Cinnamomum cassia essential oil and (*E*)-cinnamaldehyde as control agents of anthracnose on common bean seeds

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Highlights

The essential oil *Cinnamomum cassia* used have high concentrations of (*E*)-cinnamaldehyde.

Fungicides were prepared with essential oils of *Cinnamomum cassia* essential oil and (*E*)-cinnamaldehyde

The two fungicides applied in seeds of common bean, decreases incidence of anthracnose.

(*E*)-cinnamaldehyde is the active substance against *C. lindemuthianum* causing da anthracnose.

ABSTRACT

Among the fungi that cause damage to the common bean and are disseminated by the seeds, *Colletotrichum lindemuthianum* (Sacc. e Magn.) Briosi e Cavara stands out. This fungus causes anthracnose in common bean (*Phaseolus vulgaris* L.). Use of natural compounds is a viable and safer option than chemicals to manage this disease. Essential oils have shown antifungal potential against phytopathogenic fungi. According to the results of the *in vitro* test, we observed complete inhibition of the growth of *C. lindemuthianum* with the use of cassia cinnamon essential oil (*Cinnamomum cassia*) (EO) and its major component (*E*)-Cinnamaldehyde, presenting MIC of 125 µg/mL, while the commercial fungicide presented MIC of 30.6 µg/mL. And *in vivo*, where seeds naturally infected with *C. lindemuthianum* were treated with the EO and the substance in a solution with commercial soybean oil, we observed that the treatments did not affect germination and initial seed vigor. In addition, the seed treatment with solutions formulated from EO and (*E*)-cinnamaldehyde was efficient for reducing the incidence of anthracnose over the days evaluated, as well as for the commercial fungicide used (methyl thiophanate). This is the first study to demonstrate the efficacy of *C. cassia* oil and (E)-cinnamaldehyde in the control of *C. lindemuthianum* through the treatment of common bean seeds.

keywords: (*E*)-Cinnamaldehyde; *Colletotrichum lindemuthianum*; *Phaseolus vulgaris*

INTRODUCTION

Common bean (*Phaseolus vulgaris*) is one of the most consumed foods worldwide (NETO and SANTOS 2018), being cultivated in Brazil in an area of 213,000.9 ha (CONAB 2015). Brazil has the potential to increase common bean yield, but one of the limiting factors is the anthracnose, caused by the fungus *Colletotrichum lindemuthianum* (Sacc. e Magn.) Briosi e Cavara (Amin et al. 2014). Production losses can reach 100% when, under favorable environmental conditions, seeds infected with the pathogen are used or susceptible cultivars are adopted (Peloso 1988; Padder et al. 2017).

Genetic resistance is the most effective management strategy to control plant diseases (Nelson et al. 2018). However, for anthracnose in common bean, the development of new cultivars with the desired characteristics is slow and with low durability (Assefa et al. 2019), mainly due to the variability of the pathogen (Davide and de Souza 2009; Pinto et al. 2012; Costa et al. 2017). Therefore, the use of fungicides is an important component of integrated strategies to minimize losses caused by anthracnose (Conner et al. 2009; Amin et al. 2014).

In Brazil, a part of the harvested grains of common bean are destined for the sowing of the next crop, being one of the hypotheses for the low use of certified seeds in the common bean production (Castro and others 2017). As consequence, there is transmission of pathogens via seed and occurrence of diseases in the next crop. The treatment of common bean seeds with synthetic fungicides has been the most efficient method for the control of various fungal diseases in this crop (Oliveira et al. 2016). The use of these chemicals provides initial protection against soil pathogens, eliminates seed-associated pathogens, and prevents the spread and entry of new contaminants into the area (Lipps and Grove 1985; Sharma et al. 2015). On the other hand, there are related risks, among which it is worth highlighting: inconsistent economic results, development of resistance by soil

pathogens to many fungicides, risks of exposure of operators to toxic substances and negative impacts on non-target organisms (Tilman et al. 2002; Lamichhane et al. 2020). In general, strategies that make use of natural substances may be more sustainable. Therefore, it is important to study such substances to ascertain whether they can also be used for the development of more efficient and less costly fungicides (Isman 2000; Hettiarachi and Dubey 2011; Bi et al. 2012; Brum et al. 2014). One of the possibilities in this area are the essential oils, whose components may present biological activities (Pavela and Benelli 2016). In several cases the control of phytopathogenic fungi occurs through the direct action of essential oil or/and its components against the fungus (Andrade Pinto et al. 2010; Hoyos et al. 2012; Ootani et al. 2013; Zabka and Pavela 2013; Bhardwaja et al. 2015; Kumar and Kudachikar 2018). An example is dill essential oil (*Anethum graveolens* Linn.), which can break through the barrier of the permeability of the plasma membrane of the fungus *Aspergillus flavus*, provoking ROS (reactive oxygen species) accumulation (Tian et al. 2012).

Among the plant species with fungitoxic action is *Cinnamomum cassia* Presl belonging to the *Lauraceae* family. This plant is popularly known for its medicinal properties (Ravindran et al. 2003; Barceloux 2009; Nabavi et al. 2015). The essential oil can be extracted from stem, leaves and bark of plants (Balijepalli et al. 2017) which the major component is (*E*)-cinnamaldehyde, has activity against several phytopathogenic fungi (Lee et al. 2005; Cheng et al. 2006; Xing et al. 2010; El-Mogy and Alsanius 2012; Jiang et al. 2013; Moraes et al. 2018). However, there are no reports of the use of this oil or its main component for the treatment of plant seeds. Seed treatment with essential oils has been shown to be effective in controlling plant pathogens that contaminate bean seeds (Abdel-Kader et al. 2011; Khaledi et al. 2015).

Thus, the objectives of the article are: a) to identify the major components of *C. cassia* essential oil; b) to evaluate the phytotoxic effects of *C. cassia* essential oil, (*E*)-cinnamaldehyde and soybean oil, on common bean seeds; c) to evaluate the fungitoxic potential of *C. cassia* oil and (*E*)-cinnamaldehyde against *C. lindemuthianum* fungus present in naturally infected seeds of common bean.

MATERIAL AND METHODS

Essential oil: Cassia cinnamon essential oil (*Cinnamomum cassia*) was acquired from Ferquima Indústria e comércio LTDA. The extraction was carried out by steam distillation of the leaves, bark and stem of the plant. The essential oil was analyzed by gas chromatography coupled to mass spectrometry (GC-MS, Shimadzu QP-2010, Shimadzu Corporation, Kyoto, Japan), under the conditions: fused silica capillary column (30 cm long and 0.25 mm inner diameter) with stationary phase RTX®-5MS (0.25 µm film thickness) and helium as carrier gas, with flow of 1.0 mL per minute. Injector temperature of 220ºC, the initial column temperature was 60ºC, with programming to increase 2ºC per minute until reaching the temperature of 200ºC, and 5ºC per minute until reaching the maximum temperature of 250ºC. The mass spectra were obtained by electron impact at 70 eV, with a scan of 29 to 400 (m/z). Being injected 1 µL of the prepared oil solution at a concentration of 10 mg/L with a split ratio of 1:20. The identification of the compounds was performed by comparing the mass spectra with those available in the NIST17 mass spectra bank, visual interpretation of the mass spectra and comparison of arithmetic indexes (AI) with those available in the literature (Adams 2007). To calculate the arithmetic indexes, a mixture of linear alkanes (C9 to C17) was injected into the chromatograph. The relative percentage of each compound was calculated by the ratio of the area of each peak to the total area of all the constituents of the sample.

Reaction of common bean seeds to *C. cassia* essential oil /(*E*)-cinnamaldehyde: To evaluate the phytotoxic effect of *C. cassia* essential oil and (*E*)-cinnamaldehyde (Sigma-Aldrich, purity ≥99%), the germination test was performed according to the nacional guidelines (BRASIL 2009). Common bean seeds (*P. vulgaris* 'cultivar Pérola ') were previously sanitized with NaClO 2% (g/mL) for two minutes and rinsed under running water to remove NaClO residue. After dried on sterilized filter paper, the seeds were placed inside plastic bags to facilitate homogenization. And in each plastic bag we deposited treatments containing the *C. cassia* essential oil (10, 100, 500 and 2000 µg/mL) or (*E*)-cinnamaldehyde (8, 80, 400 and 1600 µg/mL) dissolved in commercial soybean oil (Liza®, Cargill Food Service), in the proportion of 40 mL/kg of seed. Water and soybean oil were used as controls of the experiment.

Germination tests were performed in a Biochemical Oxygen Demand (BOD) germination chamber at 25ºC, in a completely randomized design, with four replications. The plot consisted of a roll of Germitest® paper containing 50 seeds. The papers were previously sterilized at 105 °C for 2 hours, and moistened with distilled water at a ratio of 2.5 times the dry mass of the paper.

For seven days every 24 hours, the number of seedlings that presented root protrusion was quantified. At the end of the test, with the daily data of the number of seeds germinated, the germination speed index (GSI) was calculated, according to Maguire (Maguire 1962).

On the seventh day, the number of abnormal, normal seedlings and dead seeds was counted, and the results were expressed as percentage (BRASIL 2009). On the same day, the length of the shoot and the root of 10 random seedlings of each repetition was measured with a millimeter ruler. These plants were placed in a drying incubator at 70ºC until they reached a constant weight (48 hours), and finally weighed in analytical

147 precision scale in order to obtain the dry mass in grams. The obtained data were submitted
148 to the normality (Shapiro-Wilk) and homoscedasticity (Bartlett) tests (Snedecor and
149 Cochran 1989). Then, the analysis of variance by the F test were carried out and the means
150 grouped by the Scott Knott Test at 5% probability, with GENES software (Cruz 2016).
151
152 ***In vitro* and *in vivo* antifungal assays**
153 **Determination of minimal inhibitory concentration**: The fungus *C.*
154 *lindemuthianum* (race 65, isolate LV 238) cultivated in pods was crushed in sterile water
155 to obtain a spore suspension of 1.2 x 10^6 conidia/mL after adjusting in a Neubauer
156 chamber, using a microscope. Aliquots of 100 µL of the suspension were transferred to 2
157 mL microtubes, to which 100 µL of the EOs dissolved in DMSO and M3S were added.
158 The microtubes were kept in a B.O.D. chamber, in the dark, at 23 °C, for 5 days. After
159 the addition of the spore suspension, the lowest concentration of the sample in the
160 microtube that prevented fungal growth, by visual observation, was considered the
161 minimum inhibitory concentration (MIC) (Mota et al., 2017).

162 The soybean oil, EOs, and eugenol were dissolved in 5 µL of dimethyl sulfoxide
163 (DMSO) and diluted with M3S medium (Tu, 1985) to a concentration of 8000 µg/mL.
164 These solutions were diluted sequentially to the following final concentrations: 8000,
165 4000, 2000, 1000, 500, 250, 125, and 62.5 µg/mL. The commercial fungicide
166 thiophanate-methyl 70%, trade name: Cercobin 700WP (Iharabras S.A. Indústrias
167 Químicas, Brazil) was used as a positive control. For this, Cercobin 700WP was dissolved
168 in 5 µL of DMSO, diluted with M3S to obtain solutions of thiophanate-methyl at
169 concentrations of 490, 245, 122.5, and 30.63 µg/mL. A DMSO solution in 5% M3S (v/v)
170 was used as a negative control.

Control of *C. lindemuthianum* on common bean seeds by *C. cassia* essential oil/(*E*)-cinnamaldehyde: Common bean seeds (*P. vulgaris* L. 'cultivar BRSMGUai'), susceptible to anthracnose, were collected in Lavras, MG, Brazil, in plants with symptoms of anthracnose in the pods and leaves. Subsequently, the seeds were placed inside plastic bags to facilitate homogenization, and in each plastic bag were deposited the essential oil solutions of *C. cassia* (2000 µg/mL) and (*E*)-cinnamaldehyde (1600 µg/mL) in soybean oil. The commercial fungicide methyl thiophanate (dimethyl 4,4′-(*o*-phenylene)bis(3-thioallophanate); 70%; Cercobin 700WP, Iharabras S.A. Indústrias Químicas) in the dosage of 1g of the product/kg of seeds, commercial soybean oil and water. All treatments, except methyl thiophanate, were applied at a dosage of 40 mL/kg of seeds. The treated seeds were sown in 3.5 L plastic pots containing a mixture of substrate (Plantmax ®Brazil) and soil (1:2). The design was in randomized blocks with three replications. The plot consisted of 20 plants.

Assessed traits

Emergence and Emergence Speed Index (ESI): The number of germinated seeds was evaluated daily, from the emergence of the first seedling to the stabilization of the stand for three consecutive days, when cotyledons appeared above the substrate. The ESI was calculated based on the formula proposed by Maguire (1962) (Maguire 1962).

Incidence of anthracnose: The incidence of anthracnose was assessed at 0, 3, 6, 9, 12, 15, 18 and 21 days after the first disease symptom. We counted the number of plants with symptoms of anthracnose on leaves and stems. In percentage, the number of infected plants (with symptoms) was divided by the total number of plants assessed.

Plant Vigor (dry mass): After the final evaluation of the incidence of anthracnose, the aerial parts of the plants from all treatments were weighed on an analytical balance after

drying for 48h in a drying incubator at 70ºC. The results were expressed in mass (grams)/emerged plants.

Data analysis: Emergence, emergence speed index, and dry mass data were submitted to the normality (Shapiro-Wilk) and homoscedasticity (Bartelett) tests (Snedecor and Cochran 1989). Then, Analysis of variance was performed by the F test and the means were grouped by the Scott-Knott Test at 5% probability level, using GENES software (Cruz 2016). For incidence of anthracnose over time, Poisson regression analysis was performed using the Generalized Linear Model in the R Software (RStudio 2019).

RESULTS

Essential oil: Ten chemical constituents were found in the essential oil of *C. cassia*, the majority being (*E*)-cinnamaldehyde (82.03%), (*E*)-*o*-methoxycinamaldehyde (9.49%) and eugenol (3.56%) (Table 1).

Table 1 – Composition of *Cinnamomum cassia* essential oil.

Calculated Index	Literature Index*	Relative Concentration (%)	Similarity (%)	Compound
955	952	0.974	94	Benzaldehyde
1110	-	0.227	-	NI
1238	1239	0.43	92	o-Anisaldehyde
1269	1267	82.03	97	(*E*)-Cinnamaldehyde
1353	1356	3.56	94	Eugenol
1368	1374	0.28	78	α-Copaene
1410	1417	0.35	93	(*E*)-Caryophyllene
1427	-	1.28	-	NI
1440	1443	1.27	95	(*E*)-cinnamyl acetate
1524	1527	9.49	97	(*E*)-*o*-methoxycinamaldehyde

NI represent values not found in the literature. * (ADAMS, 2007)

Reaction of common bean seeds to *C. cassia* essential oil/(*E*)-cinnamaldehyde: Seed treatments with *C. cassia* essential oil and (*E*)-cinnamaldehyde, at all tested concentrations, had no impact on seed germination, the number of dead seeds, abnormal

seedlings, or the dry matter of the seedlings. With the exception of *C. cassia* essential oil at the concentration of 500 µg/ml the other treatments significantly reduced GSI when compared with control (water). However, *C. cassia* essential oil showed an increase in seedling root length in all tested dosages (Table 2).

Table 2 – Average values of germination (G), number of abnormal seedlings (AS) and dead seeds (DS), germination speed index (GSI), shoot length in cm (SL), root length in cm (RL), and dry matter in grams (DM) of seedlings from common bean seeds treated with *Cinnamomum cassia* essential oil and (*E*)-cinnamaldehyde.

Treatments	**Traits***								
	G	**AS**	**DS**	**GSI**		**SL**		**RL**		**DM**
Water	95.5	3.0	1.5	40.92	**A**	6.81	**A**	11.39	**B**	2.00
Soybean oil	95.0	1.5	3.5	28.13	**C**	5.73	**B**	11.74	**B**	1.86
(*E*)-cinnamaldehyde 8 µg/mL-1	95.5	1.5	3.0	29.75	**C**	7.26	**A**	12.18	**B**	1.96
(*E*)-cinnamaldehyde 80 µg/mL-1	96.0	1.0	3.0	35.69	**B**	7.04	**A**	12.52	**B**	1.94
(*E*)-cinnamaldehyde 400 µg/mL-1	95.5	1.5	3.0	27.71	**C**	6.27	**B**	12.28	**B**	1.92
(*E*)-cinnamaldehyde 1600 µg/mL-1	96.0	3.5	0.5	33.31	**B**	7.87	**A**	13.50	**A**	1.91
EO of *C. cassia* 10 µg/mL-1	94.5	2.0	3.5	35.21	**B**	6.81	**A**	13.46	**A**	1.98
EO of *C. cassia* 100 µg/mL-1	96.0	1.5	2.5	29.44	**C**	7.19	**A**	14.09	**A**	2.15
EO of *C. cassia* 500 µg/mL-1	95.0	3.5	1.5	38.67	**A**	6.90	**A**	15.01	**A**	2.07
EO of *C. cassia* 2000 µg/mL-1	95.0	3.0	2.0	28.23	**C**	6.71	**A**	13.54	**A**	2.00

*Mean values with the same letter in the same column do not differ statistically according to the Scott−Knott test ($P \leq 0.05$)

***In vitro* and *in vivo* antifungal assays**

Determination of minimum inhibitory concentration: The minimum inhibitory concentrations obtained with *C. cassia* essential oil and (*E*)-cinnamaldehyde were equal (125 µg/mL), while the commercial fungicide methyl thiophanate presented MIC of 30.6 µg/mL. Commercial soybean oil did not cause reduction in mycelial growth at any of the tested concentrations.

Control of *C. lindemuthianum* on common bean seeds by *C. cassia* essential oil/(*E*)-cinnamaldehyde No significant effect was observed regarding emergence and emergence speed index when seeds were treated with *C. cassia* essential oil, (*E*)-cinnamaldehyde, soybean oil and methyl thiophanate (Table 3).

Table 3 – Average values of emergency (**E**), Emergence Speed Index (**ESI**) and dry mass (**DM**) of seedlings from bean seeds treated with *Cinnamomum cassia* essential oil (EO) and (*E*)-cinnamaldehyde.

Treatment	**E (%)**	**ESI**	**DM**
Water (control)	96.56	16.82	0.63
Soybean oil	93.39	8.13	0.56
Methyl Thiophanate-(control)	96.56	13.84	0.92
Cinnamomum cassia essential oil	93.65	10.67	0.64
(*E*)-cinnamaldehyde	94.97	9.63	0.81

For the incidence of anthracnose, until the 9th day of evaluation the controls did not differ from the other treatments (Table S1). From the 12th day of evaluation, differences between treatments and controls are already visible, and seeds treated with water and soybean oil presented a higher anthracnose incidence in subsequent days.

C. cassia essential oil and its major compound, (*E*)-cinnamaldehyde were allocated in the same group of the commercial fungicide in the last four days of evaluation. In soybean oil treatment, the incidence of anthracnose reaches 73.1%. For seeds treated only with water, the incidence is 92.2%. The seeds treatment with solutions formulated from *C. cassia* essential oil and (*E*)-cinnamaldehyde was efficient for reducing the incidence of the disease over the days evaluated (Figure 1). The dose of 40 mL/kg formed a film adhered to the tegument with a visually uniform coating on the seeds.

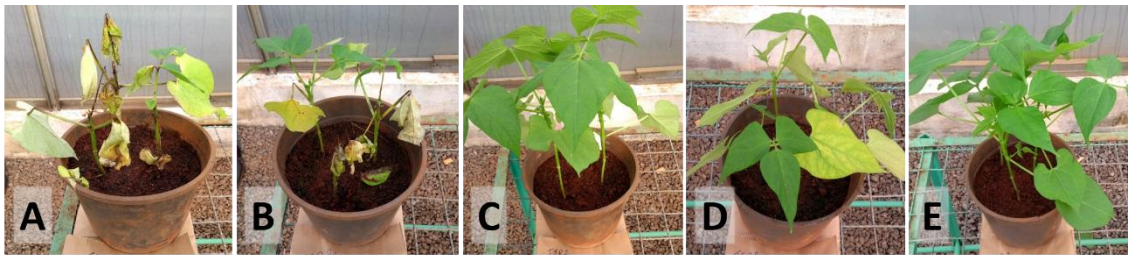

Figure 1: Common bean plants of the cultivar BRSMG Uai (last day of evaluation) from seeds treated with: A) Water (controle); B: soybean oil (control); C: methyl thiophanate . D: *C. cassia* essential oil; E: (E)-cinnamaldehyde.

The Poisson regression model shows the type of correlation between incidence and evaluation time, summarizing the evolution of the disease over time (Figure 2).

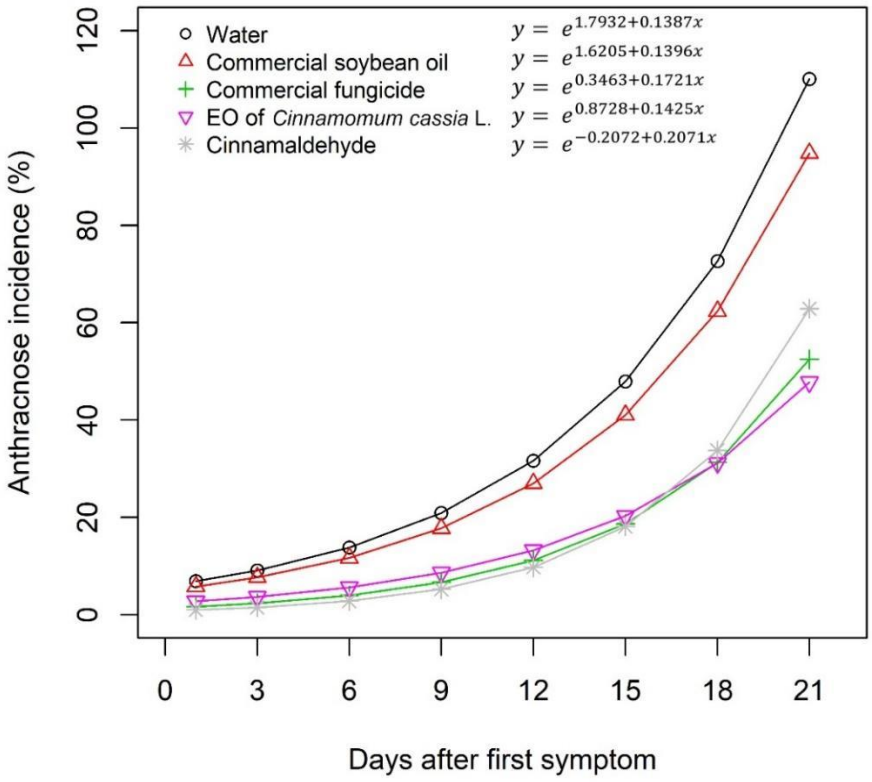

Figure 2. Incidence of anthracnose (percentage) in common bean plants of the cultivar BRSMG Uai, derived from water-treated seeds, commercial soybean oil, commercial fungicide (methyl thiophanate), essential oil of *Cinnamomum cassia* and (*E*)-cinnamaldehyde.

Although there are significant differences for the incidence of anthracnose between the control treatments and the other treatments, the same was not observed for the plant vigor at 21 days (dry mass).

DISCUSSION

The use and application of essential oils (EOs) and their bioactive molecules with antifungal properties may represent an attractive and efficient alternative approach to inhibit the growth of fungal pathogens (Abdel-Kader et al. 2011; Stević et al. 2014), but essential oils also exhibit phytotoxicity depending on the doses applied to the seeds (Sodaeizadeh et al. 2010). Thus, the present study suggested seed treatment involves the solubilization of essential oils and their majority substances in commercial soybean vegetable oil. These strategy finds theoretical support in the high apolar substance solubilization capacity of vegetable oils, their spread capacity (Chaijuckam and Davis 2010), and be easily accessible to the farmers.

The bioactivity of essential oil depends on the type, nature and concentration of its constituents (Batish et al. 2008). The analysis by GC-MS revealed that the amount of (*E*)-cinnamaldehyde (82.03%) is in accordance with the values found in the literature (Giordani et al. 2006; Li et al. 2013; Jardim et al. 2018). The narrow variation in the composition and percentage of compounds between oils is related to the environment in which the plant developed, the harvest stages, post-harvest storage time, as well as the extraction method of the essential oil (Yildirim et al. 2004; de Souza et al. 2017).

In the conditions of the present work there is no phytotoxic effect on seed germination, because in all treatments the germination percentages of the seeds were higher than 85%, which is above the national standards of production and commercialization of *P. vulgaris* seeds, which is 80% for certified seeds (MAPA 2015). In addition, seeds treated with

essential oil of *C. cassia* have significantly increased the length of the initial roots of the seedling, which can favor the establishment of the plant in the field, the water-capturing capacity of the root system, as well as a better utilization of nutrients (Lynch and van Beem 1993). The *in vivo* test with the seeds treated with the solutions of essential oils and (*E*)-cinnamaldehyde in the highest concentrations used *in vitro* showed no significant difference in the emergence, emergence speed and dry mass, evidencing that the essential oil of *C. cassia* and (*E*)-cinnamaldehyde are not phytotoxic to common bean seeds, in the evaluated conditions.

In vitro antifungal activity of *C. cassia* essential oil and (*E*)-cinnamaldehyde against *C. lindemuthianum* were similar, with MIC value (125 µg/mL). Since (*E*)-cinnamaldehyde corresponds to approximately 82% of the essential oil (Table 1), if this substance is the only component of the oil with antifungal activity, it would be expected that the MIC value of the oil would correspond to approximately 102 µg/mL (125 µg/mL x 0.82). However, the concentrations used were always multiplied at base 2, which means that there is no differentiation between these values in the experiment performed. Therefore, although it is clear that the majority component of *C. cassius* essential oil has activity against the fungus *C. lindemuthianum*, it is not possible to state that other components are inert. In any case, the antifungal activity observed in the present work for (*E*)-cinnamaldehyde is in accordance with the work of Neri et al. 2006. The authors investigated the effect of some substances on the fungus *Penicillium expansum*, and observed that (*E*)-cinnamaldehyde showed significant antifungal activity on mycelial growth, germination and sporulation of the fungus, presenting MIC value of 147 µL/L. Still on the *in vitro* test, we observed that soybean oil did not show antifungal activity, and this oil can be used as a neutral solvent for essential oils in seed treatment.

In vivo applicability of *C. cassia* oil/(*E*)-cinnamaldehyde in control of *C. lindemuthianum* on common bean seeds

The pathogen did not affect the emergence of the seedling which suggests that the fungus did not infect the whole seed, because when the infection in the field is high, there is not even the seed formation. When to the seed developed completely, consequently it carry the inoculum (Yesuf and Sangchote 2007). In general, the plants presented only typical symptoms of anthracnose (Figure 3), which confirms the presence of the fungus in the seed.

Figure 3 – Typical symptom of anthracnose on leaves of young (15 days) common bean plants (cultivar BRS Carioca MG) treated only with water.

The cinnamon known as 'true cinnamon' (*Cinnamomum zeylanicum*), which contains (*E*)-cinnamaldehyde, has been studied. Teixeira et al. 2013 demonstrated that the incidence of *Stenocarpella maydis* fungus was reduced from 57% to 28% with the use of *C. zeylanicum* oil in the treatment of corn seeds at a concentration of 0.1 µL/mL. Leite et al. 2018 observed that this oil was also efficient in decreasing the incidence of the fungus

Penicillium spp. in common bean seeds during storage, using the dose of 2.3 mL/Kg of seeds.

In conclusion, the use of essential oil of *C. cassia* and (E)-cinnamaldehyde dissolved in soybean oil for the treatment of common bean seeds was effective to reduce the symptoms caused by anthracnose, and could replace conventional fungicides recommended for seed treatments. In addition these products, did not presented phytotoxicity. Our study is the first in demonstrating the efficacy of *C. cassia* essential oil and (E)-cinnamaldehyde against *C. lindemuthianum* present in common bean seed, using seed treatment.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

Table S1 – Incidence of anthracnose in bean plants of the carioca type, cultivar BRSMG Uai, from seeds treated with water, commercial soybean oil, positive control (methyl thiophanate), essential oil (EO) of *Cinnamomum cassia* and (*E*)-cinnamaldehyde.

Treatments	**Anthracnose incidence (%)***							
	Days after first symptom							
	0º	3º	6º	9º	12º	15º	18º	21º
Water	1.6 **A**	6.9 **A**	14.1 **A**	18.0 **A**	40.4 **A**	61.5 **A**	78.5 **A**	92.2 **A**
Commercial Soybean oil	0.0 **A**	5.4 **A**	12.4 **A**	16.1 **A**	28.4 **A**	63.1 **A**	69.7 **A**	73.1 **B**
Methyl thiophanate	1.6 **A**	1.6 **A**	1.6 **A**	1.7 **A**	16.2 **B**	26.3 **B**	38.1 **B**	41.3 **C**
EO of *C. cassia*	1.9 **A**	1.9 **A**	3.5 **A**	14.3 **A**	14.3 **B**	19.6 **B**	34.4 **B**	43.3 **C**
(*E*)-Cinnamaldehyde	0.0 **A**	0.0 **A**	2.0 **A**	5.9 **A**	9.4 **B**	20.4 **B**	47.8 **B**	49.7 **C**

*Mean values with the same letter in a column do not differ statistically according to the Scott−Knott test ($P \leq 0.05$)