

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

[RC1] Comentário: Título no máximo 15 palavras.

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[RC2] Comentário: Os nomes dos autores devem estar completos, sem abreviaturas, separados por vírgulas e identificar com asterisco (*) o autor correspondente.

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

[RC3] Comentário: Abstract no máximo 250 palavras.

24
25 **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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28 **FONTES E CONCENTRAÇÕES DE FUNGICIDAS CÚPRICOS NO CONTROLE DA**
29 **MANCHA PRETA DOS CITROS**

[RC5] Comentário: Título no máximo 15 palavras.

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32 **RESUMO** – A mancha preta dos citros é uma doença severa para a citricultura do Estado de
33 São Paulo. Parte do seu manejo é focado no controle químico usando fungicidas cúpricos e
34 estrobilurinas. Este trabalho teve o objetivo de avaliar a eficácia de três fontes e três

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

51

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

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59

60 INTRODUCTION

61

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

[RC6] Comentário: Resumo no máximo 250 palavras.

[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.

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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 The control of CBS is done usually by using fungicides; in Brazil, it is controlled
70 mainly with use of cupric and strobilurin fungicides (MOTTA, 2009; VINHAS, 2011; SILVA
71 JÚNIOR et al., 2016). Cupric fungicides are commonly applied after petal fall, corresponding
72 to the stages F1 and F2, until the fruits reach diameter of 1 cm (STOLLER, 2010;), followed
73 by two to five applications of strobilurin fungicides (SCALLOPPI et al., 2012), covering the
74 more susceptible period for fruits (AGUIAR et al., 2012), from petal fall until the end of the
75 summer, when rainfall periods of more than 8 hours still occur. Ikeda (2011) reported
76 satisfactory responses of control of CBS to the use of five or six applications of cupric
77 fungicides combined or alternated with strobilurins.

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

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

94
95

96 MATERIAL AND METHODS

97

98 Experiment I – Protector effect for different sources and rates of cupric fungicides 99 against *Phyllosticta citricarpa* infection in orange fruits of the Pera cultivar

100

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

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

106 The fungicides evaluated were copper hydroxide (Kocide WDG Bioactive® 462 g of
 107 copper hydroxide, Mitsui & Co. Brasil, S.A.), copper oxychloride (Recop® 840 g of copper
 108 oxychloride, Atanor do Brasil), and cuprous oxide (Redshield 750® 750 g of cuprous oxide,
 109 Agrovant Comércio de Produtos Agrícolas Ltda). The treatments and rates used are shown in
 110 Table 1.

111 Approximately 5,000 fruits at stage F2 (STOLLER, 2010) of 100 plants were bagged on
 112 02/23/2015 to avoid infections by *P. citricarpa* naturally presents in the area. When the plants
 113 were at stage F4, they were treated with cupric fungicide on 05/13/2016. Subsequently, the
 114 fruits were inoculated with *P. citricarpa* (1×10^4 conidia mL⁻¹) in intervals of 0, 7, 14, 21, and
 115 28 days. The inoculum was prepared and the inoculation was done according to the
 116 methodology described by Almeida et al. (2008). After inoculation, the fruits were bagged
 117 again, using double layer bags (crystal paper), according to the methodology adopted by
 118 Motta (2009). The fruits were kept in the bag until the harvest (10/31/2016).

119
 120 **Table 1.** Description of the cupric fungicide treatments for the control of citrus black spot in
 121 orange plants of the Pera cultivar, and their active ingredient concentrations, formulated
 122 product rates, and metallic copper equivalent rates.

| 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 |

[RC11] Comentário: Não é aceito tabela e/ou figura com ORIENTAÇÃO na forma “paisagem”, ou que apresentem mais de 17 cm de largura.

| | | | |
|---|-----|------|------|
| Cuprous oxide (860 g kg ⁻¹) | 860 | 75.0 | 56.3 |
| Cuprous oxide (860 g kg ⁻¹) | 860 | 56.3 | 42.2 |

Control

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

126

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

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

134 The evaluations consisted of determination of the incidence (%) of symptomatic fruits
 135 for citrus black spot (CBS), and the disease severity. The CBS severity was estimated using a
 136 scale of grades, according to visual symptoms in percentage of lesion area—0 = fruits without
 137 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 =
 138 6.2% to 12.5%, 6 = more than 6.2% (SPÓSITO et al., 2004).

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

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

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

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

146

147 **Experiment II - Evaluation of rates of cupric fungicides for the control of citrus black**
 148 **spot**

149

150 The experiment was conducted in 2007, under natural conditions of infection by *P.*
151 *citricarpa*, in an orchard with orange plants of the Pera cultivar (plant spacing of 7 × 3.5 m),
152 at a private property of commercial production in Olímpia, SP, Brazil (20°47'59.17"S,
153 49°2'34.94"W).

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

156 The fungicides were applied using a mechanized sprayer (FM Copling) with 54 nozzles
157 MagnoJet-DDC4, diffusers 25 with 758.42 kPa at 540 RPM, power takeoff with 1900 RPM,
158 and tractor speed of 3.4 km h⁻¹. The mean flowrate was 7.35 L plant⁻¹, equivalent to 134 mL
159 m⁻³ on the plants' canopies. The cupric fungicides were sprayed when the plants were at the
160 stages F1 and F2 (STOLLER, 2010), on 12/02/2015 and 12/23/2015. The spraying of
161 fungicides were resumed on 01/13/2016 with foliar applications of 500 g of azoxystrobin
162 (Vantigo[®], Syngenta Proteção de Cultivos Ltda, São Paulo) at concentration of 16 g per 100 L
163 of water plus mineral oil (Agefix[®], Packblend Indústria e Comércio de Lubrificantes Ltda) at
164 0.25% (v v⁻¹) until 05/19/2016, totaling four applications with 42-day intervals.

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

167 The evaluations were carried out on 08/10/2016, 09/08/2016, 10/06/2016, and
168 11/14/2016 to determine the CBS incidence and severity in 100 random fruits collected from
169 the five central plants of each plot. The CBS severity was estimated using a scale of grades
170 (SPÓSITO et al., 2004), and the data were used to determine the disease index (DI),
171 according to the same equation used in Experiment I.

172 The DI data were used to determine the area under the disease progress curve (AUDPC)
173 by the trapezoidal method $(DI_1 + DI_2)/2 * (Day_2 - Day_1)$. The fruits were harvested on
174 11/30/2016, when the fruit yield per plant (kg) was determined. The data were subjected to
175 analysis of variance and the means were compared by the Scott-Knott test at 5% probability
176 of error. The data were also subjected to regression analysis to determine the rates of each
177 fungicide based on linear and quadratic responses of the AUDPC.

178

179

180 **RESULTS AND DISCUSSION**

181

182 **Experiment I**

183

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

190 The number of days after the application of fungicides had a significant and negative
 191 effect, with lower CBS incidence and severity when the inoculation with *Phyllosticta*
 192 *citricarpa* and the treatment was carried out on the same day. The inoculations between 7 and
 193 28 days after the fungicide application resulted in similar protections. This result is related to
 194 those reported by Motta (2009), who found incidence of 30% and 80% when the inoculation
 195 was at 1 and 28 days after application of copper oxychloride, respectively. Thus, the
 196 methodology used is efficient to evaluate and replicate results, and can be used to evaluate
 197 new formulations or fungicides.

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

208

209 **Table 2.** Incidence and disease index of citrus black spot (*Phyllosticta citricarpa*) in orange
 210 fruits of the Pera cultivar as a function of cupric fungicides rates and sources and days after
 211 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 | |

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

217

218 Experiment II

219

220 According to the first evaluations, in August, the highest cupric fungicide rates were
221 significantly more efficient to reduce the CBS incidence (Table 3). However, they did not
222 necessarily represent the same metallic copper rate (Table 1), contradicting the

223 recommendation by equivalence (SILVA JÚNIOR et al., 2016b). These data showed that the
 224 rate should be specific for each cupric fungicide source, and cannot be generalized or
 225 equalized by the equivalent metallic copper. These differences were less pronounced over the
 226 evaluations, although a high effectiveness had been maintained. The CBS incidence in the
 227 control treatment varied from 44% to 94% from the first (10/08) to the last evaluation (14/11),
 228 while in the most efficient chemical treatment it varied from 28% to 77%. These are similar
 229 results to those found by Scaloppi et al. (2012), who found that better responses are
 230 dependent on the simultaneous use of different alternatives, including fungicide with different
 231 properties from protectors and cultural practices that reduce the inoculum, thus, reducing the
 232 CBS incidence and severity.

233
 234 **Table 3.** Incidence of citrus black spot (*Phyllosticta citricarpa*) in orange fruits of the Pera
 235 cultivar treated with different cupric fungicides rates and sources in the 2015/2016 crop
 236 season.

| Treatments | Rate g 100 L ⁻¹ | Incidence | | | |
|---|----------------------------------|-----------------|-----------------------|-----------------|-----------------|
| | | Evaluation | Evaluatio | Evaluation | Evaluation |
| | | 1 08/10/2016 | n 2 09/08/201 6 | 3 10/06/2016 | 4 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 | 120.0 | 33.3 b | 36.5 a | 40.8 a | 72.5 a |

| | | | | | |
|---|------|----------|---------|----------|--------|
| kg ⁻¹) | | | | | |
| 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 |

237 The data of incidence of citrus black spot were transformed according to the equation
 238 $x' = \arcsen\sqrt{x/100}$. Means followed by the same letter in the columns do not differ by the
 239 Scott-Knott test at 5% probability of error. ** = significant by the analysis of variance at 1%
 240 probability of error; * = significant by the analysis of variance at 5% probability of error.

241

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

246

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

| Treatments | Rate g 100 L ⁻¹ | Severity | | | |
|---|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| | | Evaluation 1 | Evaluation 2 | Evaluation 3 | Evaluation 4 |
| | | 08/10/2016 | 09/08/2016 | 10/06/2016 | 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 |

250 The data of severity of citrus black spot were transformed according to the equation $x' =$
251 $\sqrt{x/0.5}$. Means followed by the same letter in the columns do not differ by the Scott-Knott
252 test at 5% probability of error. ** = significant by the analysis of variance at 1% probability
253 of error.

254
255

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

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

266
267

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

| Treatments | Rate g 100 L ⁻¹ | AUDPC | | Orange |
|--|-------------------------------|------------------|------------------|--------------------------------------|
| | | Incidence (%) | Disease index | yield |
| | | | | 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 |

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

276
 277 As in Experiment I, the results of Experiment II showed no equivalence in metallic
 278 copper rate in the treatments with the best control of CBS. The treatment 1 (copper hydroxide
 279 at 125 g 100 L⁻¹) had the lower metallic copper concentration in the solution (43.7 g 100 L⁻¹).
 280 When using 42.2 g 100 L⁻¹ with cuprous oxide, the results were significantly lower. These
 281 were similar results to those found by Feichtenberger et al. (2001), who found equivalence of
 282 control between cupric fungicides using a high rate of metallic copper (90 g of Cu⁺⁺ 100 L⁻¹).

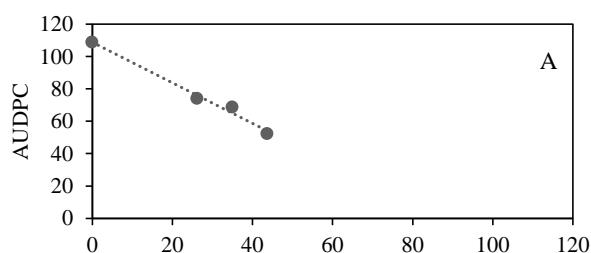
283 The orange yield presented no significant differences (Table 5). The sequence of the
 284 experiment with applications of azoxystrobin maintained the CBS severity at lower levels in
 285 the control treatment, presenting no yield losses, but losses in the fruit aesthetical quality,
 286 which were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

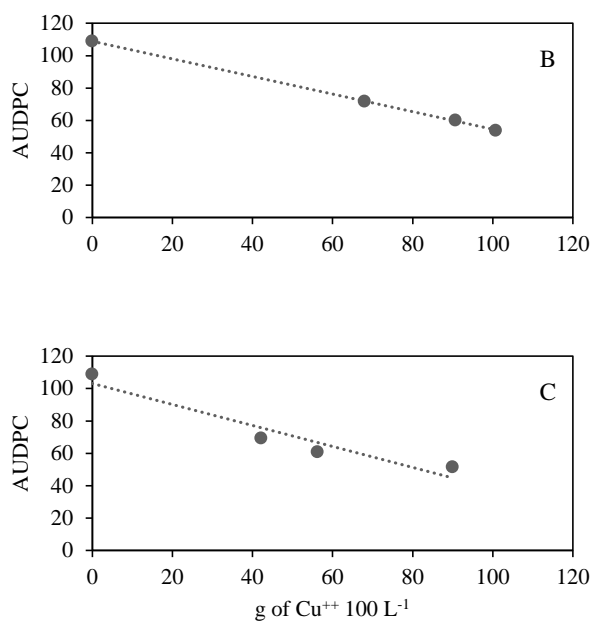
287 Significant linear responses of the CBS were found for all fungicide treatments,
 288 indicating that the better control levels of CBS are achieved with the use of increasing rates of
 289 Cu^{++} (Table 6 and Figure 1). However, this result makes unfeasible the determination of the
 290 threshold for control of CBS and maximum fungicide rate, within the range of rates
 291 established for this experiment.

292
 293 **Table 6.** Regression by analysis of variance of the area under the disease progress curve
 294 (AUDPC) for citrus black spot (*Phyllosticta citricarpa*) in orange plants of the Pera cultivar,
 295 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% |

296





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

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

302

303

304 CONCLUSION

305

306 The fungicides copper hydroxide, copper oxychloride, and cuprous oxide at rates of
 307 43.7, 90.7, and 56.3 g of Cu⁺⁺ 100 L⁻¹, respectively, are efficient and present similar results
 308 for the control of citrus black spot when applied with 21-day intervals and before applications
 309 of strobilurin fungicides.

310 The fungicides copper hydroxide, copper oxychloride, and cuprous oxide at rates of
 311 43.7, 90.7 and 90 g of Cu⁺⁺ 100 L⁻¹, respectively, can control protectively citrus fruits from
 312 infections with *Phyllosticta citricarpa* up to 28 days.

313

314

[RC12] Comentário: As figuras devem apresentar 8,5 cm de largura, não ultrapassando 17 cm.

[RC13] Comentário: Não é aceito tabela e/ou figura com ORIENTAÇÃO na forma “paisagem”, ou que apresentem mais de 17 cm de largura.

[RC14] Comentário: A resolução deve ter qualidade máxima com pelo menos 300 dpi. Não serão aceitas imagens desfocadas e com baixa qualidade.

315 **ACKNOWLEDGEMENTS**

[RC15] Comentário: Opcional.

316

317

318 **REFERENCES**

[RC16] Comentário: Devem ser digitadas em espaço 1,5 cm e separadas entre si pelo mesmo espaço (1,5 cm).

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[RC17] Comentário: O título do periódico não deve ser abreviado e recomenda-se um total de 20 a 30 referências.

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