	0.4 a	0.5 a	0.9 a
8. Cuprous oxide (860 g kg ⁻¹)	75.0	0.5 c	0.5 b	0.6 a	1.0 a

9. Cuprous oxide (860 g kg ⁻¹)	56.3	0.6 d	0.6 b	0.7 a	1.1 a
10. Control		0.7 d	0.9 c	1.1 b	1.9 b
		16.2			
F Test		1 **	11.11 **	4.08 **	8.15 **
CV (%)		4.01	3.98	6.55	6.12

243 The data of severity of citrus black spot were transformed according to the equation $x' =$
 244 $\sqrt{x/0.5}$. Means followed by the same letter in the columns do not differ by the Scott-Knott
 245 test at 5% probability of error. ** = significant by the analysis of variance at 1% probability
 246 of error.

247
248

249 The initial cupric fungicide applications by spraying were essential to control CBS,
 250 since the control treatment without application of cupric fungicides presented higher CBS
 251 incidence and severity (Table 5).

252 According to the area under the disease progress curve (AUDPC) for CBS incidence,
 253 only the lowest rates of copper oxychloride (135 g 100 L⁻¹) and cuprous oxide (75 g 100 L⁻¹)
 254 presented significant lower efficiency, increasing the CBS incidence (Table 5). The AUDPC
 255 for CBS severity showed that all the treatments were significantly different, and that they
 256 were different from the control treatment. Regarding the copper hydroxide, only the highest
 257 rate (125 g 100 L⁻¹) was equivalent to the best treatments; the intermediate and highest rates
 258 of copper oxychloride and cuprous oxide presented the best results of control.

259
260

261 **Table 5.** Area under the disease progress curve (AUDPC) for incidence and severity of citrus
 262 black spot (*Phyllosticta citricarpa*) and yield of orange plants of the Pera cultivar as a
 263 function of cupric fungicides rates and sources, in the 2015/2016 crop season.

Treatments	Rate g 100 L ⁻¹	AUDPC		Orange yield
		Incidence (%)	Disease index	Kg plant ⁻¹ 11/30/2016
Copper hydroxide (538 g kg ⁻¹)	125.0	4114.6 a	52.3 a	70.9 a

Copper hydroxide (538 g kg ⁻¹)	100.0	5011.8 a	68.6 b	68.6 a
Copper hydroxide (538 g kg ⁻¹)	75.0	4911.7 a	74.1 b	49.9 a
Copper oxychloride (840 g kg ⁻¹)	200.0	4504.4 a	53.7 a	75.4 a
Copper oxychloride (840 g kg ⁻¹)	180.0	4555.4 a	60.1 a	77.0 a
Copper oxychloride (840 g kg ⁻¹)	135.0	5574.4 b	71.7 b	62.3 a
Cuprous oxide (860 g kg ⁻¹)	120.0	4301.6 a	51.5 a	68.7 a
Cuprous oxide (860 g kg ⁻¹)	75.0	4682.4 a	60.8 a	61.7 a
Cuprous oxide (860 g kg ⁻¹)	56.3	5571.1 b	69.2 b	69.4 a
Control		6584.1 c	108.8 c	58.2 a
F Test		5.70 **	9.02 **	0.40 ns
CV (%)		6.17	7.88	39.46

264 The data of incidence and severity of citrus black spot were transformed according to the
 265 equations $x' = \arcsen\sqrt{x/100}$, and $x' = \sqrt{x + 0.5}$, respectively. Means followed by the
 266 same letter in the columns do not differ by the Scott-Knott test at 5% probability of error. **
 267 = significant by the analysis of variance at 1% probability of error; ns = not significant by the
 268 analysis of variance at 5% probability of error.

269

270 As in Experiment I, the results of Experiment II showed no equivalence in metallic
 271 copper rate in the treatments with the best control of CBS. The treatment 1 (copper hydroxide
 272 at 125 g 100 L⁻¹) had the lower metallic copper concentration in the solution (43.7 g 100 L⁻¹).
 273 When using 42.2 g 100 L⁻¹ with cuprous oxide, the results were significantly lower. These
 274 were similar results to those found by Feichtenberger et al. (2001), who found equivalence of
 275 control between cupric fungicides using a high rate of metallic copper (90 g of Cu⁺⁺ 100 L⁻¹).

276 The orange yield presented no significant differences (Table 5). The sequence of the
 277 experiment with applications of azoxystrobin maintained the CBS severity at lower levels in
 278 the control treatment, presenting no yield losses, but losses in the fruit aesthetical quality,
 279 which were not suited for marketing as fresh fruits.

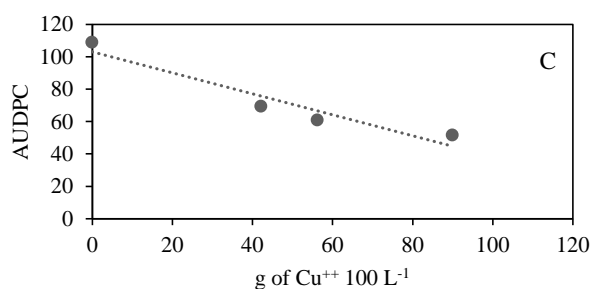
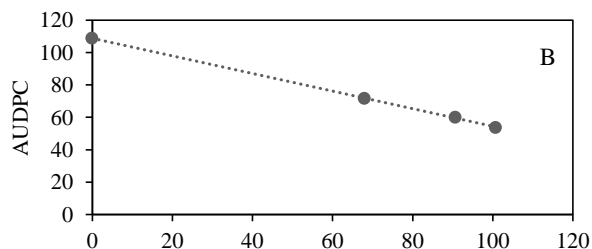
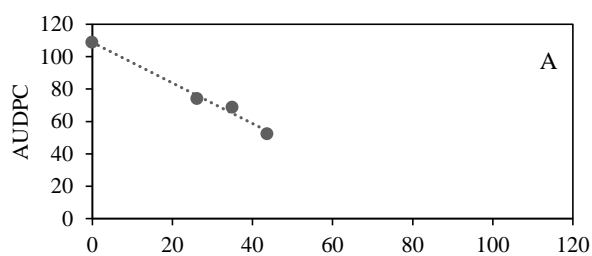
280 Significant linear responses of the CBS were found for all fungicide treatments,
 281 indicating that the better control levels of CBS are achieved with the use of increasing rates of
 282 Cu⁺⁺ (Table 6 and Figure 1). However, this result makes unfeasible the determination of the
 283 threshold for control of CBS and maximum fungicide rate, within the range of rates
 284 established for this experiment.

285

286 **Table 6.** Regression by analysis of variance of the area under the disease progress curve
 287 (AUDPC) for citrus black spot (*Phyllosticta citricarpa*) in orange plants of the Pera cultivar,
 288 for each cupric fungicide as a function of the rate used, in the 2015/2016 crop season.

Cupric fungicide	Equation model	Equation	CV (%)	F Test	R ²
Copper hydroxide	Linear	$y = -1.2523x + 108.79$	20.69	27.178**	98.80%
Copper oxychloride	Linear	$y = -0.5431x + 108.82$	15.38	56.837**	99.98%
Cuprous oxide	Linear	$y = -0.6483x + 103.14$	14.84	60.386**	91.85%

289



290

A = Copper hydroxide; B = Copper oxychloride; C = cuprous oxide

291 **Figure 1.** Graph of the linear regression model for the area under the disease progress curve
292 (AUDPC) for citrus black spot (*Phyllosticta citricarpa*) in orange of the Pera cultivar, for
293 each cupric fungicide as a function of the metal rate copper used, in the 2015/2016 crop
294 season.

[RC11] Comentário: As figuras devem apresentar 8,5 cm de largura, não ultrapassando 17 cm.

[RC12] Comentário: Não é aceito tabela e/ou figura com ORIENTAÇÃO na forma “paisagem”, ou que apresentem mais de 17 cm de largura.

[RC13] Comentário: A resolução deve ter qualidade máxima com pelo menos 300 dpi. Não serão aceitas imagens desfocadas e com baixa qualidade.

[RC14] Comentário: Opcional.

297 ACKNOWLEDGEMENTS

300 CONCLUSION

302 The fungicides copper hydroxide, copper oxychloride, and cuprous oxide at rates of
303 43.7, 90.7, and 56.3 g of Cu⁺⁺ 100 L⁻¹, respectively, are efficient and present similar results
304 for the control of citrus black spot when applied with 21-day intervals and before applications
305 of strobilurin fungicides.

306 The fungicides copper hydroxide, copper oxychloride, and cuprous oxide at rates of
307 43.7, 90.7 and 90 g of Cu⁺⁺ 100 L⁻¹, respectively, can control protectively citrus fruits from
308 infections with *Phyllosticta citricarpa* up to 28 days.

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[RC15] Comentário: Devem ser digitadas em espaço 1,5 cm e separadas entre si pelo mesmo espaço (1,5 cm).

[RC16] Comentário: O título do periódico não deve ser abreviado e recomenda-se um total de 20 a 30 referências.

[RC17] Comentário: Veja as normas de referências em <https://periodicos.ufersa.edu.br/index.php/caatinga/preparadosmanuscritos>.

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