

Original Research Article

Phosphite-based products in the *in vitro* *Colletotrichum musae* control

ABSTRACT

Aims: The aim of this study was to evaluate the *in vitro* effect of different phosphite formulations and concentrations on the development of *Colletotrichum musae*. Sample: to evaluate the inhibition of germination, mycelial growth and sporulation of *Colletotrichum musae*.

Study Design: Treatments were conducted in a completely randomized design, with 4 replicates, each replicate consisting of 1 Petri dish.

Place and Duration of Study: Laboratory of Post-Harvest Pathology, State University of Montes Claros, between March and October 2017.

Methodology: three different phosphite formulations were used: FCu1 (4% Cu + 20% P₂O₅), FCu2 (4% Cu + 22% P₂O₅) at concentrations of 0.5; 1.0; 1.5 and 2.0 mL L⁻¹ and FK (42% P₂O₅ + 27.7% K₂O) at concentrations of 0.5; 1.0; 1.5 and 2.0 mg.L⁻¹. Products were incorporated into the respective culture media. Culture medium alone and culture medium + imazalil were used as controls. Petri dishes were housed in BOD chamber at 25 ° C under a 12 hours photoperiod.

Results: Results were submitted to analysis of variance and regression, and means were compared by the Tukey test ($P < 0.05$). Control was compared to the other treatments by the Dunnett's test ($P < 0.05$). Among the tested phosphite formulations, copper and potassium phosphites were found to reduce the mycelial growth of *Colletotrichum musae*. FCu2 presents a fungicide-like effect from the concentration of 0.5 mL.L⁻¹ in the control of conidia production. As for the FCu1, a fungicide-like effect was observed in the control of germination from the concentration of 1.5 mL.L⁻¹.

Conclusion: A significant fungistatic effect was observed between the concentrations of the products in the mycelial growth, sporulation and germination obtaining control of up to 100% of the development of *C. musae*. Copper phosphites were as effective as fungicide in inhibiting fungal development.

Keywords: disease; anthracnose; alternative treatment.

1. INTRODUCTION

Anthracnose caused by *Colletotrichum musae* (Berk & Curt.) von Arx. (Teleomorph: *Glomerella musarum* Petch) stands out as the most important post-harvest disease in banana crops. Fruits infected by the fungus have accelerated maturation, an undesirable

24 aspect for consumers, which makes them unviable for export. Losses due to anthracnose
25 can reach up to 80%, causing various damages to fruits [1].

26 Among the methods for controlling the disease, the most important are cultural and
27 chemical control with the use of Tiabendazol and Imazalil fungicides [2, 3]. The latter method
28 presents as negative effects damage to the environment and the emergence of fungal
29 isolates resistant to fungicidal molecules. In addition, they may affect human health since
30 they can leave residues in fruit pulp [4, 5, 6].

31 The excessive use of agrochemicals in fruit trees is a growing worldwide concern with real
32 possibilities of environmental contamination. Thus, the demands of the consumer market for
33 high-quality fruits produced with the substitution of pollutant and non-renewable inputs are
34 increasing [7]. There are several alternative strategies for controlling diseases such as
35 modified atmosphere [8], use of essential oils and extracts [9, 10, 11] to control diseases
36 caused by phytopathogenic fungi.

37 Phosphites are substances originating from the neutralization reaction of phosphorous acid
38 by a base [12]. These products have been used in agriculture to stimulate plant growth for
39 presenting direct action on pathogens or for inducing defense mechanisms, being presented
40 as an alternative to the application of fungicides [13, 14, 15].

41 *In vitro* results confirm the effect of potassium phosphite on the reduction of the mycelial
42 growth of *C. musae* by 84% when comparing with control [10]. The application of phosphites
43 in other species of the genus *Colletotrichum* as well as other genus of fungi has been
44 investigated by several authors. Lopes et al. [16] observed that magnesium and potassium
45 phosphites inhibited 50% of the mycelial growth of *Colletotrichum gloeosporioides*.
46 Alexandre et al. [17] found that potassium phosphite showed fungitoxic activity in the
47 development of *Colletotrichum tamarilloi*. In *Fusarium solani*, potassium phosphite inhibited
48 growth and mycelial density with the application of 50 ppm [18].

49 The effect of phosphite application on the management of plant diseases may vary
50 according to the type of phosphite, dose applied and target pathogen. There are reports of
51 partial and / or total inhibition of mycelial growth, conidial production / germination, and
52 appressorium formation of different fungi [19, 11, 20, 17, 10, 21]. In this sense, the aim of
53 this study was to evaluate the *in vitro* effect of different phosphite formulations and
54 concentrations on *C. musae* development.

55

56 2. MATERIAL AND METHODS

57

58 Experiments were carried out at the Laboratory of Post-Harvest Pathology, State University
59 of Montes Claros, Minas Gerais, MG. *C. musae* isolate was obtained from bananas
60 purchased in a commercial growing area, which were selected for showing dark spots and
61 mass of orange conidia, typical anthracnose symptoms.

62 For the *in vitro* sensitivity assessment copper phosphites FCu1 (4% Cu + 20% P₂O₅),
63 copper FCu2 (4% Cu + 22% P₂O₅) at concentrations of 0.5; 1.0, 1.5 and 2.0 mL.L⁻¹ and
64 potassium phosphite FK (42% P₂O₅ + 27.7% K₂O) at concentrations of 0.5, 1.0, 1.5 and 2.0
65 mg.L⁻¹ were incorporated into melting BDA medium and poured on to Petri dishes of 9 cm in
66 diameter. After solidification of the culture medium, a 5 mm diameter mycelium disc with 7
67 days of culture was transferred to the center of dishes containing treatments. BDA culture
68 medium alone and BDA + Imazalil medium (0.5 mL.L⁻¹) were used as controls. The sides of
69 dishes were sealed with clear plastic film to avoid possible evaporation of compounds and

drying of the culture medium. Petri dishes were housed in BOD chamber at 25°C under a 12 hours photoperiod. Measurements were carried out by means of daily measurements of the diameter of colonies (average of the two diametrically opposed measurements), 24 hours after the beginning of the experiment, always at the same time and ending when the mycelial growth of control reached the edge of the dish. Data were used to calculate MGRI (Mycelial Growth Rate Index) in mm / day, using the following formula [22]: $\Sigma \text{MGRI} = (D - D_a) / N$, where: D: Current mean diameter; D_a : Previous mean diameter; N: number of days after pricking.

When the mycelial growth of control (absence of phosphite) reached the entire dish, conidia production was evaluated. For this, 50 mL of distilled sterile water were added to each Petri dish using the Drigalski loop, colonies were scraped for the release of conidia. The spore suspension was filtered through a double layer of sterile gauze. Then, 500µL of each suspension was removed and placed in Newbauer chamber, where conidia were counted using an optical microscope and spore counter.

The effect of phosphites on conidia germination at the same concentrations previously used was also verified. Treatments were added to the agar-melting water medium, and then the medium was poured onto 9 cm diameter Petri dishes. After solidification, 1 mL of the conidia suspension at concentration of 2.5×10^5 *C. musae* spores / mL was placed on the agar-water medium and spread with the aid of the Drigalsk loop. Dishes were taken to BOD chamber at 25°C under a 12 hours photoperiod for 15 hours. Then, they were taken to the refrigerator to stop germination. The germination rate was determined by counting germinated spores of the fungus. Conidia presenting the length of the germinative tube greater or equal to the conidia diameter were considered germinated.

The design was completely randomized in a 3x4 + 2 factorial scheme, with three phosphate formulations (FCu1, FCu2 and FK), four concentrations (0.5; 1.0; 1.5 and 2.0 mL.L⁻¹) and controls (absence of treatment and Imazalil fungicide). Four replicates were used per treatment, each replicate consisted of a Petri dish. Data were submitted to analysis of variance and the means compared by the Tukey test at 5% probability. Controls were compared to the other treatments by the Dunnet's test at 5% probability. Analyses were performed using the R software [23].

3. RESULTS AND DISCUSSION

Significant interaction ($P < 0.05$) was observed among sources of phosphite at different concentrations used for all characteristics evaluated. However, as there was no adjustment of regression models, and the mean values of MGRI, sporulation and germination of *C. musae* conidia were compared by the Tukey test ($P < 0.05$) and controls were compared to the other treatments by the Dunnet's test ($P < 0.05$).

Table 1 shows that at concentration of 0.5 mL.L⁻¹, the lowest MGRI was promoted by FCu1 and FK. At concentrations of 1.0, 1.5 and 2.0 mL.L⁻¹, the sources that promoted the greatest reduction in MGRI were FCu1 and FCu2.

These results demonstrate the efficiency of phosphites in controlling the development of *C. musae*. In this way, different sources of copper and potassium phosphite are able to control different phytopathogens (*Pythium*, *C. gloeosporioides*, *Monilinia fruticola* e *Colletotrichum tamarilloi*) [24, 25, 26, 18, 17].

118 It was verified that in treatments using FCu1 and FCu2 from concentration of 1.0 mL.L⁻¹
 119 were as efficient as Imazalil fungicide, showing 100% inhibition of fungal mycelial growth
 120 (Table 1).

122 In treatment using FK, only the lowest concentration showed fungistatic effect on *C. musae*.
 123 However, Nojosa et al. [27] observed the opposite effect, reporting in their work that
 124 potassium phosphite inhibits 62,26% the mycelial growth of *Phoma costaricensis* Echandi in
 125 coffee tree at the highest applied concentration (10.00 mL.L⁻¹).

126 Inhibition of pathogen development by phosphite-based products may occur due to
 127 the direct action of the product on the fungus, acting in the process of oxidative
 128 phosphorylation as observed in Oomycetes [28]. The direct action of phosphites on
 129 pathogens under *in vitro* conditions can be verified even at doses lower than those
 130 recommended by the manufacturer [10, 29].

132 **Table 1. Mycelial growth rate index (MGRI) of *Colletotrichum musae* submitted**
 133 **to different phosphite concentrations.**

Sources of Phosphite	0.5mL.L ⁻¹	Concentrations 1.0 mL.L ⁻¹	1.5 mL.L ⁻¹	2.0 mL.L ⁻¹
F Cu 1	0.75 aB	0.0 aA	0.0 aA	0.0 aA
F Cu 2	1.5 bB	0.0 aA	0.0 aA	0.0 aA
	0.5 mg.L ⁻¹	Concentrations 1.0 mg.L ⁻¹	1.5 mg.L ⁻¹	2.0 mg.L ⁻¹
F K	0.25 aA	0.75 bAB	1.0 bB	1.25bB
Absence of phosphite		3.23		
Imazalil		0.0		
CV (%)		72.73		

135 Means followed by the same lowercase letter in the column and uppercase in the row do not differ by
 136 the Tukey's test ($P < 0.05$).

138 In the comparison of treatments to controls by means of the Dunnet's test at 5% probability,
 139 all sources associated to all concentrations reduced MGRI (Table 2).

140 In comparison with the fungicide, it was verified that FCu1 and FCu2 at concentrations of 1.0
 141 mL.L⁻¹, 1.5 mL.L⁻¹ and 2.0 mL.L⁻¹ did not differ significantly, which shows that such sources
 142 associated with these concentrations were as efficient as Imazalil.

144 As the phosphite concentration increases, better results are obtained, as can be verified in
 145 other patossystems [16, 22, 30,31].

147 Copper phosphites present different results according to the fungal species. Dantas et al.
 148 [21] obtained control of the mycelial growth of *Lasiodyplodia theobromae* when applying
 149 copper phosphite at concentration of 2.0 mL.L⁻¹, but the same control was not obtained
 150 when applying in *Alternaria* sp, *Colletotrichum gloeosporioides*, *Fusarium* sp., *Rhizopus* sp.

Borin et al. [32] found that copper phosphite showed positive effect on the reduction of 52% to 76% and 82% to 96% of the radial growth of *Fusarium verticillioides* and *F. graminearum* isolates, respectively, using copper phosphite when comparing with control.

The success of the application of phosphites in the control of fungal development occurs due to the reduction of aerobic respiration, affecting ATP production, which is the source of energy responsible for the development of *C. musae* [24].

FK showed no significant difference among concentrations tested in both controls. Oliveira et al. [10] disagree with this result, since the authors reported that potassium phosphite at concentration of $3\mu\text{L.mL}^{-1}$ inhibited the mycelial growth of *C. musae* by 91.8% compared to the absence of treatment.

The results obtained by Spolti et al. [33] disagree with those obtained in this experiment; the authors verified that the mycelial growth rate index (MGRI) presented inverse quadratic order relationship to potassium phosphite in the culture medium.

Table 2. Means of treatments compared by the Dunnet's test for the following variables: mycelial growth rate index (MGRI), sporulation and germination of *Colletotrichum musae* conidia submitted to different phosphite concentrations.

Sources of Phosphite		MGRI	Sporulation	Germination (%)
FCu1	0.5	0.75 x y	41.50 x y	89.25 y
	1.0	0.0 x	30.25 x y	39.50 x y
	1.5	0.0 x	0.00 x	3.25 x
	2.0	0.0 x	0.00 x	0.25 x
FCu2	0.5	1,5 x y	6.00 x	48.25 x y
	1.0	0,0 x	12.00 x	22.00 x y
	1.5	0.0 x	8.25 x	48.25 x y
	2.0	0.0 x	4.50 x	37.00 x y
FK	0.5	0.25 x y	10.00 x	96.50 y
	1.0	0.75 x y	34.50 x	90.50 y
	1.5	1.0 x y	46.25 x y	88.25 y
	2.0	1.25 x y	92.25 y	91.00 y
Absence of phosphite		3.23	102.00	100.00
Imazalil		0.00	0.00	0.00

Averages of treatments followed by the letter X and means of treatments followed by the letter Y differ statistically from control, absence of phosphite and Imazalil by the Dunnet's test ($P < 0.05$), respectively.

The antsporulating effect of phosphites on *C. musae* is shown in Table 3. At concentration of 0.5 mL.L^{-1} , the lowest sporulations were observed when FCu2 and FK were used. At concentration of 1.0 mL.L^{-1} , the three sources of phosphite promoted the same effect. At concentrations of 1.5 and 2.0 mL.L^{-1} , FCu1 and FCu2 showed the greatest reduction in the production of *C. musae* conidia.

185 Spores are reproductive and infective units of phytopathogenic fungi responsible for
 186 producing propagules that spread and infect the plant. Thus, the greater the inhibition of
 187 spore formation, the more efficient is the product, and this is a very important feature in the
 188 pathogen management in the field [31, 34].

189
 190 In the comparison of treatments to controls, it was verified that only treatment using FK at
 191 concentration of 1.5 and 2.0 mL.L⁻¹ did not reduce sporulation (Table 2). In the comparison
 192 with Imazalil, it was verified that FCu1 at concentration of 0.5 mL.L⁻¹ and FK at
 193 concentrations of 1.5 and 2.0 mL.L⁻¹ differed from this treatment, indicating that the fungicide
 194 was more effective in the control of conidia production than these treatments. There are
 195 reports that some products may serve as a stimulus for the fungus to reproduce [35].

196
 197 When increasing the FCu1 concentration, sporulation control of up to 100% is verified, being
 198 similar to Imazalil fungicide. For FCu2, it was verified that from the lowest concentration
 199 applied, no significant difference from Imazalil was observed, demonstrating that FCu2 was
 200 as efficient as the fungicide in the control of this variable.

201
 202 It is likely that sporulation inhibition occurs due to the fungistatic effect of higher phosphite
 203 concentrations on the mycelial growth, which results in the change from vegetative to
 204 reproductive stages as a survival strategy of the microorganism [36].

205
 206 The results observed for the FK treatment obtained in the present experiment differ from
 207 those obtained in studies using similar sources of phosphite in different phytopathogens [34,
 208 29, 31].

209
 210 **Table 03. Production of *Colletotrichum musae* conidia submitted to different**
 211 **sources of phosphite at different concentrations.**

Sources of Phosphite	Concentrations			
	0.5 mL.L ⁻¹	1.0 mL.L ⁻¹	1.5 mL.L ⁻¹	2.0 mL.L ⁻¹
F Cu 1	41.5bB	30.25 a AB	0.0 aA	0.0 aA
F Cu 2	6.0 aA	12.0 aA	8.25 aA	4.5 a A
	Concentrations			
	0.5 mg.L ⁻¹	1.0 mg.L ⁻¹	1.5 mg.L ⁻¹	2.0 mg.L ⁻¹
F K	10.0 aA	34.5 aAB	46.25 bB	92.25 b C
Absence of phosphite	102.0			
Imazalil	0.0			
CV (%)	75.73			

214 Means followed by the same lowercase letter in the column and upper case in the row do not differ by
 215 the Tukey's test ($P < 0.05$). Means of treatments followed by the letter X and means of treatments
 216 followed by the letter Y differ statistically from controls without phosphite and Imazalil, by the Dunnet's
 217 test ($P < 0.05$) respectively.

218
 219 For germination, the results presented in Table 4 show that FCu1 yielded the highest *C.*
 220 *musae* germination reduction at concentrations of 1.5 and 2.0 mL.L⁻¹. For FCu2, the highest

germination reduction was obtained at concentration of 1.0 mL.L⁻¹. FK showed no significant difference among applied concentrations. It is verified that only FCu1 at concentration of 1.5 mL.L⁻¹ did not differ from control using the fungicide, demonstrating the efficiency of this treatment.

By fixing the concentrations used in the different phosphate formulations, it is possible to verify that at concentrations of 0.5 and 1.0 mL.L⁻¹, FCu2 presented lower germinated conidia values. At concentration of 1.5 and 2.0 mL.L⁻¹, FCu1 promoted greater control in the germination of *C. musae* conidia.

At all concentrations tested, FCu2 showed difference in relation to control treatment without the use of phosphites. This result demonstrates the efficacy of FCu2 when compared to the absence of phosphite. Although the results were superior to those obtained by the control, they are still considered unsatisfactory when compared to chemical control.

Comparing the results obtained to controls, it was verified that only FCu1 at concentrations of 1.5 and 2.0 mL.L⁻¹ did not statistically differ from control using Imazalil, showing inhibition percentage up to 99.75% (Table 2). This result demonstrates that these treatments showed the same efficiency of the fungicide in the control of *C. musae* germination.

When compared to the absence of phosphite application, it was verified that FK did not differ significantly at any concentrations used, as did FCu1 at concentration of 0.5 mL.L⁻¹. These results demonstrate inefficiency in the control of *C. musae* germination.

Phosphites can act directly by inhibiting fungal spore germination, penetrating in the plant, blocking mycelial growth and spore production. Indirectly, they act by stimulating the metabolism involved in the resistance induced in the plant, as in the production of lignin, phytoalexin and hydrolytic enzymes [37].

Several studies using potassium phosphite report the efficiency of phytopathogen control, and these results are different from those obtained in this experiment. Tests carried out by Alexandre et al. [17], with K, Mg and Cu phosphites found that the germination of *Colletotrichum gloeosporioides* conidia was inhibited even at low concentrations (0.25; 0.5; 0.75 g.L⁻¹). Ribeiro Júnior, et al. [38] reported that even at reduced doses, potassium phosphite had toxic effect on the germination of *Verticillium dahliae* conidia. This trend was also verified by Ogoshi et al. [11], in the germination control of *Colletotrichum gloeosporioides* of up to 63.1% with the use of potassium phosphite at concentration of 10.0 mL.L⁻¹.

274 **Table 04. Germination of *Colletotrichum musae* conidia under different sources**
 275 **of phosphite at different concentrations.**
 276

Fontes de Fosfito	Concentrações			
	0.5 mL.L ⁻¹	1.0 mL.L ⁻¹	1.5 mL.L ⁻¹	2.0 mL.L ⁻¹
F Cu 1	89.25 bC	39.5 bB	3.25 aA	0.25 aA
F Cu 2	48.25 aB	22.0 aA	48.25 bB	37.0 bB
	Concentrações			
	0.5 mg.L ⁻¹	1.0 mg.L ⁻¹	1.5 mg.L ⁻¹	2.0 mg.L ⁻¹
F K	96.5 bA	90.5 cA	88.25 cA	91.0 cA
Ausência de fosfito	100.0			
Imazalil	0.0			
CV (%)	13.15			

277 Means followed by the same lowercase letter in the column and upper case in the row do not differ by
 278 the Tukey's test ($P < 0.05$). Means of treatments followed by the letter X and means of treatments
 279 followed by the letter Y differ statistically from controls without phosphite and Imazalil, by the Dunnet's
 280 test ($P < 0.05$) respectively.
 281

282 Phosphites have demonstrated fungal control potential, both in *in vitro* and *in vivo*
 283 conditions. The results obtained here encourage the conduction of further studies for the
 284 alternative management of banana anthracnose with the use of less toxic products.
 285
 286

287 4. CONCLUSION

288
 289 Copper and potassium phosphites reduce the mycelial growth of *Colletotrichum musae*
 290 when compared to the absence of treatment.

291 FCu2 presents a fungicide-like effect from concentration of 0.5 mL.L⁻¹ on the control of *C.*
 292 *musae* conidia production.

293 FCu1 presents a fungicide-like effect from concentration of 1.5 mL.L⁻¹ on the control of *C.*
 294 *musae* germination.

295 In view of the results obtained in the experiment, it is concluded that the application of
 296 phosphites is viable in the control of the development of *C. musae in vitro*.

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299 COMPETING INTERESTS

300
 301 The authors declare that they have no conflict of interest related to this study.

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REFERENCES

1. Bill M, Sivakumar D, Korsten L, Thompson AK. The efficacy of combined application of edible coatings and thyme oil in inducing resistance components in avocado (*Persea americana* Mill.) against anthracnose during post-harvest storage. *Crop Prot.* 2014; 64:159-167. <https://doi.org/10.1016/j.cropro.2014.06.015>
2. Reis EM, Casa RT, Bianchin V. Control of plant diseases by crop rotation. *Summa Phytopathologica.* 2011; 37 (3): 85-91.
3. AGROFIT. Phytosanitary pesticide systems. Available in: http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Accessed on: 02/10/2019.
4. Rabbit AS, Dias MS, Rodrigues ML, Leal PA. Post-Harvest control of anthracnose of banana 'Prata Anã' treated with fungicides and kept under refrigeration. *Science and Agrotechnology.* 2010; 34 (4): 1004-1008. <https://doi.org/10.1590/S1413-70542010000400029>.
5. Cross MJ, Clemente E, Cruz ME, Mora F, Cossaro L, Pelisson N. Effect of bioactive natural compounds on post-harvest conservation of hose fruits cv. Tommy Atkins. *Science and Agrotechnology.* 2010; 34 (2): 428-433. <https://doi.org/10.1590/S1413-70542010000200022>.
6. Vilaplana R, Pazmiño L, Valencia-Chamorro S. Control of anthracnose, caused by *Colletotrichum musae*, on postharvest organic banana by thyme oil. *Postharvest Biology and Technology.* 2018; 138:56–63. <https://doi.org/10.1016/j.postharvbio.2017.12.008>
7. Negreiros RJZ, Salomão LCC, Pereira OL, Cecon PR, Siqueira DL. Post-harvest anthracnose control of 'Prata' bananas with alternative products to conventional agrochemicals. *Revista Brasileira de Fruticultura.* 2013; 35: 1, 051-058.
8. Cunha Junior LC, Jacomino AP, Trevisan MJ, Scarpore Filho, JÁ. High concentrations of oxygen favor the conservation of strawberry 'Big Bear'. *Revista Brasileira de Fruticultura.* 2011; 33.4: 1074-1083.
9. Rodrigues, MLM, Mizobutsi, EH, Nacarath, IRFF, Fernandes MB, Mizobutsi GP, Ribeiro RCF, et al. Essential Oils in the Control of Anthracnose on 'Prata Ana' Banana. *Journal of Agricultural Science.* 2018; 10, 9: 116. <https://doi.org/10.5539/jas.v10>.
10. Oliveira ES, Viana FMP, Martins MVV. Alternatives to Synthetic Fungicides in the Control of Banana Anthracnose. *Summa Phytopathologica.* 2016; 42, 4: 340-350.
11. Ogoshi, C, Abreu MS de, Silva BM da, Santos Neto H, Ribeiro Júnior PM, Resende MLV de. Potassium phosphite: a promising product in the management of diseases caused by *Colletotrichum gloeosporioides* in coffee plants. *Bioscience Journal.* 2013; 29: 1558-1565.
12. Hirose, EH, Creste JE, Custódio CC, Machado-Neto NB. In vitro growth of sweet potato fed with potassium phosphite. *Acta Scientiarum. Agronomy Maringá.* 2012., 34, 1: 85-91. Doi: 104025 / actasciagron.v34i1.10810.
13. Fontana DC, Kulczynski SM, Trevisan R, MVM Pine, Diel MI, MO Pinheiro. Control of pathogens during the development and post-harvest of peach fruits. *Agronomic Culture.*

2018; 27, 1: 124-140.

14. Araújo JL, Faquin V, Ávila FW de, Pedroso TQ. Phosphite and phosphate interaction in the growth and phosphate nutrition of common bean in nutrient solution. *Brazilian Journal of Soil Science*. 2013; 37: 482-490.

15. Tófoli JG, Mello SC, Domingues RJ, Garcia Junior O. Effect of potassium phosphite isolated and in mixture with fungicides in tomato blight control. *Archives Biological Institute*. 2012; 79.9: 201-208.

16. Lopes LF, Cruz AF, Barreto MLA, Vasconcelos TMM, Blum LEB. Post-harvest treatment with Ca-phosphite reduces anthracnose without altering papaya fruit quality. *The Journal of Horticultural Science and Biotechnology*. 2018. 93:3, 272-278. DOI: 10.1080/14620316.2017.1361342.

17. Alexandre ER, Herculano LM, Silva da JM, Oliveira SMA de. Phosphites in the management of anthracnose of jiló. *Pesquisa Agropecuária Brasileira*. 2014. 49,12: 930-938. DOI: 10.1590 / S0100-204X201400120000.

18. Rocha Sobrinho GG, Rodrigues GB, Santos A, Jesus Junior WC, Novaes QS. Effect of potassium phosphite on the growth and mycelial density of passion fruit *Fusarium solani*. *Summa Phytopathologica*. 2016; 42, 2: 180-182. DOI: 10.1590 / 0100-5405 / 2139.

19. Cato HCRM, Sales NL de P, Azevedo DMQ, Flávio NSD da S., J. B. de C .; Barbosa LV, Martinez RAS. Fungicides and alternative products in the mycelial growth and germination control of *Alternaria tomatophila*. *IDESIA (Chile)* 2013; 1: 3.

20. Roma, R. C. C. Potassium phosphate to control post-harvest diseases in 'Italy' grape berries and possible mechanisms of action for *Rhizopus stolonifer*. Thesis (Doctorate), Luiz de Queiroz College of Agriculture, 118 p. 2013.

21. Dantas AM of M, Birth SR of C, Cross BLS of, Silva FHA of, Ambrósio MM of Q, Senhor RF. Alternative control of post-harvest diseases in Tainung 1 papaya. *Tropical Agriculture Research*. 2018. 48, 1: 29-35. (<http://dx.doi.org/10.1590/1983-40632018v4850938>).

22. Araújo L, Stadnik M J, Borsato L, Vadebenito-Sanhueza RM. Phosphite of potassium and ulvana in the control of the leaf mass of the gala in apple tree. *Tropical Plant Pathology*. 2008. 33, 2: 148-152.

23. R CORE TEAM. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2016. Disponível em: <https://www.Rproject.org/>. (Acesso em 22/11/2018)

24. Santos SL dos, Campos T de, Dallacosta NL, Mazaro SM. Potential of products based on phosphites in the control of *Pythium* sp. under in vitro conditions. *Applied Research & Agrotechnology*. 2018.11,1: 105-110. DOI: 10.5935 / PAeT.V11.N1.13.

25. Fontana DC, Kulczynski SM, Trevisan R, MVM Pine, Diel MI, Pinheiro MO. Control of pathogens during the development and post-harvest of peach fruits. *Agronomic Culture*. 2018.27, 1: 124-140.

26. Ferraz DMM, Blum LEB, Barreto, MLA, Uesugi CH, Peixoto JR, Cruz AF. Phosphite in

413 the control of anthracnose and post-harvest quality of guava in conventional and organic
414 cultivation. Journal of Agriculture. 2016. 91.3: 249-264.

415 27. Nojosa GBA, Resende MLV, Barguil BM, Moraes SRG, Vilas Boas CH. Effect of
416 resistance inducers on coffee against *Phoma* leaf spot. Summa Phytopathologica. 2009.
417 35,1:60-62.

418 28. McGrath M.T. What are fungicides? The Plant Health Instructor. Disponível em: <
419 <https://www.apsnet.org/edcenter/intropp/topics/Pages/Fungicides.aspx>> Acesso em Julho
420 2018.

421 29. Lopes LF. Effects of post-harvest applications of phosphites, acetylsalicylic acid and 1-
422 methylcyclopropene on the anthracnose of papaya. 2008. 82 f. Dissertation (Master in
423 Phytopathology) - University of Brasília, Brasília, DF, 2008.

424

425 30. Araújo L, Valdebenito-Sanhueza RM, Stadnik MJ. Evaluation of potassium phosphite
426 formulations on *Colletotrichum gloeosporioides* in vitro and on the post-infection control of
427 *Glomerella* leaf spot in apple trees. Tropical Plant Pathology. 2010.35, 1: 54-59.

428

429 31. Caixeta AO, Vieira BS, Canedo EJ. Effect of potassium phosphite on phytopathogenic
430 fungi of common bean. Journal of the University Center of Patos de Minas. 2012. 3: 35-43.

431

432 32. Borin RC, Possenti JC, King M of SR, Bernardi C, Mazaro SM. Fosfitos associated with
433 fungicides to control disease and sanity of corn seeds. Brazilian Journal of Applied
434 Technology for Agricultural Science, 2017.10, 1: 83-92. (DOI): 10.5935 / PAeT.V10.N1.09.

435

436 33. Spolti P, Valdebenito-Sanhueza RM, Campos AD, Del Ponte EM. Mode of action of
437 potassium phosphites in the control of ox-eye rot in apples. Summa Phytopathologica. 2015.
438 41, 1: 42-48.

439

440 34. Simon JM, Schwan-Estrada KRF, Jardinetti VA, Oliva LSC, Silva JB, Scarabeli IGR.
441 Atividade fungitóxica de extratos vegetais e produtos comerciais contra *Diplocarpon rosae*.
442 Summa Phytopathologica. 2016. 42, 4: 351-356.

443

444 35. Venturoso LR, Bacchi LMA, Gavassoni WL. Atividade antifúngica de extratos vegetais
445 sobre o desenvolvimento de fitopatógenos. Summa Phytopathologica. 2011.37,1: 18-23.

446

447 36. Tzortzakis NG, Economakis CD. Antifungal activity of lemongrass (*Cymbopogon citratus*
448 L.) essential oil against key postharvest pathogens. Innovative Food Science and Emerging
449 Technologies. 2007. 8: 253–258. DOI: 10.1016/j.ifset.2007.01.002.

450

451 37. Brackmann A, Giehl RFH, Sestari I, Weber A, Pinto JAV, Eisermann AC. Controle de
452 podridões em maçãs 'Fuji' Frigoconservadas com a aplicação de fosfitos e cloretos de
benzalcônio em pré e pós-colheita. Revista da FZVA. 2008.15, 2: 35-43.

453

454 38. Ribeiro Júnior KPM, Resende MLV, Pereira RB, Cavalcanti RS, Amaral DR, Pádua MA.
Effect of potassium phosphite on the induction of resistance in cocoa seedlings (*Theobroma*
455 cacao L.) against *Verticillium dahliae*. Ciência Agrotecnologia. 2006. 30, 4: 629-636.