

Some Plants Showing Antagonism to Five Plant Pathogenic Fungi

M. E. N. Ferreira¹, C. F. Pinto¹, R. R. de Sena¹, J. G. de Mendoça Neto¹, C. R. Lobo¹, L. E. Chagas¹, D. L. da Silva¹, E. M. dos Santos¹, F. H. C. Santos¹, F. A. M. Nakamura¹ & Eder Marques¹

¹ UPIS Integrated Colleges, Brasilia, Brazil

Correspondence: Eder Marques, Department of Agronomy, Fazenda Lagoa Bonita, BR 020 KM 12, DF 335 KM 4,8-Planaltina, Brasília, DF, Brazil. Tel: 55-61-3488-9900. E-mail: eder.marques.08@gmail.com

Received: September 20, 2020

Accepted: October 25, 2020

Online Published: November 15, 2020

doi:10.5539/jas.v12n12p144

URL: <https://doi.org/10.5539/jas.v12n12p144>

Abstract

Fungi are among the main agents of plant diseases, being responsible for major losses in agriculture. The control of these microorganisms carried out using chemical compounds and numerous cases of resistance have already been observed, which makes it necessary to search for alternative methods of management of these pathogens. Therefore, the aim of this study, to evaluate the antifungal potential in plants. Twenty-four (24) plant extracts were tested for their antifungal potential against five plant pathogenic fungi: *Sclerotinia sclerotiorum* (Ss), *Stromatinia cepivora* (Sc), *Fusarium oxysporum* (Fox), *Colletotrichum gloesporioides* (Cg) and *Verticillium dahliae* (Vd). For the evaluation of the fungicidal potential, plant extracts were prepared by liquefying the plants in distilled water. The extracts were incorporated into PDA (Potato-Dextrose-Agar) culture medium to a final concentration of 35% and autoclaved. Then, PDA discs colonized by the aforementioned fungi were added to the center of each plate with the respective treatments (plant extracts). When all control treatments (PDA medium without plant extract) had colonized the entire Petri dish, the diameters of the fungal colonies were measured to calculate the Mycelial Growth Inhibition Index (MGI). Tests showed that all these plant extracts have some antifungal activity, ranging from 0 to 100% inhibition. In general, extracts of basil, lavender, guaco, rue, toxic cassava and black plum were the ones that stood out, with MGIs above 50%. New studies are being conducted to evaluate the activity of plant extracts without autoclaving, inhibition of sclerotia formation, to determine the minimum inhibitory concentration, as well as other parts of plants like roots and seeds, mixtures of plant extracts and *in vivo* antagonism tests.

Keywords: *in vitro* antagonism, mycelial growth inhibition, plant extracts, plant pathogens

1. Introduction

Plant diseases are among the most important phytosanitary problems, ahead of insects/arthropods and weeds. Among the phytopathogens, fungi stand out both in number and importance (Agrios, 2005). The control of these pathogens is basically performed with the use of chemical fungicides (Haq et al., 2020). Despite important strategies, it is known that such products are mostly costly and can affect the environment and living beings. In addition, many fungi have efficient survival mechanisms against adverse conditions (Massola Jr. & Krugner, 2011) and may also develop resistance to fungicide molecules used, as has often been observed in agriculture (Hobbelen et al., 2014).

Given these facts, there is undeniable concern and a search for alternative methods of pest and disease management (Machado et al., 2007). Examples of alternative methods are biological control or use of plant growth promoting bacteria (Kannoja et al., 2019), in addition to botanical fungicides. Some studies have been conducted to obtain alternative methods of disease management that are cheaper and less aggressive to the environment. To this end, the investigation of the biological activity of compounds present in plants may constitute a potential form of alternative control of diseases in cultivated plants (Schwan-Estrada et al., 2005), since many of them are the source of several bioactive secondary metabolites, such as tannins, terpenoids, saponins, alkaloids, flavonoids and other compounds, which have antifungal properties (Arif et al., 2009). From these studies, important information is obtained for the search for new fungicide molecules (Martínez, 2012), as well as for the direct use of extracts or their use processed as oils and mixtures in agricultural systems, such as organic agriculture (Machado et al., 2007). Commonly used to control pests and diseases in the organic system are plant extracts of neem (*Azadirachta indica* A. Juss., Meliaceae), garlic (*Allium sativum* L., Amaryllidaceae)

and pepper (*Capsicum* spp. L., Solanaceae), as well as essential oils and the Bordeaux, Viçosa and Sulfocalcium mixtures (Souza & Rezende, 2003).

According to a search carried out in Agrofit (Phytosanitary Pesticides System) of the Brazilian Ministry of Agriculture Livestock and Food Supply, only three herbal products were found: neem oil, registered for the control of common bean powdery mildew (*Erysiphe polygoni* DC) and white fly (*Bemisia* Quaintance, Baker) for all crops with biological target occurrence; *Reynoutria sachalinensis* (F. Schmidt, Nakai-Polygonaceae) root and stem extract, registered for various plant pathogenic fungi; and the leaf extract of *Melaleuca alternifolia* (Maiden, Betche Myrtaceae), registered for several fungi and plant pathogenic bacteria (MAPA, 2020). This demonstrates the lack of formulation of such products in agriculture, although scientific studies report the antifungal potential in several plant species.

In the view of above, the present study aimed to evaluate the *in vitro* antifungal potential of aqueous extract from 24 plants against five plant pathogenic fungi.

2. Method

2.1 Plant Pathogenic Fungi Tested

Five plant pathogenic fungi were tested: *Colletotrichum gloesporioides* (Penz.) Penz. & Sacc. (from passion fruit, *Passiflora edulis* L.), *Fusarium oxysporum* Smith & Swingle (from chickpeas, *Cicer arietinum* L.), *Sclerotinia sclerotiorum* (Lib.) de Bary (from common bean, *Phaseolus vulgaris* L.), *Stromatinia cepivora* (Berk.) Whetzel (from garlic, *Allium sativum* L.) and *Verticillium dahliae* Kleb. (from strawberry, *Fragaria* sp.). These fungal strains were provided by Embrapa-Cenargen (Brazilian Agricultural Research Corporate-Genetic Resources and Biotechnology), from its Collection of Fungi for the Control of Plant Pathogens and Weeds, through a transfer agreement signed between the institutions.

2.2 Obtaining Plant Extracts

The study was conducted in the federal district Federal District, Brazil, during the years 2019 and 2020. According to the Köppen classification, the place has a AW Tropical seasonal climate of megathermic savannah, average annual precipitation of 1,400 mm, average temperature of the coldest month above 18 °C concentrated between the months of October and March, dry period of April to September and with average temperatures of minimum 15.9 °C and maximum of 26.4 °C (Cardoso et al., 2014).

All plants used were collected, in the morning (before 10 am), on the college *Campus* in the department's garden of medicinal and toxic plants.

Twenty-four plants were studied (Table 1). Plant extracts were obtained by liquefying plant parts (leaf, branches and/or flowers, as appropriate) in sterile distilled water at an initial concentration of 50%. After this process, the extracts were incorporated into commercial Potato-Dextrose-Agar (PDA) culture medium to a final concentration of 35%, autoclaved and poured into 80 mm diameter plastic Petri dishes.

Table 1. Description of the plants used in the present research study of antifungal properties

Common Name	Scientific Name	Botanical Family	Part Used
Basil	<i>Ocimum gratissimum</i> L.	Lamiaceae	B and L*
Horsetail	<i>Equisetum arvense</i> L.	Equisetaceae	B
Carqueja	<i>Baccharis trimera</i> (Less.) DC	Asteraceae	B
Lavender	<i>Lavandula dentata</i> L.	Lamiaceae	B, L and F
Guaco	<i>Mikania glomerata</i> Spreng	Asteracea	B and L
Aloe vera	<i>Aloe vera</i> L.	Asphodelaceae	L
Rue	<i>Ruta graveolens</i> L.	Rutaceae	B, L and F
Mexican-tea	<i>Dysphania ambrosioides</i> L.	Amaranthaceae	B and L
Lemongrass	<i>Cymbopogon citratus</i> (DC) Stapf.	Poaceae	L
Pomegranate	<i>Punica granatum</i> L.	Punicaceae	B and L
Sage	<i>Salvia officinalis</i> L.	Lamiaceae	B, L and F
Indian coleus	<i>Plectranthus barbatus</i> Andrews	Lamiaceae	B and L
Fennel	<i>Foeniculum vulgare</i> Mill.	Apiaceae	B, L and F
Bigleaf mint	<i>Mentha rotundifolia</i> L.	Lamiaceae	B and L
Wild cassava	<i>Manihot esculenta</i> Crantz	Euphorbiaceae	L
Citronella	<i>Cymbopogon winterianus</i> Jowitt	Poaceae	L
Rosemary	<i>Rosmarinus officinalis</i> L.	Lamiaceae	B and L
Ginger Bush	<i>Tetradenia riparia</i> (Hochst.) Codd	Lamiaceae	B and L
Comfrey	<i>Symphytum officinale</i> L.	Boraginaceae	B, L and F
Black plum	<i>Syzygium cumini</i> L.	Myrtaceae	L
Banana	<i>Musa</i> sp.	Musaceae	L
Brazilian joyweed	<i>Alternanthera brasiliiana</i> (L.) Kuntze	Amaranthaceae	B and L
Horseradish	<i>Moringa oleifera</i> (L.) Mill.	Moringaceae	B and L
Mexican sunflower	<i>Tithonia diversifolia</i> (Hemsl.) A. Gray.	Asteraceae	B and L

Note. *B = Branches, L = Leaves and F = Flowers.

2.3 In vitro Antagonism Evaluation

To evaluate the antifungal potential of crude plant extracts, a disc of PDA medium colonized by the pathogens mentioned was used and placed in the center of each Petri dish. The control treatment consisted of Petri dishes containing only PDA medium, without plant extract.

When the control treatment colonized the entire surface of the medium, the diameters of the fungal colonies were measured with the aid of a millimeter ruler. Assays were performed in triplicate. Radial mycelial growth data were used to calculate the Mycelial Growth Inhibition index (MGI) according to the formula: $MGI = (D - T/D) \times 100$, where D is the diameter of the control colony, and T represents the mycelial growth, in cm, from treatment with plant extract (Menten et al., 1976).

2.4 Statistical Analysis

The experiment was conducted using a completely randomized design (CRD). MGI data were submitted to analysis of variance (ANOVA), followed by the Scott-Knott test, at 5% significance level, using the Sisvar 5.6 program (Ferreira, 2014).

3. Results

Considering the fungus *Cg* (Table 2, column), there was a variation in the MGI between 0 and 76.29% (Figure 1). The plant that stood out in the inhibition of growth of this pathogen was wild cassava (76.29%), with a significant difference from all others, which showed MGI below 34.16%. For *Fox*, the MGI ranged from 0 to 80%. In the inhibition of this plant pathogen, basil (80%) stood out, followed by sage (63.75%), lavender (60%), rue (53.33%), black plum (50.22%) and pomegranate (48.89%). As for *Ss*, the MGI ranged from 0 to 100%. In the inhibition of this fungus were highlighted the autoclaved extracts of basil, lavender and wild cassava (all with 100% of inhibition), followed by rue (70.41%) and guaco (62.50%). Horsetail extract inhibited only 7% of growth and the others were not antagonistic to this fungus. Against *Sc*, a variation was also observed in MGI between 0 and 100%. Five plant extracts formed an inhibition group without significant difference: lavender,

guaco, cassava and citronella (both with 100% inhibition) and basil (98.75%). A second inhibition group was formed with five more extracts of: fennel (79.16%), rue (70.83%), rosemary (66.66%), black plum (60.95%), bigleaf mint (60.41), Mexican-tea (60.41) and Indian coleus (50 %). Finally, when evaluating the extracts against *Vd*, it was observed that all extracts exhibited some activity, with MGI ranging from 4.76 to 100%. The group of plant extracts with the highest antifungal activity in this case consisted of: basil, lavender, guaco and pomegranate, both with 100% inhibition of *Vd* mycelial growth and wild cassava, with 88.57%. Then, and with a significant difference, came the extract of horsetail (74.36%), citronella (72.22%) and black plum (65.71%). In the case of this last fungus mentioned, an intermediate inhibition group was formed by the extracts of lemongrass (52.37%) and fennel (51.22%), while the others inhibited less than 38.89%.

Table 2. Result of bioassay with autoclaved plant extracts in inhibition of mycelial growth (MGI%) of plant pathogenic fungi

Plants/Extracts	MGI of plant pathogenic fungi					CV ²
	<i>Colletotrichum gloesporioides</i>	<i>Fusarium oxysporum</i>	<i>Sclerotinia sclerotiorum</i>	<i>Stromatinia cepivora</i>	<i>Verticillium dahliae</i>	
Basil	10.41dC ¹	80.00aB	100.00aA	98.75aA	100.00aA	3
Horsetail	0.00eB	15.41dB	0.00eB	4.16dB	74.36bA	44
Carqueja	13.75dB	31.25cA	21.66dB	35.41cA	28.20dA	21
Lavender	16.16dC	60.00bB	100.00aA	100.00aA	100.00aA	2
Guaco	0.00eD	37.50cC	62.50cB	100.00aA	100.00aA	4
Aloe	0.00eB	0.0eB	0.00eB	0.00dB	5.12eA	193
Rue	34.16bC	53.33bB	70.41bA	70.83bA	33.33dC	12
Mexican-tea	0.00eB	0.0eB	0.00eB	60.41bA	10.25eB	40
Lemongrass	15.42dB	0.0eB	0.00eB	8.33dB	52.37cA	43
Pomegranate	19.41cD	48.89bB	0.00eE	41.66cC	100.00aA	8
Sage	3.12eC	63.75bA	0.00eC	64.58bA	26.83dB	23
Indian coleus	0.00eB	32.08cA	0.00eB	50.00bA	26.83dA	49
Fennel	27.12cD	40.27cC	0.00eE	79.16bA	51.22cB	10
Bigleaf mint	13.98dA	6.25eA	0.00eA	60.41bA	26.01dA	117
Wild cassava	76.29aA	10.74dB	100.00aA	100.00aA	88.57aA	15
Citronella	29.63bC	37.50cC	0.00eD	100.00aA	72.22bB	19
Rosemary	24.07cC	20.37dC	0.00eD	66.66bA	38.89dB	18
Ginger Bush	14.81dA	11.11dA	0.00eA	32.59cA	27.78dA	73
Comfrey	0.00eB	0.0eB	0.00eB	0.00dB	11.11eA	96
Black plum	33.33cC	50.22bB	0.00eD	60.95bA	65.71bA	12
Banana	13.89dA	8.88dA	0.00eA	0.00dA	4.76eA	103
Brazilian joyweed	8.89dA	15.55dA	0.00eA	0.00dA	19.05eA	97
Horseradish	10.55dA	2.22eA	7.40eA	0.00dA	14.29eA	94
Mexican sunflower	11.11dA	0.0eB	0.00eB	0.00dB	19.05eA	87
CV ²	37	33	19	25	22	NA

Note. ¹ Means followed by the same letter do not differ by the Scott-Knott test ($p > 0.05$), lowercase in the column and uppercase in the row.

² Coefficient of variation row and column.

³ Not applicable in this case.

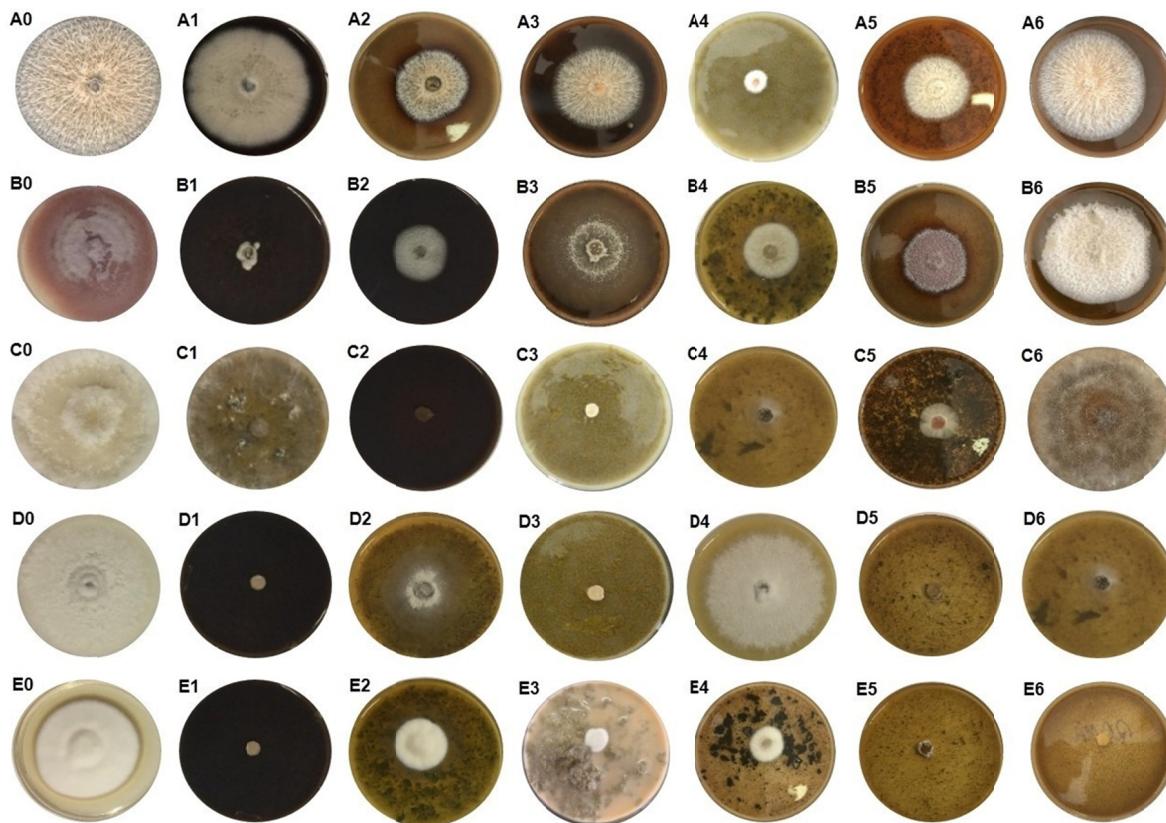


Figure 1. Mycelial growth inhibition bioassay of plant pathogenic fungi by autoclaved plant extracts, where, A is *Colletotrichum gloesporioides*, A0: Control treatment, A1: Pomegranate, A2: Black plum, A3: Citronella, A4: Wild cassava, A5: Rue and A6: Basil; B is *Fusarium oxysporum*, B0: Control treatment, B1: Basil, B2: Lavender, B3: Sage, B4: Rue, B5: Pomegranate and B6: Black plum; C is *Sclerotinia sclerotiorum*, C0: Control treatment, C1: Aloe vera, C2: Basil, C3: Wild cassava, C4: Rue, C5: Guaco and C6: Mexican-tea; D is *Stromatina cepivora*, D0: Control treatment D1: Guaco, D2: Fennel, D3: Wild cassava, D4: Horsetail, D5: Citronella and D6: Mexican-tea and E is *Verticillium dahliae*, E0: Control treatment, E1: Basil, E2: Rue, E3: Pomegranate, E4: Citronella, E5: Guaco and E6: Pomegranate

Analyzing plant performance in relation to plant pathogenic fungi (Table 2, row), it was observed that basil was not only efficient against *Cg*, where the MGI was 10.41%, for the other fungi was higher than 80%. Horsetail autoclaved extract only showed antifungal potential against *Vd* (74.36%), while for the others mycelial growth inhibition was less than 15.41%. Carqueja extract led to below median inhibition; the highest MGI were against *Sc* (34.41%), *Fox* (31.25) and *Vd* (28.2%). Lavender, like basil, exhibited good antagonism against almost all fungi, except *Cg*. Autoclaved guaco aqueous extract was 100% efficient against *Sc* and *Vd*, but also stood out against *Ss* (62.5%). Rue extract was a good inhibitor of the *Sc* (70.83%) and *Ss* (70.41%) fungi; in *Fox*'s case the inhibition was median (53.33%). The Mexican-tea extract only efficiently inhibited *Sc* (60.41%). Regarding the lemongrass extract, the greatest inhibition was against *Sc* (53.37%). Pomegranate extract was 100% efficient in inhibiting *Vd*, but the others fungi inhibited less than 48.89%. Sage only inhibited considerably *Fox* (63.75) and *Sc* (64.58). Indian coleus extract exhibited low antagonism and was only median for *Sc* (50%). Fennel was efficient in inhibiting *Sc* (79.16%) and median for *Vd* (51.22%). The bigleaf mint extract was also only good antagonistic to *Sc* (60.41%). Wild cassava leaf extract was effective against almost all fungi except *Fox* (10.74%). Citronella was efficient in inhibiting *Sc* (100%) and *Vd* (72.22%). Rosemary extract showed only inhibition against *Sc* (66.66%). Black plum exhibited the highest inhibition against *Sc* (60.45) and *Vd* (65.71). Extracts with low fungitoxic effect were: aloe (< 5.12%), Ginger Bush (< 32.59%), comfrey (< 11.11%), Banana (< 13.89%), Brazilian joyweed (< 19.05%), horseradish (< 14.29%) and Mexican sunflower (< 19.05%).

4. Discussion

The autoclaved aqueous basil extract was not efficient in inhibiting mycelial growth of *Cg*. Similar results were observed by Silva et al. (2009), where the infusion of the aqueous extract of this plant was not efficient in

antagonizing this pathogen. The alcoholic extract of this plant, dried and dissolved at 1% in water, inhibited 13% of *Cg* spore germination (Silva et al., 2009). Against *Fox*, no papers published in full in scientific journals were found that reported the use of autoclaved aqueous extract of basil, although the result here was significant: 80% inhibition. Camatti-Sartori et al. (2011) reported inhibition of 30.03 and 42.17%, with acetic extract at concentrations of 25 and 50%, respectively; and inhibition of 1.84 and 0% with ethanolic extract of this plant at 25 and 50% concentration, respectively. As regards *Ss*, 100% inhibition with the aqueous extract in question was observed here. Conversely, but using the same technique for a final concentration of 30%, Garcia et al. (2012) report an inhibition of only 25% of this pathogen. No scientific studies reporting the *in vitro* inhibition of *Sc* and *Vd* by basil extracts were accessed.

With regard to horsetail extract, in the present study only satisfactory antifungal activity was observed for *Vd* (74.36%). Using the same methodology, Rozwalka et al. (2008) observed 4.44% of inhibition growth of *Cg* from guava. Against *Ss*, *Sc* and *Vd* no works were found published in scientific journals that reported the use of autoclaved aqueous extract of this plant. Studying acetic and ethanolic extract, Camatti-Sartori et al. (2011) reported similar results, where they observed that two concentrations (25 and 50%) led to a low inhibition of *Fusarium* sp. (< 15.38%).

Carqueja extract at 35% showed low inhibition of the studied fungi (< 35.41%). In the case of *Cg* the inhibition was 13.75%. Studying different concentrations and with the same methodology, Milanesi et al. (2009) reported results close: 34.08% inhibition of this fungus. Against *Fox* no full scientific papers were found reporting the use of this plant to control the growth of this pathogen. For *Ss*, Pansera et al. (2012) observed that plant extracts obtained by infusion, hydroethanolic and ethanolic were not able to inhibit the fungus. Data on inhibition of *Sc* and *Vd* growth by compounds produced by this plant were not found.

With regard to lavender extract, excellent inhibition (> 60%) was observed for most fungi, except for *Cg* (16.16%), but no information about this fungus was available in literature with the present methodology. On the other hand, according to Domingues et al. (2009), *L. augustifolia* hexane extract exhibited good antagonism to *C. acutatum* (70%). Aqueous lavender extract completely inhibited the growth of *Ss*, *Sc* and *Vd*.

The aqueous extract of guaco was not antifungal regarding *Cg*. However, Bonett et al. (2012) observed that the 20% ethanolic extract of this plant was able to inhibit the fungus in a medium way. As for *Fox*, *Ss*, *Sc* and *Vd*, no information was found in the literature, although there was excellent antagonism of guaco toward the last three pathogens (100%).

Aloe, in the form of autoclaved extract, showed no fungicidal effect at the 35% concentration, except against *Vd*, which was low (5.12%). In contrast, Ranjitha et al. (2019) observed that this plant at a much lower concentration (7.5%) inhibited 50% of *Cg* growth. With different methodology, incorporation of plant filtrate into PDA medium after autoclaving, Mendy et al. (2019) reported that the 50% concentration was the most effective, inhibiting 100% of *Cg* growth, suggesting that heat sterilization may inactivate plant fungicidal compounds. The same was reported by Mendy et al. (2019) for *Fusarium* sp. *Ss* and *Sc* inhibition data were not accessed by extracts of this plant. Using another methodology, drying and incorporation of paper disk filtrate, Khaskheli et al. (2016) observed inhibition of *Vd* mycelial growth by approximately 24%.

The rue extract exhibited low *Cg* inhibition (34.16%). Using another methodology, dry plant material ground and diluted in boiling water, Celoto et al. (2008) report inhibition of 22.2% and 9.2% for extract with and without autoclaving at 20%, respectively, suggesting that this sterilization process may reduce the fungitoxic potential. In another study, the alcoholic extract dried and dissolved at 1% in water inhibited 6.6% of *Cg* spore germination (Silva et al., 2009). In the present study rue extract inhibited 53.33% *Fox* growth. Another species, *F. solani*, was inhibited by 77.6% with the autoclaved lyophilized extract of this plant (Oliva et al., 1999). The extract obtained from the milling and immersion in water, prepared by Garcia et al. (2016) at 30% concentration, inhibited 27.71% of the growth of *Ss*, a result lower than that observed here (70.41%). The aqueous extract of this plant inhibited 30 and 20% of growth of *Sc* at concentrations of 20 and 2%, according to Fuga et al. (2018), a result lower than that observed in the present study, of 70.83%. Autoclaved lyophilized extract, together with the culture medium, provided a 70.6% inhibition of *Vd*, according to Oliva et al. (1999). The result observed here was lower (33.33%).

The Mexican-tea did not show antifungal activity regarding *Cg* with the methodology employed. Similarly, but using another methodology, low activity was observed by Celoto et al. (2008): 4.7% and 0.5% inhibition for extract with and without autoclaving at 20%, respectively. Using different concentrations of aqueous extracts obtained from dry and filtered material (without autoclaving), Ohunakin & Bolanle (2017) observed greater inhibition of *Fox* at 60% concentration. In the present study, there was no inhibition of autoclaved extract,

indicating that it is possible that this process may have affected the properties of the botanical fungicide. No information on the antifungal effect of rue was accessed from *Ss*, *Sc* and *Vd*.

The aqueous extract of lemongrass showed low activity against most of the tested fungi. For *Cg* the inhibition was 15.42%. Moura et al. (2012) observed that the filtered aqueous crude extract inhibited the fungus more (35.1%) when compared to the autoclaved one (25%). A study developed by Silva and coworkers (2014), with the 20% extract and paper disc method, ie without autoclaving, indicated a 17.04% inhibition of this fungus. The infusion of lemongrass leaves in PDA medium (autoclaved) led to a median inhibition, being higher at a concentration of 20% when compared to previously reported 5 and 10% (Marcondes et al., 2014). Using the same methodology as in the present study, Rozwalka et al. (2008) observed a 26.66% inhibition of *Cg* growth, isolated from guava. Using another methodology described earlier, Celoto et al. (2008) report superior inhibition, 38% and 0.5% of this fungus, with and without autoclaving, respectively, of the 20% extract. No data were found on lemongrass extract to inhibit *Fox*, *Ss*, *Sc* and *Vd*.

Pomegranate extract exhibited low inhibition of the fungus *Cg*; however, the alcoholic extract dried and dissolved at 1% in water of this plant inhibited 72% of *Cg* spore germination (Silva et al., 2009). No information was found in the literature about the potential antagonist of this extract to *Fox*, *Ss*, *Sc* and *Vd*.

The sage plant in the form of autoclaved aqueous extract exhibited median antifungal potential for only two fungi. Regarding *Cg*, the inhibition was low (3.12%). The sage leaf infusion in PDA medium (autoclaved) led to a median inhibition of this fungus, being higher at 20%, when compared to previously reported 5 and 10% (Marcondes et al., 2014). The dried alcoholic extract, dissolved at 1% in water, inhibited 72% of *Cg* spore germination (Silva et al., 2009). The autoclaved extract in question was a good inhibitor of *Fox* growth (63.75%). No information on antagonistic sage extract was accessed for *Fox* in the literature; however, against *F. solani*, median inhibition was observed (Marcondes et al., 2014). The aqueous extract obtained by 50% hot water infusion was not effective in inhibiting *Ss* (Pansera et al., 2012), as observed in the present study. Also, information about the antagonistic sage extract was not accessed from *Sc* and *Vd*.

The Indian coleus extract showed, in general, low fungicidal potential. There was no inhibition of *Cg* with the extract of this plant. However, Figueiredo et al. (2016) observed 58.9% inhibition of *C. musae*. There are no reports in the literature of *Fox*, *Ss*, *Sc* and *Vd* inhibition by this plant.

The greatest antifungal potential of fennel extract was for *Sc*, although there is no report in the literature of the use of this plant as a fungicide. With regard to *Cg*, low inhibition (27.12%) was observed; using the same methodology, Rozwalka et al. (2008) observed 13.33% inhibition of the growth of this fungus of guava. The alcoholic extract of this plant, dried and dissolved at 1% in water, inhibited 85% of *Cg* spore germination (Silva et al., 2009). *Fox* inhibition by this plant was 40.27%. Using 10% alcohol extract, Bonapaz et al. (2019) observed 55% of mycelial growth inhibition. No information on the use of this plant to inhibit the fungus *Ss* and *Vd* was found in the literature.

Bigleaf mint extract exhibited low antifungal potential against *Cg* (13.98%). Similarly, Ribeiro & Bedendo (1999) report that the filtered extract of *Mentha* sp. (without autoclaving) and at 1000 ppm concentration inhibited the growth of this fungus only slightly (29.57%). Inhibition of aqueous plant extract was low (6.25%) for *Fox*. Camatti-Sartori et al. (2011) report inhibition of 26.41 and 45.49%, with acetic extract at concentrations of 25 and 50%, respectively; and inhibition of 0 and 2.74% with ethanolic extract of *M. piperita* at 25 and 50% concentration, respectively. No data were found on *Ss*, *Sc* and *Vd* inhibition by bigleaf mint extracts.

Autoclaved wild cassava extract inhibited almost all fungi. No information was found on *Cg* inhibition by this plant, although here it showed good inhibition (76.29%). *Fox* inhibition by autoclaved extract was low (10.74%); however, Ferreira et al. (2015) observed that only 10% root peel extract, without heat sterilization, led to inhibition of 53.17% of this passion fruit fungus. The extract of this plant showed low *Ss* inhibition (6.55%), according to a study by Garcia et al. (2016). In contrast, total inhibition of growth of this fungus was observed here, perhaps because it is a toxic cassava cultivar, which usually has more than 100 mg HCN/kg. No data on the antifungal potential of *Sc* and *Vd* of this plant were accessed, although they showed good inhibition of mycelial growth of 100 and 88.57%, respectively.

Citronella aqueous extract showed low inhibition of *Cg* (29.63%). The 20% aqueous extract and using the paper disc method, ie without autoclaving, led to a 59.22% inhibition of this fungus (Silva et al., 2014). Following the same pattern, the extract in question showed low fungitoxic activity against *Fox* (37.50%). The study carried out by Silva et al. (2014) indicated an inhibition of 48.28%. According to Monteiro et al. (2013), the 1% aqueous extract of this plant inhibited 90% mycelial growth of this fungus. On the other hand, this plant in the 2000 (0.2%) and 2500 ppm (0.25%) concentrations inhibited 94.44% of the *Fox* mycelial growth (Sreenivasa et al.,

2011). The aqueous extract of this plant inhibited 52% growth of *Sc* at a concentration of 20%, according to Fuga et al. (2018), a result lower than that observed in the present study, of 100% inhibition. No citronella *Ss* and *Vd* inhibition data were accessed, although there was good fungal inhibition in the present study (72.22%).

Rosemary exhibited low inhibition of the evaluated fungi. *Cg* was inhibited by 24.07%; however, using the same methodology as the present study, Rozwalka et al. (2008) observed 51.11% inhibition of growth of this *Cg* guava fungus. Similarly, 10% alcohol extract inhibited 45% growth of this fungus (Bonapaz et al., 2019), and the infusion of rosemary leaves, autoclaved in PDA medium, led to median inhibition of this fungus, being higher in the concentration of 20% when compared to previously reported 5 and 10% (Marcondes et al., 2014). Low inhibition was also observed for autoclaved aqueous extract against *Fox* (20.37%). A study carried out by Şesan et al. (2017) reports 58.6% growth inhibition of this fungus with 20% ethanolic extract. According to Monteiro et al. (2013), the 1% aqueous extract of this plant inhibited *Fox* mycelial growth by more than 80%. There was no inhibition of *Ss* with the aqueous extract of the plant. Ethanolic extract at 10, 15 and 20% inhibited 100% growth and sclerotia formation of this fungus (Goussous et al., 2013). On the other hand, autoclaved aqueous extract of this plant at a lower concentration (5%) inhibited 94.22% fungal growth (Montes-Belmont & Prados-Ligero, 2006).

Ginger Bush aqueous extract showed low antifungal activity. Testing aqueous extract at 7% of concentration against *C. lindemuthianum*, Pinto et al. (2009) observed an inhibition of 23.8%, slightly higher than that observed here (14.81%) for *Cg*, with 35% extract. No information was found in the literature on the investigation of fungicidal properties of this plant to the fungi *Fox*, *Ss*, *Sc* and *Vd*.

The plant commonly known as comfrey also showed no fungicidal activity, from the methodology used, except for a very low inhibition of *Vd* mycelial growth. The 1% alcoholic extract of this plant inhibited 67% of spore germination of *Cg* isolated from coffee (Silva et al., 2009). In contrast, studies carried out by Celoto et al. (2008) showed that neither aqueous nor hydroethanolic extracts inhibited papaya *Cg* conidia germination. No data were found in the scientific literature on the antifungal potential of this plant toward *Fox*, *Ss*, *Sc* and *Vd*.

Black plum extract showed low activity against *Cg* (33.33%); on the other hand, according to a study conducted by Srivastava et al. (2015), there was excellent antimycotic action of ethanolic extract to 10 and 15% of this plant, when compared to aqueous extract, to fungus *C. capsici*. *Fox* inhibition by aqueous extract was median (50.22%); however, according to More and colleagues (2017), the use of different extraction solvents provided inhibition of mycelial growth of this fungus ranging from 68.83 to 82.04%. The extract of this plant showed low inhibition of *Ss* (2.38%), according to a study by Garcia et al. (2016), similar to what was observed in the present study, where there was no inhibition of the fungus as an autoclaved extract. No report was found in the scientific literature on the use of this plant to inhibit the fungus *Sc*, which here was inhibited 60.95%. However, the autoclaved extract of the species *S. aromaticum* (clove) inhibited this pathogen by 85.44 % at a concentration of 5% (Montes-Belmont & Prados-Ligero, 2006). No report was found in the scientific literature regarding the use of this plant to inhibit the fungus *Vd*, which here was inhibited by 65.71%.

Banana leaf extract showed low mycelial growth inhibition of the evaluated fungi. For *Cg*, the inhibition was 13.89%. Evaluating the antifungal activity of banana tree leachate toward some postharvest fungi, Bele et al. (2018) observed that there was 100% inhibition of *C. musae* mycelial growth at the three concentrations tested (10, 15 and 20%). However, against *F. verticillioides* there was 100% inhibition at 20% concentration. Here, only 8.88% inhibition of *Fox* growth was observed using autoclaved leaf extract. No information was found in the literature on inhibition of *Ss*, *Sc* and *Vd* by extracts of this plant.

The antifungal activity of Brazilian joyweed extract was low, and scientific information was found in the literature only on its antiviral activity of this plant (Lagrota et al., 1987).

Another plant that showed low activity against the studied fungi was horseradish. MGI of *Cg* was only 10.55%. In contrast, Ranjitha et al. (2019) observed that this plant, at a much lower concentration (7.5%), inhibited *Cg* mycelial growth by 50%. On the other hand, the alcoholic extract at 1% inhibited 88.3% of *Cg* spore germination (Silva et al., 2009). Horseradish activity against *Fox* was even lower (2.22%). According to studies by Hlokwe et al. (2018), using the alcoholic extract of leaves, the greatest inhibition (35%) of this fungus was observed at a concentration of 6 g/ml. One mix of the dry extract from various parts of the plant at concentrations of 25 and 75% was able to inhibit *Fox* mycelial growth by 73.71 and 100%, respectively, according to studies carried out by Dwivedi and Sangeet (2015). Using different parts of the plant and seed oil, El-Mohamedy and Mohamed (2018) observed that the greatest inhibition of both *Fox* and *Ss* was with 50% leaf extract, 20% root extract and seed 3% oil. *Ss* sclerotia production was totally inhibited with 3% seed oil. No information was found in scientific articles on the use of this plant as an antagonist to fungi *Sc* and *Vd*.

Finally, the autoclaved aqueous of Mexican sunflower extract also exhibited low or no fungicidal activity. Inhibition of mycelial growth of the plant pathogenic fungi *Cg* was 11.11%; on the other hand, at a concentration of 1000 ppp (0.1%) inhibited 68.6% growth of this fungus (Bhuyan et al., 2015). A study carried out by Dissanayake and Jayasinghe (2013) showed that 20% extract inhibited 20% growth of *Cg*. According to Ngegba et al. (2018), the extract of the leaves of this plant at 100 and 40% provided an inhibition of 87.4 and 30.1% of *Fox*, respectively. At a lower concentration, 20%, Dissanayake and Jayasinghe (2013) observed an inhibition of approximately 10%. Here, no inhibition by extract of this plant was observed. No information was found in scientific papers published in widely circulated journals dealing with the antifungal potential of Mexican sunflower to *Ss*, *Sc* and *Vd*.

5. Conclusion

The aqueous extracts that stood out, inhibiting mycelial growth of some plant pathogenic fungi tested above 50%, were basil, lavender, guaco, rue, wild cassava, citronella and black plum. New studies are being conducted to evaluate the activity of plant extracts without autoclaving, inhibition of sclerotia formation, to determine the minimum inhibitory concentration, as well as other parts of plants like roots and seeds, mixtures of plant extracts and *in vivo* antagonism tests.

Acknowledgements

The authors thank Gislaine G. Gonçalves and Neide B. Rocha (UPIS Integrated Colleges) for their support in carrying out the experiments and also Dr^a Sueli Correa Marques de Melo (Embrapa-Cenargen) for providing the fungal strains used.

References

- Agrios, G. N. (2005). *Plant Pathology*. Elsevier Academic Press.
- Arif, T., Bhosale, J. D., Kumar, N., Mandal, T. K., Bendre, R. S., Lavekar, G. S., & Dabur, R. (2009). Natural products-antifungal agents derived from plants. *Journal of Asian Natural Products Research*, 11(7), 621-38. <https://doi.org/10.1080/10286020902942350>
- Bele, L., Kouame, D. K., Assir, K. P., & Diallo, H. A. (2018). Antifungal activity of Banana rachis leachate on some fungi responsible for Banana (*Musa acuminata Colla*) post-harvest diseases. *International Journal of Environmental & Agriculture Research*, 4(3), 1-6. <https://doi.org/10.5281/zenodo.1213546>
- Bhuyan, P. D., Phatik, P., & Boruah, P. (2015). *In-vitro* efficacy of certain essential oils and plant extracts against three major pathogens of *Jatropha curcas* L. *American Journal of Plant Sciences*, 6(02), 362-365. <https://doi.org/10.4236/ajps.2015.62041>
- Bonapaz, L. S., Afonso, M. A., Dutra, M. S., Francescaato, L. N., & Diel, V. B. N. (2019). Potencial fungitóxico de óleos voláteis e extratos vegetais no controle alternativo *in vitro* de fungos dos gêneros *Aspergillus* e *Fusarium*. *Revista de Ciências Ambientais*, 13(3), 07-16. <https://doi.org/10.18316/rca.v13i3.4003>
- Bonett, L. P., Muller, G. M., Wessling, C. R., & Gamello, F. P. (2012). Extrato etanólico de representantes de cinco famílias de plantas e óleo essencial da família Asteraceae sobre o fungo *Colletotrichum gloeosporioides* coletados de frutos de mamoeiro (*Carica papaya* L.). *Revista Brasileira de Agroecologia*, 7(3), 116-125.
- Camatti-Sartori, V., Magrini, F. E., Crippa, L. B., Marchett, C., Venturi, L., & Silva-Ribeiro, R. T. (2011). Avaliação *in vitro* de extratos vegetais para o controle de fungos patogênicos de flores. *Revista Brasileira de Agroecologia*, 6(2), 117-122.
- Cardoso, M. R. D., Marcuzzo, F. F. N., & Barros, J. R. (2014). Classificação climática de Köppen-Geiger para o Estado de Goiás e o Distrito Federal. *Acta Geografica*, 8(16), 40-55. <https://doi.org/10.5654/actageo2014.0004.0016>
- Celoto, M. I. B., Papa, M. F. S., Sacramento, L. V. S., & Celoto, F. J. (2008). Atividade antifúngica de extratos de plantas a *Colletotrichum gloeosporioides*. *Acta Scientiarum*, 30(1), 1-5. <http://doi.org/10.4025/actasciagron.v30i1.1104>
- Dissanayake, M. L. M. C., & Jayasinghe, J. A. N. (2013). Antifungal activity of selected medicinal plant extracts against plant pathogenic fungi: *Rhizoctonia solani*, *Colletotrichum musea* and *Fusarium oxysporum*. *International Journal of Science Inventions Today*, 2(5), 421-431.

- Domingues, R. J., Souza, J. D. F., Töfoli, J. G., & Matheus, D. R. (2009). Ação “in vitro” de extratos vegetais sobre *Colletotrichum acutatum*, *Alternaria solani* e *Sclerotium rolfsii*. *Arquivos do Instituto Biológico*, 76(4), 643-649.
- Dwivedi, S. K., & Sangeeta. (2015). Efficacy of some medicinal plant extract against *Fusarium oxysporum* f. sp. *ciceri* causing chickpea wilt. *Asian Journal of Crop Science*, 7(2), 138-146. <https://doi.org/10.3923/ajcs.2015.138.146>
- El-Mohamedy, R. S. R., & Mohamed, S. K. (2018). Effect of *Moringa oleifera* seed oil, root and leave extracts on growth of major pathogenic fungi of tomato, green bean and potato *in vitro*. *Asian Journal of Crop Science*, 7(2), 505-520.
- Ferreira, D. F. (2014). Sisvar: A Guide for its Bootstrap procedures in multiple comparisons. *Ciência e Agrotecnologia*, 38(2), 109-112. <https://doi.org/10.1590/S1413-70542014000200001>
- Ferreira, R. B., Rodrigues, A. A. C., Moraes, F. H. R., Silva, E. K. C., & Nascimento, I. O. (2015). Resíduos orgânicos no controle de *Fusarium oxysporum* f. sp. *passiflorae* em maracujazeiro amarelo (*Passiflora edulis* f. *flavicarpa*). *Acta Biológica Colombiana*, 20(3), 111-120. <https://doi.org/10.15446/abc.v20n3.44720>
- Figueiredo, Y. F., Altoé, L. S., Gonçalves, L. C., & Silva, M. B. (2016). Uso de extrato de *Plectranthus barbatus* como controle alternativo de *Colletotrichum musae*. *Encyclopédia Biosfera, Centro Científico Conhecer-Goiânia*, 13(24), 1-7. https://doi.org/10.18677/EnciBio_2016B_101
- Fuga, C. A. G., Lopes, E. A., Vieira, B. S., Soares, M. S., & Fernandes, R. V. B. (2018). Inhibition of the mycelial growth and germination of *Stromatinia cepivora* by plant extracts and essential oils. *Científica*, 46(3), 257-263. <https://doi.org/10.15361/1984-5529.2018v46n3p257-263>
- Garcia, R. A., Juliatti, F. C., Barbosa, K. A. G., & Cassemiro, T. A. (2012). Atividade antifúngica de óleo e extratos vegetais sobre *Sclerotinia sclerotiorum*. *Bioscience Journal*, 28(1), 48-57.
- Goussous, S. J., Mas'ad, I. S., Abu El-Samen, F. M., & Tahhan, R. A. (2013). *In vitro* inhibitory effects of rosemary and sage extracts on mycelial growth and sclerotial formation and germination of *Sclerotinia sclerotiorum*. *Archives of Phytopathology and Plant Protection*, 46(8), 890-902. <https://doi.org/10.1080/03235408.2012.753708>
- Haq, I. U., Sarwar, M. K., Faraz, A., & Latif, M. Z. (2020). Synthetic Chemicals: Major Component of Plant Disease Management. *Plant Disease Management Strategies for Sustainable Agriculture through Traditional and Modern Approaches*, 13, 53-81. <https://doi.org/10.1007/978-3-030-35955-3>
- Hlokwe, M. T. P., Kena, M. A., & Mamphiswa, N. D. (2018). Evaluating crude extracts of *Monsonia burkeana* and *Moringa oleifera* against *Fusarium* wilt of tomato. *Acta Agriculturae Scandinavica*, 68(9), 757-764. <https://doi.org/10.1080/09064710.2018.1484946>
- Hobbelen, P. H., Paveley, N. D., & Van Den Bosch, F. (2014). The emergence of resistance to fungicides. *PLoS One*, 9(3), e91910. <https://doi.org/10.1371/journal.pone.0091910>
- Kannoja, P., Choudhary, K. K., Srivastava, A. K., & Singh, A. K. (2019). Chapter Four-PGPR Bioelictors: Induced Systemic Resistance (ISR) and Proteomic Perspective on Biocontrol. *Food Security and Environmental Management*, 67-84. <https://doi.org/10.1016/B978-0-12-815879-1.00004-5>
- Khaskheli, M. I., Sun, J. L., He, S. P., Pan, Z. E., Jia, Y. H., Zhu, H. Q., ... Du, X. M. (2016). Chinese medicinal plants: an alternative approach for management of *Verticillium* wilt of cotton. *Phytopathologia Mediterranea*, 55(3), 323-336. https://doi.org/10.14601/Phytopathol_Mediterr-17782
- Lagrota, M. H. C., Wigg, M. D., Santos, M. M. G., Miranda, M. M. F. S., Camara, F. P., Couceiro, J. N. S. S., & Costa, S. S. (1994). Inhibitory activity of extracts of *Alternanthera brasiliiana* (Amaranthaceae) against the herpes simplex virus. *Phytotherapy Research*, 8, 358-361. <https://doi.org/10.1002/ptr.2650080609>
- Machado, L. A., Barbosa E., Silva, V., & Oliveira, M. M. (2007). Uso de extratos vegetais no controle de pragas em horticultura. *O Biológico*, 69(2), 103-106.
- MAPA (Ministry of Agriculture, Livestock and Supply of Brazil). (2020). *Search for formulated products*. Retrieved from http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons
- Marcondes, M. M., Martins, M., Baldin, I., Maia, A. J., Leite, C. D., & Faria, C. M. D. R. (2014). Influência de diferentes extratos aquosos de plantas medicinais no desenvolvimento de *Colletotrichum gloeosporioides* e de *Fusarium moniliforme*. *Revista Brasileira de Plantas Medicinais*, 16(4), 896-904. https://doi.org/10.1590/1983-084X/12_113

- Martínez, J. A. (2012). Fungicides for Plant and Animal Diseases. In D. Dhanasekaran, N. Thajuddin, & A. Panneerselvam (Eds.), *Natural Fungicides Obtained from Plants*. IntechOpen. <https://doi.org/10.5772/26336>
- Massola Jr., N. S., & Krugner, T. L. (2011). Fungos Fitopatogênicos. In L. Amorin, J. A. M. Rezende, & A. Bergamin Filho (Eds.), *Manual de Fitopatologia* (5th ed., Vol. 1, pp. 149-206). Editora Agronômica Ceres Ltda, São Paulo.
- Mendy, T. K., Misran, A., Mahmud, T. M. M., & Ismail, S. I. (2019). Antifungal properties of *Aloe vera* through *in vitro* and *in vivo* screening against postharvest pathogens of papaya fruit. *Scientia Horticulturae*, 257, 1-7. <https://doi.org/10.1016/j.scientia.2019.108767>
- Menten, J. O. M., Minussi, C. C., Castro, C., & Kimati, H. (1976). Efeito de alguns fungicidas no crescimento micelial de *Macrophomina phaseolina* (Tass.) Goid. "in vitro". *Fitopatologia Brasileira*, 1, 57-66.
- Milanesi, P. M., Blume, E., Muniz, M. F. B., Brand, S. C., Junges, E., Manzoni, C. G., & Weber, M. N. D. (2009). Ação fungitóxica de extratos vegetais sobre o crescimento micelial de *Colletotrichum gloeosporioides*. *Revista da FZVA*, 16(1), 1-13.
- Monteiro, F. P., Ferreira, L. C., Silva, J. L., Pacheco, L. P., & Souza, P. E. (2013). Influence of plant extracts and essential oils against panama disease (*Fusarium oxysporum* f. sp. *Cubense*) in banana seedlings. *Journal of Agricultural Science*, 5(4), 63-74. <https://doi.org/10.5539/jas.v5n4p63>
- Montes-Belmont, R., & Prados-Ligero, A. M. (2006). Influence of plant extracts on *Sclerotium cepivorum* development. *Plant Pathology Journal*, 5(3), 373-377. <https://doi.org/10.3923/ppj.2006.373.377>
- More, Y. D., Gade, R. M., & Shitole, A. V. (2017). *In vitro* antifungal activity of *Aegle marmelos*, *Syzygium cumini* and *Pongamia pinnata* extracts against *Fusarium oxysporum* f. sp. *cicero*. *Indian Journal of Pharmaceutical Sciences*, 79(3), 457-462. <https://doi.org/10.4172/pharmaceutical-sciences.1000249>
- Moura, G. S., Schwan-Estrada, K. R. F., Alves, A. P. F., Franzener, G., & Stangarlin, J. R. (2012). Controle da antracnose em maracujá-amarelo por derivados de capim-limão (*Cymbopogon citratus*). *Arquivos do Instituto Biológico*, 79(3), 371-379. <https://doi.org/10.1590/S1808-16572012000300007>
- Ngegba, P. M., Kanneh, S. M., Bayon, M. S., Ndoko, E. J., & Musa, P. D. (2018). Fungicidal effect of three plants extracts in control of four phytopathogenic fungi of tomato (*Lycopersicum esculentum* L.) fruit rot. *International Journal of Environment Agriculture and Biotechnology*, 3(1), 112-117. <https://doi.org/10.22161/ijeab/3.1.14>
- Ohunakin, A. O., & Bolanle, O. O. (2017). *In vitro* antifungal activities of plant extracts against *Fusarium oxysporum Schlechtend. Fr. f. sp. lycopersici* (Sacc.) causal organism of Fusarium wilt in tomato. *Journal of Plant Sciences and Agricultural Research*, 1, 1-5.
- Oliva, A., Lahoz, E., Contillo, R., & Aliotta, G. (1999). Fungistatic activity of *Ruta graveolens* extract and its allelochemicals. *Journal of Chemical Ecology*, 25(3), 519-526. <https://doi.org/10.1023/A:1020949703205>
- Pansera, M. R., Vicenço, C. B., Prancutti, A., Sartori, V. C., & Ribeiro, R. T. S. (2012). Controle alternativo do fungo *Sclerotinia sclerotiorum* (Lib.) De Bary causador da podridão de sclerotinia, com óleos essenciais e extratos vegetais. *Revista Brasileira de Agroecologia*, 7(3), 126-133.
- Pinto, J. M. A., Souza, E. A., & Oliveira, D. F. (2009). Antifungal properties of medicinal plants against *Colletotrichum lindemuthianum*. *Annual Report of the Annual Report of the Bean Improvement Cooperative*, 52, 42-43.
- Ranjitha, N., Devappa, V., & Sangeetha, C.G. (2019). Evaluating eco-friendly botanicals against *Colletotrichum gloeosporioides* causing anthracnose of mango. *International Journal of Current Microbiology and Applied Sciences*, 8(5), 1809-1816. <https://doi.org/10.20546/ijcmas.2019.805.210>
- Ribeiro, L. F., & Bedendo, I. P. (1999). Efeito inibitório de extratos vegetais sobre *Colletotrichum gloeosporioides*-agente causal da podridão de frutos de mamoeiro. *Scientia Agricola*, 56(4), 1267-1271. <https://doi.org/10.1590/S0103-90161999000500031>
- Rozwalka, L. C., Lima, M. L. R. Z. C., Mio, L. L. M., & Nakashima, T. (2008). Extratos, decoctos e óleos essenciais de plantas medicinais e aromáticas na inibição de *Glomerella cingulata* e *Colletotrichum gloeosporioides* de frutos de goiaba. *Ciência Rural*, 38(2), 301-307. <https://doi.org/10.1590/S0103-84782008000200001>

- Şesan, T. E., Enache, E., Lacomi, B. M., Oprea, M., Oancea, F., & Lacomi, C. (2017). *In vitro* antifungal activity of some plant extracts against *Fusarium oxysporum* in blackcurrant (*Ribes nigrum* L.). *Acta Scientiarum Polonorum Hortorum Cultus*, 16(6), 167-176. <https://doi.org/10.24326/ASPHC.2017.6.15>
- Show-Estrada, K. R. F., Stangarlin, J. R., & Cruz, M. E. S. (2005). Uso de extratos vegetais no controle de fungos fitopatogênicos. *Floresta*, 30(1/2), 129-137. <https://doi.org/10.1590/0100-2945-223/13>
- Silva, A. C., Salres, N. L. P., Araújo, A. V., & Caldeira Júnior, C. F. (2009). Efeito *in vitro* de compostos de plantas sobre o fungo *Colletotrichum gloeosporioides* Penz. isolado do maracujazeiro. *Ciência e Agrotecnologia*, 33, 1853-1860. <https://doi.org/10.1590/S1413-70542009000700026>
- Silva, J. L., Souza, P. E., Monteiro, F. P., Freitas, M. L. O., Silva Júnior, M. B., & Belan, L. L. (2014). Antifungal activity using medicinal plant extracts against pathogens of coffee tree. *Revista Brasileira de Plantas Medicinais*, 16(3), 539-544. https://doi.org/10.1590/1983-084X/12_155
- Souza, J. L., & Resende, P. (2003). *Manual de Horticultura Orgânica* (2nd ed., p. 843). Viçosa, Aprenda Fácil.
- Sreenivasa, M. Y., Dass, R. S., Raj, A. P. C., Prasad, M. N. N., Achar, P. N., & Janardhana, G. R. (2011). Assessment of the growth inhibiting effect of some plant essential oils on different *Fusarium* species isolated from sorghum and maize grains. *Journal of Plant Diseases and Protection*, 118(6), 208-213. <https://doi.org/10.1007/BF03356405>
- Srivastava, M., Srivastava, C., Srivastava, G. K., & Prabhiji, S. K. (2015). Evaluation of antifungal efficacy of leaf extracts of *Aegle marmelos*, *Terminalia arjuna*, *Lawsonia inermis*, *Artemisia vulgaris* and *Syzygium cumini* against post-harvest fungal pathogens affecting certain vegetables. *International Journal of Phytomedicines and Related Industries*, 7(3), 241-244. <https://doi.org/10.5958/0975-6892.2015.00034.9>

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).