v. 6, n. 6, 2025

Journal of
Agricultural
Sciences
Research

Acceptance date: 03/07/2025

OCCURRENCE OF BRANCH CANKER AND STEM-END ROT IN AVOCADO TREES IN SÃO PAULO ORCHARDS

Ivan Herman Fischer
Agency Paulista Agribusiness Technology - Regional, Bauru, SP, Brazil
*Corresponding author

Rosemary Marques de Almeida Bertani
Agency Paulista Agribusiness Technology - Regional, Bauru, SP, Brazil

Lukas Yujii dos Santos
UNISAGRADO, Bauru, SP, Brazil

Juliana Cristina Sodario Cruz
Agency Paulista Agribusiness Technology - Regional, Bauru, SP, Brazil

Bruno Henrique Leite Gonçalves
Unifio Centro Universitário de Ourinhos, Ourinhos, SP, Brazil

Ana Carolina Firmino
College of Agricultural and Technological Sciences, São Paulo State University, Dracena, SP, Brazil

Lilian Amorim
Department of Plant Pathology and Nematology, Luiz de Queiroz College of Agriculture, University of São Paulo, Piracicaba, SP, Brazil

Abstract: Branch canker and stem-end rot of avocado trees were characterized in 15 commercial orchards in the State of São Paulo, evaluating factors such as incidence of diseased branches and fruits, presence of pathogens, phytosanitary management, and foliar and soil chemical analysis. Fungal pathogens were isolated on potato dextrose agar medium from fragments of diseased branches, identifying the fungal genus by conidial morphology. The disease exhibited a high incidence, with an average of over 97% symptomatic plants in orchards, varying significantly among orchards and in the number of diseased branches per plant. Disease prevalence increased with plant age, predominantly affecting older branches. The presence of diseased branches associated with wood-boring beetle attack and the absence of protection of pruning wounds with fungicides were observed in most orchards. Fungi of the Botryosphaeriaceae family and *Phomopsis* sp. were the main causative agents of the disease, with an average incidence of 49.0% and 32.0%, respectively. Stem-end rot was the predominant postharvest disease compared to fruit body rot, with *Colletotrichum* sp. being the most frequent pathogen, affecting more than 15% of the fruits, followed by *Lasiodiplodia* sp. and *Fusicoccum*/*Neofusicoccum* sp. However, no significant correlation was observed between the incidence of diseased branches and the occurrence of fruit rot. Nutritional analysis revealed imbalances in soil and foliar levels of certain nutrients in most orchards. The results highlight the need for more effective management strategies, especially in phytosanitary and nutritional management, protection of pruning wounds and removal of infected branches, to minimize the spread of the disease and its implications on avocado productivity.

Keywords: *Persea americana*, dieback, Botryosphaeriacea, *Phomopsis*.

INTRODUCTION

The avocado tree (*Persea americana* Mill.) is a crop of significant economic importance in Brazil, with substantial growth in both production and demand in the domestic and international markets. The country stands out as one of the leading global producers, with cultivation concentrated in the State of São Paulo, followed by Minas Gerais and Paraná (IBGE, 2025). However, the expansion of the crop faces phytosanitary challenges, such as branch canker or dieback, which can compromise the viability of the orchard (Valencia *et al*., 2019).

The symptoms of avocado branch canker include the exudation of white powdery substance from cracks in the bark of the branches, necrosis of the underlying wood, leaf chlorosis, branch dieback, and plant death (Dann *et al*., 2013). In Peru, the incidence of diseased plants reached 86%, with 10% of affected plants dying (Alama *et al*., 2006). Even if the plant does not die, the damage to the branches affects the accumulation and viability of the reserves necessary for fruiting, potentially reducing orchard productivity (Valencia *et al*., 2019). The disease can be a serious problem in newly planted orchards established with scion wood that is latently infected, as these infections can kill the graft union (Menge and Ploetz, 2003). Additionally, stem-end rot can occur in the fruits, reducing their quality and compromising their marketability.

The disease is caused by a complex of fungi, primarily from the Botryosphaeriaceae family and, less frequently, Diaporthaceae, and has been reported in various countries, including Chile, Mexico, New Zealand, Peru, South Africa, Spain, and the United States (Menge and Ploetz, 2003; McDonald and Eskalen, 2011; Eskalen *et al*., 2013; Arjona-Girona *et al*., 2019; Valencia *et al*., 2019). At least 25 species of Botryosphaeriaceae have been identified as causing the disease (Möller *et al.*, 2025). In Brazil, branch cankers have been attributed to Lasiodiplodia sp. (Duarte *et al.*, 2021), while Neofusicoccum parvum and Fusicoccum aesculi have been identified as causing stem-end rots (Firmino *et al.*, 2016). Members of Botryosphaeriaceae have a worldwide distribution and cause branch cankers and stem-end rots in a wide range of hosts (Urbez-Torres *et al.*, 2006; Lazzizera *et al.*, 2008; Netto *et al.*, 2017; Slippers *et al.*, 2017).

These pathogens survive in the orchard on cultural residues due to their saprophytic ability. They also occur as endophytic or phyllophytic in the extra-cambial tissue of avocado trunks, branches, and pedicels (Johnson and Kotze, 1994; Hartill and Everett, 2002). However, it is believed that the endophytic occurrence may become pathogenic when the host undergoes some type of stress or during postharvest (Slippers and Wingfield, 2007; Dann *et al.*, 2013; Slippers *et al.*, 2017). The pathogens Lasiodiplodia and Fusicoccum/Neofusicoccum have been found in fruits at the early stages of development, with a length of 0.8 cm (Fischer *et al.*, 2019).

The pathogen inoculum in the orchard is produced under high humidity conditions and disseminated by raindrop splashes, wind, or the swaying of branches during fruit harvest (Hartill and Everett, 2002). Spores or hyphal fragments penetrate the tissues primarily through wounds and lenticels (Navarro *et al.*, 2022). According to Dann *et al.* (2013), wounds are a prerequisite for infection in the branches; thus, the disease is associated with wounds resulting from pruning, sunburn, frost damage, mechanical damage, bark cracking caused by wind, and grafting wounds.

The recommended management involves cultural practices that minimize plant stress and reduce inoculum sources. Pruning is advised under dry conditions, along with the removal of diseased branches, proper fertilization, and irrigation, as well as pest monitoring and control. Copper-based fungicides should be applied after pruning, before flowering, and two to three more sprays during fruiting (Dann *et al.*, 2013; Fischer and Firmino, 2023), and they may be combined with strobilurins to increase efficacy in controlling stem-end rot (Fischer *et al.*, 2018).

Research on avocado branch canker is limited in Brazil, highlighting the need for further studies to elucidate its occurrence in orchards, as well as its etiology of causal agents. Such knowledge is essential for developing effective disease management strategies, ensuring sustainable production, and mitigating its impact. Therefore, this study aimed to characterize the occurrence of branch canker and stem-end rot in avocado orchards in the State of São Paulo and to identify the main fungal genera associated with these symptoms.

MATERIAL AND METHODS

CHARACTERIZATION OF BRANCH CANKER IN AVOCADO ORCHARDS

From July to October 2022, 15 commercial avocado orchards in the State of São Paulo, located in 13 different cities, were visited. These orchards were selected based on reports from farmers regarding the occurrence of branch canker. For each orchard, information such as geographic location, cultivar and rootstock variety, age, plant spacing, presence and type of irrigation, fungicides used (application date), and whether pruning wounds were protected with fungicide was recorded. The incidence of symptomatic plants in each orchard was estimated through visual observation of the disease symptoms in 100 plants per plot, considering a plant symptomatic if it exhibited at least one diseased branch. Diseased branches were categorized into old branches [old branch (OB) = base of the diseased branch inserted into a woody trunk], primarily located in the internal and lower portions of the plant; tip dieback or new branches [new branch (NB) = base of the diseased branch inserted into a non-woody trunk]; and new branches with attached leaves (AL), considered the type of symptom preceding NB and OB (Figure 1). In addition to the percentage of diseased plants and branches, the diameter of diseased branches and the presence of wood-boring beetle holes and pruning wounds on affected or adjacent diseased branches were evaluated in each sampled tree (Figure 2).

Figure 1. Symptoms of avocado branch canker disease, characterized in branches as attached leaves (A); tip dieback (B) or new branches (C), and old branches (D).

Figure 2. Symptoms of branch canker associated with the presence of wood-boring beetle holes (A and B) and pruning wounds (C and D).

Up to 30 samples of branches exhibiting symptoms of dieback were collected, with 10 samples representing each symptom type (OB, NB, and Al) from different trees in each orchard. In the laboratory, the transition zones between healthy and diseased tissue in each sample were disinfected by immersion in 70% ethanol for 30 seconds, followed by 1% NaOCl for 1 minute, and rinsed with sterile distilled water for 30 seconds. After drying under a laminar flow hood, small fragments of approximately 0.5 cm in length were excised using a scalpel from the inner bark tissue and diseased xylem. These fragments were then transferred to Petri dishes containing potato dextrose agar (PDA) medium supplemented with 0.5 g L^{-1} streptomycin sulfate (Netto *et al.*, 2017). The plates were incubated at 25°C for three to five days, after which pure cultures were obtained by transferring hyphal tips from the colonies to PDA medium. Based on the typical morpho-cultural characteristics of fungal genera (colony pigmentation, type and growth rate of mycelium, and conidial morphology) (Barnett and Hunter, 1998), the isolation frequency was calculated in relation to the diseased branches. The different fungal isolates obtained were inoculated into

‘Hass’ avocado seedlings maintained in a greenhouse, with two seedlings used for each isolate. Inoculation was performed by affixing a 5-mm-diameter mycelial disc of each isolate onto the seedling stem with adhesive tape, following a prior wound created using a 3-mm-diameter cork borer to an approximate depth of 1 mm. Isolates were considered pathogenic when lesions of at least 0.5 cm in length developed on the stems within the first 14 days post-inoculation.

Leaf and soil samples (20 cm depth) were randomly collected from 10 plants out of the 100 plants in the studied plot of each orchard for chemical analysis of macro- and micronutrients.

POSTHARVEST DISEASES IN AVOCADO ORCHARDS

Avocado fruits at the commercial maturity stage were collected using scissors disinfected with 0.02% NaOCl from the previously sampled orchards exhibiting branch canker symptoms. Two fruits were randomly sampled per tree, totaling 200 fruits per orchard. The fruits were disinfected by immersion in 0.02% NaOCl for 5 minutes, rinsed with running water, individually placed in plastic trays, and stored in a chamber at 25°C and 80–85% relative humidity (RH) for 8–12 days until ripening (>70% of the fruits ready for consumption). Postharvest disease incidence was assessed at 2-day intervals based on visual symptoms and presence of pathogen reproductive structures under an optical microscope.

DATA ANALYSIS

The incidence of diseased plants and branches, as well as the diameter of diseased branches and the incidence of Botryosphaeriaceae and Phomopsis sp. in branches, were compared among orchards and across the three symptom types using nonparametric analysis and a multiple proportion comparison test (p=0.05) (Zar, 1999). Pearson’s linear correlation analysis (p=0.05) was performed between the number of diseased branches and plant age to assess the relationship between disease occurrence and orchard age.

The relationship between foliar and soil macro- and micronutrient levels and the number of diseased branches in the 10 sampled plants, as well as the incidence of *Botryosphaeriaceae* and *Phomopsis* sp. isolated from the 30 diseased branches, was determined using Pearson’s linear correlation analysis (p=0.05).

The relationship between branch canker incidence in the orchards and both the total incidence of postharvest diseases and the main pathogens responsible for stem-end rot (*Colletotrichum* and *Botryosphaeriaceae* isolates) in each orchard was also assessed using Pearson’s linear correlation analysis (p=0.05). The incidence data of postharvest pathogens in fruits were compared among orchards and between pathogens using nonparametric analysis and a multiple proportion comparison test (p=0.05) (Zar, 1999).

RESULTS AND DISCUSSION

CHARACTERIZATION OF BRANCH CANKER IN AVOCADO ORCHARDS

Among the 15 avocado orchards evaluated, ranging in age from 2.7 to 6.8 years, the Hass avocado cultivar was assessed in 10 orchards, along with four other cultivars (Carmen, Geada, Margarida, and Quintal). As rootstocks, ‘Hass’ was used in seven orchards, ‘Margarida’ in four, and the ‘Crioulo’ rootstock (of unknown origin from seed propagation) in the remaining four orchards. Plant spacing varied between 4.2 × 6.6 m and 8 × 10 m, while the number of plants per plot ranged from 280 to 9,300. Irrigation was present in 9 out of the 15 orchards, predominantly through drip irrigation. The presence of diseased branches showing symptoms of wood-boring beetle infestation was observed in all orchards, with incidences ranging from 1% to 30% of the 100 evaluated plants per orchard. However, in most orchards, only a single diseased branch per plant was affected by wood-boring beetle. Diseased branches that had been pruned or were adjacent to diseased pruned branches were recorded in 11 orchards, with incidences ranging from 1% to 13% of the evaluated plants, predominantly with a single affected branch per plant.

Only four orchards applied copper-based fungicides to protect pruning wounds. Notably, the highest incidences (6% and 13%) of diseased pruned branches or branches adjacent to diseased pruned branches were observed in two orchards that did not implement wound protection (Table 1). The occurrence of wood-boring beetle infested diseased branches in all orchards, even at low incidence levels, and the lack of fungicidal protection of pruning wounds in most orchards highlight the need for more effective phytosanitary management. Pruning wounds serve as an entry point for pathogens responsible for branch canker (Dann *et al.*, 2013).

The majority of orchards employed some type of pesticide or fertilizer aimed at disease management, except for the Arealva 3 orchard, which had not received any application up to the fruit harvest (Table 2). The Bariri orchard applied only organic fertilizers, whereas the orchards in Bauru, Piraju, and Pirajuí combined chemical and microbiological fungicides. Potassium phosphite fertilizer was used in three orchards with a history of Phytophthora root rot disease. The orchards received between 1 and 11 fungicide spray applications (azoxystrobin, azoxystrobin+mancozeb, captan, copper hydroxide, copper oxychloride, cuprous oxide, difenoconazole+azoxystrobin, metalaxyl+mancozeb, pyraclostrobin, tebuconazole+trifloxystrobin) in the last growing season, primarily targeting the control of foliar diseases. Notably, pyraclostrobin and tebuconazole+trifloxystrobin are not registered for avocado cultivation to date. Among these, only cuprous oxide is registered with the Ministry of Agriculture, Livestock, and Food Supply for the management of canker and fruit rot caused by *Dothiorella gregaria* (Agrofit, 2025).

Orchard (denomination)	Coordinates	Variety (scion/rootstock)	Age (years)	Spacing (m)	Plants /plot	Irrigation	Wounds on infected branches		
							Wood-boring beetle[1]	Pruning[1]	Protection with Cu
Dourado	22°07'47.6"S 48°22'37.9"W	Geada/Crioulo	3.8	8 x 10	2900	No	2 (1.0)	3 (1.3)	No
Bauru	22°14'09.7"S 49°08'31.6"W	Carmen/Hass	3.8	6 x 8	400	Drip	8 (1.1)	0	No
Arealva 3	22°10'02.7"S 49°02'02.1"W	Hass/Hass	2.7	6 x 8	2000	Drip	12 (1.2)	0	No
Pirajuí	21°58'42.0"S 49°27'46.3"W	Hass/Hass	3.0	6 x 8	8400	Drip	11 (1.0)	2 (1.0)	Yes
Arealva 1	22°07'17.1"S 48°57'07.9"W	Hass/Margarida	4.0	5 x 8	2000	Drip	20 (1.4)	3 (1.0)	Yes
Arealva 2	22°08'00.5"S 48°57'02.6"W	Hass/Margarida	2.8	5 x 8	8500	Micro-sprinkling	2 (1.0)	2 (1.0)	Yes
São Manuel	22°45'07.2"S 48°36'56.5"W	Hass/Hass	3.8	5 x 6	800	Drip	1 (1.0)	1 (1.0)	No
Jaú	22°13'21.8"S 48°25'03.5"W	Hass/Hass	4.5	6 x 8	2000	Drip	22 (2.0)	0	No
Bariri	22°02'07.8"S 48°44'22.6"W	Quintal/Margarida	3.9	5 x 10	280	No	16 (1.4)	4 (1.0)	No
Bernardino C.	22°05'34.8"S 49°30'36.7"W	Hass/ Crioulo	4.3	5 x 8	2723	No	30 (1.3)	2 (1.0)	No
Piraju	23°10'38.5"S 49°25'25.4"W	Hass/Hass	3.4	4.2 x 6.6	9300	Drip	6 (1.0)	5 (1.0)	Yes
Óleo	22°57'0.88"S 49°24'0.93"W	Hass/Hass	3.6	5 x 7	1500	Drip	25 (1.1)	6 (1.2)	No
Timburi	23°14'41.9"S 49°34'02.7"W	Hass/ Crioulo	6.8	5 x 7	2500	No	9 (1.0)	13 (1.5)	No
Manduri	22°54'27.7"S 49°17'35.2"W	Margarida/Margarida	3.8	8 x 10	500	No	3 (1.0)	0	No
Botucatu	22°59'26.8"S 48°28'25.4"W	Margarida/ Crioulo	4.0	6 x 8	1500	No	6 (1.0)	2 (1.0)	No

[1]Percentage of plants with diseased branches showing symptoms of wood-boring beetle attack or adjacent to pruned diseased branches (branches/plant).

Table 1. Information on the avocado orchards sampled in the state of São Paulo.

Orchard (denomination)	Sampling dates		Fungicides/fertilizers (application dates)
	Branches	Fruits	
Dourado	14/09/22	27/01/23	Potassium phosphite, metalaxyl+mancozeb (27/04/22), azoxystrobin (18/06/22, 21/10/22, and 15/01/23), and tebuconazole+trifloxystrobin (24/11/22)
Bauru	27/07/22	13/02/23	Tebuconazole+trifloxystrobin (06/10/22), copper oxide (22/11/22, 13/01/23, and 06/02/23), gray bokashi (24/11/2022), and microorganism mixture via fertigation (*Bacillus subtilis*, *B. aryabhattai*, *Azospirillum brasilense*, and *Trichoderma asperellum*) (monthly)
Arealva 3	14/10/22	13/02/23	No fungicide was applied
Pirajuí	10/08/22	14/02/23	Captan, difenoconazole+azoxystrobin (03/08/22), difenoconazole+azoxystrobin, folpet, *Ascophyllum nodosum* (05/09/22), difenoconazole+azoxystrobin, folpet, and *A. nodosum* (15/12/22)
Arealva 1	04/08/22	17/02/23	Bordeaux mixture (10/04/22), pyraclostrobin (20/06/22), difenoconazole+azoxystrobin (15/08/22, 15/09/22, 03/11/22, 25/11/22, and 14/12/22), and copper oxychloride (15/03/22, 20/06/22, and 08/10/22)
Arealva 2	28/08/22	17/02/23	Bordeaux mixture (10/04/22), pyraclostrobin (20/06/22), difenoconazole+azoxystrobin (15/08/22, 15/09/22, 03/11/22, 25/11/22, and 14/12/22), and copper oxychloride (15/03/22, 20/06/22, and 08/10/22)
São Manuel	05/10/22	27/02/23	Difenoconazole+azoxystrobin (25/08/22), azoxystrobin+mancozeb (19/09/22), copper oxide, difenoconazole+azoxystrobin (05/12/22), and copper oxychloride (17/02/23)
Jaú	19/10/22	28/02/23	Tebuconazole+trifloxystrobin (10/10/22) and copper oxide (26/11/22, 18/01/23, and 10/02/23)
Bariri	23/09/22	11/04/23	Only biological organic fertilizers, via soil or foliar: Humus® (Si 1% + total organic carbon (TOC) 3%) (05/10/22); Repor® (N 1% + TOC 16%) (02/11/22); Fulvic® (N 1% + TOC 6%) (20/01/22, 10/10/22, and 08/01/23); and Amino® (K2O 1% + TOC 3%) (20/01/22, 10/10/22, and 08/01/23)
Bernardino de Campos	02/09/22	05/04/23	Difenoconazole+azoxystrobin (10/05/21 and 04/10/22), copper hydroxide (11/07/21 and 01/10/22), potassium phosphite (16/11/22), copper oxide (16/11/22), and copper oxychloride (11/01/23)
Piraju	22/08/22	05/04/23	Carbendazim (20/07/22 and 05/09/22), pyraclostrobin (05/08/22 and 20/09/22), tebuconazole (20/08/22), copper oxide (15/01/22, 15/02/22, 15/03/22, 15/10/22, and 06/02/23), mancozeb (10/11/22 and 30/12/22), and *B. subtilis*+*B.* a*myloliquefaciens* (monthly)
Óleo	27/10/22	13/04/23	Carbendazim (29/06/22), pyraclostrobin (27/07/22 and 10/10/22), tebuconazole (19/09/22 and 03/12/22), potassium phosphite (14/11/22), and copper oxide (04/01/22, 25/02/22, 30/12/22, and 10/04/23)
Timburi	09/09/22	08/05/23	Difenoconazole+azoxystrobin (24/09/21 and 23/09/22), copper hydroxide (24/10/21 and 26/10/22), copper oxide (19/04/22, 29/11/22, and 13/04/23), potassium phosphite (09/11/22), and copper oxychloride (11/01/23)
Manduri	15/09/22	22/05/23	Difenoconazole+azoxystrobin (25/08/22)
Botucatu	11/10/22	05/06/23	Copper oxychloride (20/11/21 and 04/10/22)

Table 2. Fungicides/fertilizers and application dates in avocado orchards sampled in the state of São Paulo.

The majority of avocado orchards exhibited more than 97% of trees with branches showing symptoms of basipetal dieback, differing from the Arealva 2 orchard, where 83% of trees were symptomatic (Table 3). The number of diseased branches per tree also varied among orchards, with the Jaú orchard presenting the highest frequency (31.3), exceeding those of the Manduri, Arealva 3, Pirajuí, São Manuel, and Arealva 2 orchards, the latter two having fewer than three diseased branches per tree. A predominance of diseased older branches was observed, compared to younger branches and those with adhered leaves. The canker symptom on branches with adhered leaves is characterized as the initial visual manifestation of the disease in the field. The high occurrence of diseased older branches highlights the failure to remove these branches during annual pruning in most of the studied orchards. Another frequently observed symptom was the presence of whitish exudates at the base of diseased branches. No significant differences were observed in the diameter of diseased branches when comparing older, younger, and leaf-adhered branches among orchards and across the orchard average, with the mean diameter of diseased branches being less than 1 cm.

The symptoms of cankers on branches, characterized by the release of whitish exudates and leaf desiccation, accompanied by defoliation and basipetal dieback of branches, observed in the present study, resemble those described in the literature for avocado trees (Alama *et al*., 2006; McDonald and Eskalen, 2011). In surveys of disease occurrence in Peru, the incidence of diseased plants was also high, ranging from 80% to 86% (Alama *et al*., 2006). According to Twizeyimana *et al*. (2013a), the disease has the potential to significantly reduce plant production. Despite the high incidence of the disease found in orchards in São Paulo, especially in older branches, there is a lack of information regarding its impact on crop production in Brazil. Periodic monitoring over several years in newly established orchards, coupled with the removal of diseased branches from some trees, would allow for the acquisition of plants categorized as healthy, diseased, and treated (pruned). This would enable a comparison of production in relation to the disease and assess the effectiveness of pruning under local conditions.

It is expected that orchards with high plant density, which require more frequent pruning, could increase the spread of the pathogens causing canker among trees, leading to an increase in disease incidence and a potential decrease in productivity as cankered branches are pruned (McDonald and Eskalen, 2011). It is therefore important to define management strategies to protect pruning wounds from pathogen invasion. Preventive treatment with the fungicides azoxystrobin+propiconazole and metconazole reduced lesion length by up to 61% in branches inoculated with Dothiorella iberica, N. australe, N. luteum, N. parvum, and Phomopsis sp. under field conditions (Twizeyimana *et al*., 2013a). Studies on the effect of phosphites on branch canker in avocado are lacking. According to Larach *et al*. (2020), some vineyards in Chile have used potassium phosphite in an attempt to reduce the incidence and severity of "Botryosphaeria dieback," but results are still pending. In postharvest, potassium phosphite controlled peduncular rot in mango and papaya, caused by L. theobromae (Lins *et al*., 2011; Amaral *et al*., 2017).

In a study of variables associated with the susceptibility of Chilean orchards to the disease, it was concluded that older orchards, with larger canopy volume and trunk diameter, appear to be more associated with higher incidences than younger orchards with higher planting densities and vigor levels

(Valencia *et al*., 2022). Correlation analysis of the number of diseased branches per tree with tree age was also significant (r = 0.55) in the present study, confirming the trend of disease growth with orchard age. However, for other orchard characteristics, such as irrigation presence and fungicide spray frequency, no apparent relationship with disease occurrence was observed, considering the high variability among orchards regarding active ingredient, timing, and spray frequency, necessitating further studies in more controlled experimental conditions for more conclusive results. A reduction in rot incidence in avocados in New Zealand was associated with an increased number of fungicide applications in the orchard, with more than eight applications (Everett *et al*., 2007). To maximize their control activity in plants, fungicides must be applied at regular intervals, as reported in the control of other diseases (Miles *et al*., 2007; Viret and Gindro, 2025).

Due to the high occurrence of the disease in orchards in São Paulo, a preventive management approach is recommended, with an emphasis on avoiding water and nutritional stress; periodic inspections in the orchard, including the removal of dry branches, rotten fruits, and dead plants; protection of pruning wounds with fungicides; and monitoring and control of wood-boring beetle populations (Dann *et al*., 2013; Fischer and Firmino, 2023). In orchards with the disease in Spain, pruning residues began to be burned, as it is believed that simply cutting and mixing pruning residues into the soil may increase the fungal inoculum of pathogens (Arjona-Girona *et al*., 2019). In walnut orchards, composting pruning residues processed through chippers, even when 90% of the barks branches contained pycnidia of Botryosphaeriaceae or Phomopsis sp. fungi, did not result in the survival of these pathogens; therefore, it is considered safe to return the composted material to the orchard (Michailides *et al*., 2014; Moral *et al*., 2019).

The main pathogens identified in orchards exhibiting branch canker symptoms belonged to the family Botryosphaeriaceae and the genus Phomopsis sp., with an average frequency of 49% and 32% in orchard branches, respectively (Table 4). Since no differences ($p > 0.05$) were observed among the three types of symptomatic branches sampled (OB, NB, and AL) for each pathogen family within each orchard or among orchards, comparisons were conducted considering the total number of branches. *Botryosphaeriaceae* was more frequent in the Bauru and Pirajuí orchards, with an incidence exceeding 75% of branches, compared to the São Manuel and Piraju orchards, where it was found in less than 20% of branches (Table 4). Although no significant differences were observed between pathogens on average across orchards, *Botryosphaeriaceae* was more frequently detected in six orchards (Arealva 3, Bariri, Bauru, Bernardino de Campos, Pirajuí, and Timburi), whereas *Phomopsis* sp. predominated in the São Manuel orchard.

Based on morphological characteristics of spores (Barnett and Hunter, 1998), 104 isolates of *Botryosphaeriaceae* (up to eight isolates per orchard) that exhibited pathogenicity in avocado seedlings were identified as 86 isolates of *Fusicoccum/Neofusicoccum* sp. and 18 isolates of *Lasiodiplodia* sp. A preliminary study associated branch canker and dieback in avocado trees from two orchards in São Paulo with unidentified *Lasiodiplodia* species (Duarte *et al*., 2021), although the pathogenicity of these isolates has yet to be confirmed. Meanwhile, *N. parvum* and *F. aesculi* have been identified as causal agents of stem-end rot in avocados from orchards in São Paulo (Firmino *et al*., 2016).

The results obtained in this study are consistent with findings from avocado orchards in other countries, where species of the *Botryosphaeriaceae* family are the primary causal agents of branch canker symptoms

Orchard	Diseased plants	Number of branches/plant				Branch diameter			
		OB	NB	AL	Total	OB	NB	AL	Mean
Jaú	100 A	28.5	2.7	0.1	31.3 A	0.90	0.77	1.05	0.91 ^{ns}
Timburi	99 A	16.6	6.2	0.2	23.0 AB	0.84	0.70	1.02	0.85
Bernardino	100 A	16.5	4.0	1.2	21.7 AB	0.75	0.70	0.88	0.78
Bariri	100 A	16.8	4.0	0.2	21.0 AB	0.84	0.79	1.09	0.91
Piraju	98 A	14.7	5.5	0.2	20.4 AB	0.70	0.64	0.84	0.73
Óleo	100 A	14.3	5.2	0.2	19.7 AB	0.82	0.74	0.96	0.84
Botucatu	99 A	15.9	2.8	0.2	18.9 AB	0.75	0.71	0.78	0.75
Bauru	100 A	12.4	1.1	0.7	14.2 ABC	0.85	0.78	0.98	0.87
Dourado	100 A	10.6	3.0	0.3	13.9 ABC	0.76	0.68	0.82	0.75
Arealva 1	100 A	10.4	2.5	0.3	13.2 ABC	0.63	0.72	0.92	0.76
Manduri	98 A	7.8	1.8	0.1	9.7 BC	0.74	0.68	0.73	0.72
Arealva 3	100 A	7.2	2.0	0.1	9.3 BC	0.78	0.66	1.00	0.81
Pirajuí	94 AB	6.7	0.9	0.2	7.8 BC	0.70	0.66	0.88	0.75
São Manuel	93 AB	1.7	1.0	0.1	2.8 C	0.65	0.76	0.77	0.73
Arealva 2	83 B	1.4	0.6	0.1	2.1 C	0.56	0.60	1.01	0.72
Mean	97.6	12.1 a	2.9 b	0.3 b	15.3	0.75 ^{ns}	0.71	0.92	0.79

Data followed by the same letter, lowercase in the row and uppercase in the column, do not differ from each other based on the non-parametric analysis and multiple proportions comparison test ($p = 0.05$) (Zar, 1999).

Table 3. Diseased plants (%), number, and diameter of avocado branches [old branches (OB), new branches (NB), and with attached leaves (AL)] showing drought symptoms, from different orchards in the State of São Paulo.

(McDonald and Eskalen, 2011; Eskalen *et al.*, 2013; Twizeyimana *et al.*, 2013b; Guarnaccia *et al.*, 2016; Arjona-Girona *et al.*, 2019; Valencia *et al.*, 2019; Hernández *et al.*, 2023). In California, USA, *Botryosphaeriaceae* accounted for 82% of the pathogens associated with branch canker, with *N. luteum* and *N. australe* being the predominant species, while *Phomopsis* sp. was found at a lower incidence (McDonald and Eskalen, 2011). Similarly, in Spain, *Neofusicoccum* species were the most prevalent pathogens causing the disease, including *N. parvum* (50%), *N. luteum* (16.2%), and *N. mediterraneum* (1.5%), along with *C. gloeosporioides* (17.6%) and *L. theobromae* (1.5%) (Arjona-Girona *et al.*, 2019). In Peru, *Lasiodiplodia* sp. was the only species identified as the causal agent of the disease, with an 80% isolation frequency from 50 symptomatic branch samples (Alama *et al.*, 2006). In Thailand, *L. pseudotheobromae* was the sole pathogen identified as causing branch canker in avocado trees, and it was also capable of inducing stem-end rot (Trakunyingcharoen *et al.*, 2015). These findings highlight that branch canker in avocado can be caused by a diverse range of pathogens, with different species predominating in different orchards.

In addition to the fact that members of *Botryosphaeriaceae* have a worldwide distribution and cause branch canker and fruit rot in a wide range of hosts (Urbez-Torres *et al.*, 2006; Lazzizera *et al.*, 2008; Netto *et al.*, 2017; Slippers *et al.*, 2017), climatic factors have not provided a clear explanation for the distribution of *Botryosphaeriaceae* species. The same species have been detected in both northern and southern states of the United States (McDonald and Eskalen, 2011) as well as across different climatic zones in Chile (Valencia *et al.*, 2019; Valencia *et al.*, 2022). The growth of *Neofusicoccum* spp. was highest at temperatures between 20 and 30°C, whereas only *L. theobromae* exhibited significant growth and lesion formation at 35°C, suggesting a greater adaptation to warmer regions (Avenot *et al.*, 2023).

Pathogens of the genera Colletotrichum, Fusarium, and Pestalotiopsis exhibited lower isolation frequencies, averaging 20.9%, 8.8%, and 1.8% of branches, respectively, across orchards. Due to their low prevalence, these genera were not included in the analyses. The incidence of opportunistic fungal genera (Alternaria, Aspergillus, Cladosporium, Epicoccum, Penicillium, and Trichoderma), which did not exhibit pathogenicity in inoculated seedlings, was low (5.8%) in branches. Additionally, no fungal growth was observed in 16.8% of the branch samples (data not shown).

The predominance of Botryosphaeriaceae in diseased branches highlights the importance of this pathogen family in disease occurrence. Other fungal genera found in lower proportions in diseased branches, such as *Phomopsis*, Colletotrichum, and Fusarium, exhibited lower aggressiveness in branch inoculations, according to Avenot *et al.* (2023). The authors suggest that these fungi may act as potential secondary invaders, occasionally competing with Botryosphaeriaceae species under certain, yet unknown, conditions.

The results of soil and foliar chemical analyses for macro- and micronutrients from the 15 orchards are presented in Tables 5 and 6, respectively. Organic matter, P and K levels were considered adequate in the soil of most orchards, except for P in the orchards of Timburi, Dourado, and Bariri, where levels were classified as high (Table 5). Low Ca and Mg levels observed in some orchards were associated with base saturation (V%) below 70% in five orchards, indicating the need to adjust base saturation to 80% in most orchards and to increase Mg levels to at least 8 mmolc dm^{-3}. The high base saturation (V%) observed in the soil of the

Orchard	Pathogens in the samples (%)							
	Botryosphaeriaceae				*Phomopsis* sp.			
	OB	NB	AL	Mean	OB	NB	AL	Mean
Bauru	90.0	60.0	90.0	80.0 Aa[1]	10.0	10.0	0.0	6.7 bB
Pirajuí	90.0	60.0	80.0	76.7 aAB	60.0	40.0	10.0	36.7 bAB
Timburi	50.0	80.0	80.0	70.0 aABC	30.0	40.0	0.0	23.3 bAB
Bernardino	70.0	60.0	70.0	66.7 aABC	20.0	30.0	10.0	20.0 bAB
Bariri	80.0	60.0	60.0	66.7 aABC	10.0	30.0	20.0	20.0 bAB
Arealva 3	60.0	70.0	70.0	66.7 aABC	40.0	10.0	10.0	20.0 bAB
Botucatu	70.0	50.0	70.0	63.3 aABC	50.0	40.0	30.0	40.0 aAB
Manduri	30.0	80.0	33.3	47.8 aABCD	20.0	40.0	22.2	27.4 aAB
Jaú	50.0	50.0	30.0	43.3 aABCD	20.0	50.0	30.0	33.3 aAB
Dourado	30.0	40.0	50.0	40.0 aABCD	60.0	50.0	60.0	56.7 aA
Arealva 1	40.0	30.0	20.0	30.0 aCD	20.0	20.0	30.0	23.3 aAB
Arealva 2	30.0	10.0	50.0	30.0 aBCD	70.0	50.0	20.0	46.7 aAB
Óleo	30.0	20.0	20.0	23.3 aCD	50.0	30.0	40.0	40.0 aAB
São Manuel	30.0	20.0	0.0	16.7 bD	60.0	50.0	66.7	58.9 aA
Piraju	20.0	10.0	10.0	13.3 aD	30.0	30.0	20.0	26.7 aAB
Mean	51.3	46.7	48.9	49.0 a	36.7	35.3	25.3	32.0 a

Data followed by the same letter, lowercase in the row and uppercase in the column, do not differ from each other based on the non-parametric analysis and multiple proportions comparison test (p = 0.05) (Zar, 1999)

Table 4. Incidence of Botryosphaeriaceae and *Phomopsis* sp. isolates obtained from avocado trees exhibiting branch canker [old branches (OB), new branches (NB), and with attached leaves (AL)].

Bariri orchard is associated with elevated pH values and the accumulation of cations, especially Ca. However, the unbalanced Ca-to-Mg ratio suggests a disequilibrium in the composition of the effective cation exchange capacity (CEC). The soil also showed high levels of nutrients such as P, Ca and S, possibly resulting from frequent applications of organic and/or foliar fertilizers, which may have contributed to element disproportion and affected the nutritional balance of the system. Approximately 50% of the orchards evaluated showed sulfur deficiency, with concentrations ranging from 2 to 4 mg dm^{-3}. The presence of exchangeable aluminum (Al^{3+}) in the 0–20 cm soil layer in the orchards of Arealva 2, Dourado, and Manduri indicates the need for agricultural gypsum application to correct subsurface acidity and supply Ca and S to the root zone. Soil chemical analysis also revealed micronutrient imbalances, with Cu and Zn deficiency levels ranging from 0.3–1.4 mg dm^{-3} and 0.4–3.1 mg dm^{-3}, respectively, and excessive Fe levels (15–53 mg dm^{-3}) in most orchards (Table 5) (Cantarella *et al.*, 2022).

Foliar chemical analysis (Table 6) revealed that, with the exception of foliar magnesium, most orchards exhibited at least one foliar nutrient outside the recommended range for avocado cultivation. Only a few orchards showed deficiencies in N (15 g kg^{-1}), P (0.7 g kg^{-1}), K (6 g kg^{-1}), Ca (5–8 g kg^{-1}), and/or Zn (14–27 mg kg^{-1}), while most exhibited deficiencies in S (1.0–1.9 g kg^{-1}) and B (5–46 mg kg^{-1}). Additionally, some orchards showed excessive concentrations of Cu (16–63 mg kg^{-1}), Fe (260–302 mg kg^{-1}), and Mn (656–1028 mg kg^{-1}) (Teixeira *et al.*, 2022) The excessive foliar Cu concentrations found in some orchards may indicate accumulation resulting from repeated applications of copper-based protectants.

When analyzing the relationship between nutrient levels and both the frequency of diseased branches in trees and the *Botryosphaeriaceae* and *Phomopsis* sp. isolates obtained, a significant positive linear correlation (r = 0.68, $p < 0.05$) was observed only between foliar Ca content and the number of diseased branches. In other words, as Ca levels in leaves increased, the number of diseased branches also increased. No significant relationships were found between other nutrients and disease occurrence ($-0.51 \leq r \leq 0.43$); however, boron deficiency has been associated with trunk canker and branch canker symptoms in avocado (Avocado Information Kit, 2001). Balanced nutrition contributes to plant health, reducing disease susceptibility and infection (Tripathi *et al.*, 2022). Although a positive correlation was observed between foliar calcium content and the occurrence of diseased branches, the literature highlights the structural importance of this element. Its deficiency has been linked to increased susceptibility of plants to fungi that preferentially invade the xylem, dissolving the cell walls of conductive vessels and leading to plant wilting (Hirschi, 2004). For the management of stem-end rot, Everett *et al.* (2007) recommend calcium applications in orchards to increase the (calcium + magnesium) / potassium ratio above 0.065 in fruit. However, in a São Paulo orchard, three applications of calcium chloride during fruit development did not reduce the incidence of fruit rots (Fischer *et al.*, 2018). Thus, although the literature emphasizes the protective role of calcium, overall nutritional balance appears to be more relevant (Tripathi *et al.*, 2022).

Orchard	pH	O.M.	P_{resin}	Al^{3+}	H+Al	K	Ca	Mg	SB	CEC	V%	S	B	Cu	Fe	Mn	Zn
(denomination)	$CaCl_2$	g/dm³	mg/dm³	---------------- mmolc/dm³ -------------------								------------------ mg/dm³ --------------					
Bauru	6.1	10	19	0	15	1.5	30	15	46	61	75	4	0.18	1.1	29	6.2	1.7
Arealva 1	6.2	6	5	0	11	1.3	16	11	28	39	72	4	0.32	1.4	15	4.4	0.8
Pirajuí	5.6	6	12	0	13	1.7	12	6	19	32	60	11	0.41	4.7	16	8.1	1.1
Piraju	5.7	29	28	0	28	3.4	69	29	101	130	78	7	1.35	3.8	53	1.7	5.3
Arealva 2	4.8	13	7	1	22	2.1	11	7	19	41	47	6	0.79	0.8	33	8.1	0.7
Bernardino	5.8	26	35	0	23	3.1	73	28	104	127	82	8	1.17	5.4	25	4.6	1.8
Timburi	5.7	21	53	0	17	3.4	69	35	107	124	87	2	1.04	4.5	32	2.8	5.7
Dourado	4.7	11	96	1	26	2.0	13	5	21	46	45	7	0.73	2.9	34	4.7	3.1
Manduri	4.6	9	16	4	30	0.5	9	4	13	43	30	4	0.40	1.1	53	2.8	2.3
Bariri	7.3	21	217	0	7	3.4	197	11	212	219	97	157	0.27	0.9	10	1.8	5.7
São Manuel	6.0	11	7	0	17	3.1	30	18	50	67	75	3	0.48	2.7	28	4.9	2.7
Botucatu	5.0	12	4	0	27	3.4	13	6	23	50	46	4	0.12	0.6	34	1.0	0.4
Arealva 3	5.9	9	24	0	10	2.5	25	9	37	47	78	5	0.33	0.3	16	2.8	0.7
Jaú	5.9	11	36	0	13	3.3	32	15	50	64	79	7	0.44	1.2	41	4.8	1.4
Óleo	5.5	9	16	0	12	1.8	21	5	28	40	70	11	0.45	0.8	28	4.1	2.3

Table 5. Results of soil chemical analysis (0–20 cm) in avocado orchards in the State of São Paulo.

Orchard	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
(denomination)	------------------ g kg^{-1} ------------------						-------------- mg kg^{-1} --------------				
Bauru	16	1.1	11	11	4.9	1.5	27	13	164	410	26
Arealva 1	15	0.9	9	12	4.3	2.0	40	63	136	328	32
Pirajuí	24	2.8	13	5	3.4	1.8	32	15	59	139	37
Piraju	19	1.4	11	17	5.1	1.9	39	29	95	331	54
Arealva 2	19	1.1	10	11	6.1	1.6	30	23	168	446	32
Bernardino	18	1.1	9	18	7.6	1.4	12	15	302	1028	66
Timburi	19	1.0	7	16	5.9	1.6	16	18	104	283	27
Dourado	19	0.7	8	13	5.1	1.3	11	7	260	745	17
Manduri	20	1.2	6	12	6.7	1.2	58	10	129	495	17
Bariri	16	0.8	7	18	4.3	1.5	5	7	163	656	14
São Manuel	25	1.2	11	12	3.8	1.8	46	12	93	82	33
Botucatu	15	1.0	10	19	4.9	1.0	19	50	99	62	19
Arealva 3	20	2.9	18	8	4.7	2.4	107	18	86	65	36
Jaú	15	0.9	12	20	5.7	1.7	29	16	149	432	31
Óleo	20	1.6	16	16	3.4	2.4	127	6	64	215	52

Table 6. Results of foliar chemical analysis from samples collected in avocado orchards in the State of São Paulo.

POSTHARVEST DISEASES IN AVOCADO ORCHARDS

Avocado orchards exhibited differences in the incidence of Colletotrichum sp., Lasiodiplodia sp., and Fusicoccum/Neofusicoccum sp. in postharvest assessments, as well as in the overall proportion of diseased fruits. The orchards of Botucatu, São Manuel, and Arealva 1 had the lowest incidence of fruit rots (<12%) compared to the orchards of Bariri and Bernardino de Campos, where more than 30% of the fruits were affected (Table 7). Colletotrichum sp. was the most frequently detected pathogen in most orchards, differing significantly from the others in the overall orchard average, with more than 15% of fruits affected. The remaining pathogens individually had an average incidence below 5% and did not differ statistically from each other. However, Lasiodiplodia sp. stood out with an occurrence ranging from 4.5% to 21% in five orchards, while Fusicoccum/Neofusicoccum sp. had an incidence between 6% and 13% in two orchards.

The symptom of stem-end rot was the predominant one compared to rots in the fruit body in the majority of the 15 avocado samples, representing the totality for the pathogens Pestalotiopsis sp., Fusarium sp., and Phomopsis sp., and the majority for the pathogens Lasiodiplodia sp. (95%), Fusicoccum/Neofusicoccum sp. (83%), and Colletotrichum sp. (71%) (Table 7, Figure 3). A study in New Zealand also observed a higher incidence of stem-end rots (37.9%) compared to body rots (25.6%), with 6.4% of the fruits exhibiting both types of rots (Hartill and Everett, 2002).

A higher occurrence of Colletotrichum sp. in avocados produced in the State of São Paulo, compared to other pathogens, had already been reported in other studies (Fischer *et al.*, 2011; Fischer *et al.*, 2019). An incidence of over 90% of anthracnose was observed in 'Hass' avocados grown under conditions favorable to the disease in Australia (Willingham *et al.*, 2006). In South Africa, 44% of avocado fruit rotted, with anthracnose responsible for 66% of the total (Bezuidenhout and Kuschke, 1983). In contrast to the findings of the present study, where Colletotrichum sp. was the main pathogen causing stem-end rot, N. luteum was the most frequent pathogen causing stem-end rot in orchards in Southern California, with 65% incidence of the 177 isolates obtained, followed by C. gloeosporioides (33%) and *Phomopsis* sp. (2%) (Twizeyimana *et al.*, 2013b). Species of Botryosphaeriaceae, commonly associated with high incidences of stem-end rot (Yahia, 2012), vary according to the geographical region. For example, the main cause of peduncular rot in Israel was L. theobromae; in Australia and New Zealand, N. luteum and N. ribis; and in South Africa, N. luteum and Nectria pseudotrichia (Menge and Ploetz, 2003). However, Hartill and Everett (2002) mainly found N. parvum and *Phomopsis* spp. in another study in New Zealand.

The visual symptoms of the diseases were observed, mostly (78.5%), in the last two days of fruit ripening (Figure 4). Important postharvest pathogens in avocados, such as species of Colletotrichum and Botryosphaeriaceae, are known to cause latent infections that become active when physiological and biochemical changes, associated with a reduction in the concentration of fungal inhibitors, are initiated in the harvested fruit (Johnson and Kotzé, 1994; Bowen *et al.*, 2018).

No significant correlation ($-0.19 \leq r \leq 0.14$) was observed between the incidence of diseased branches in the orchards and the total rot in the respective orchards, as well as with the main pathogens causing stem-end rot (Colletotrichum sp., Lasiodiplodia sp., and Fusicoccum/Neofusicoccum sp.). However, in older trees in New Zealand, the occurrence of rot in avocados was directly related to the plant canopy index, which, according to Everett *et al*. (2007), is associated with the amount of dead branches and, consequently, the amount of fungal inoculum. Spores of fungal pathogens that cause postharvest rot in avocados require high humidity conditions for dispersal, germination, and infection (Ahimera *et al*., 2004). Humidity is reduced in a more open canopy, which can minimize infections (Everett *et al*., 2007).

Figure 3. Avocado fruits with rot symptoms caused by Lasiodiplodia sp. (A), *Fusicoccum/Neofusicoccum sp.* (B), *Phomopsis sp.* (C), *Colletotrichum sp.* (D), *Fusarium sp.* (E), and *Pestalotiopsis sp.* (F).

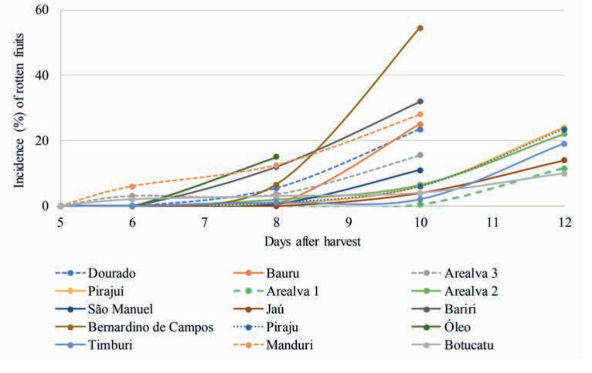

Figure 4. Incidence (%) of rot in avocados collected from 15 orchards in São Paulo, during ripening at 25°C.

CONCLUSIONS

Avocado branch canker exhibited a high incidence in the State of São Paulo, with an average orchard infection rate exceeding 97% of symptomatic plants and significant variation among orchards and in the number of diseased branches per plant between orchards. The predominance of the disease in older branches and its increase with plant age, likely due to the lack of removal of dead branches within the canopy in most orchards, suggests management failures, particularly in eliminating these infected tissues.

Fungi from the Botryosphaeriaceae family, predominantly *Fusicoccum/Neofusicoccum* sp., and to a lesser extent *Lasiodiplodia* sp., as well as from the genus *Phomopsis* sp., were the main etiological agents of branch canker, with no significant difference between the Botryosphaeriaceae and *Phomopsis* sp. pathogens across the orchards. The nutritional analysis revealed imbalances in both foliar and soil nutrient levels in most orchards, with notable deficiencies of S and B in the plants; deficiencies of Ca, Mg, S, Cu and Zn in the soil of some orchards, and low base saturation. These findings highlight the need for corrective measures to align soil fertility with the nutritional requirements of avocado cultivation. Positive correlation between leaf calcium content and the number of infected branches, suggesting a possible relationship between the plant's nutritional status and its susceptibility to the disease. These results reinforce the importance of careful monitoring and nutritional management, aiming not only at productivity but also at plant health and the prevention of diseases associated with nutritional imbalances.

In postharvest conditions, *Colletotrichum* sp. was the most frequent pathogen, with stem-end rot being more prevalent than rot in the fruit's body. However, no correlation was found between the incidence of branch canker and fruit rot occurrence, indicating that branch infection is not a determining factor for postharvest disease occurrence.

Journal of Agricultural Sciences Research ISSN 2764-0973 DOI https://doi.org/10.22533/at.ed.9735112503071

Orchard origin	Postharvest pathogens						Diseased
(avocado variety)	Colletotrichum	Lasiodiplodia	Fusicoccum/ Neofusicoccum	*Phomopsis*	*Pestalotiopsis*	*Fusarium*	fruits
Botucatu (Margarida)	9.0 (9.0/0.0)[1] bA[2]	0.5 aA	1.0 aAB	0.0 aA	0.0 aA	0.0 aA	10.0 A
São Manuel (Hass)	10.0 (5.0/7.5) bA	0.0 aA	0.0 aA	0.0 aA	0.0 aA	1.0 aA	11.0 A
Arealva 1 (Hass)	6.5 (1.5/5.5) bA	2.0 abA	2.0 abAB	0.0 aA	0.5 aA	0.0 aA	11.5 A
Jaú (Hass)	10.0 (1.5/9.0) bA	1.0 aA	2.0 aAB	1.0 aA	0.5 aA	0.0 aA	14.0 AB
Óleo (Hass)	11.5 (0.0/15.0) bA	3.0 aA	0.0 aA	0.5 aA	0.0 aA	0.0 aA	15.0 AB
Arealva 3 (Hass)	9.0 (6.0/3.0) bA	3.0 abA	2.5 aAB	1.5 aA	0.0 aA	0.0 aA	15.5 AB
Timburi (Hass)	16.5 (2.0/15.5) bAB	1.5 aA	2.5 aAB	0.0 aA	0.0 aA	0.0 aA	19.0 AB
Arealva 2 (Hass)	10.5 (3.0/7.5) cA	7.0 bcAB	2.5 abAB	0.5 aA	1.0 aA	0.5 aA	22.0 AB
Dourado (Geada)	20.5 (8.0/15.5) bAB	2.0 aA	0.0 aA	0.0 aA	2.5 aA	0.0 aA	23.5 AB
Piraju (Hass)	16.5 (5.0/15.5) cAB	5.0 bA	0.5 aA	0.0 aA	0.0 aA	1.0 abA	23.5 AB
Pirajuí (Hass)	15.5 (2.5/13.0) cAB	6.0 bAB	1.5 abAB	0.5 aA	0.0 aA	0.5 aA	24.0 AB
Bauru (Carmen)	19.5 (4.0/18.0) cAB	4.5 bA	1.5 abAB	0.0 aA	0.0 aA	0.0 aA	25.0 AB
Manduri (Margarida)	26.5 (26.5/5.5) cB	2.5 abA	6.0 bAB	0.5 aA	a0.0 A	0.0 aA	28.0 AB
Bariri (Quintal)	18.5 (17.5/1.0) cAB	3.0 abA	13.0 cB	0.0 aA	0.0 aA	0.0 aA	32.0 BC
Bernardino de Campos (Hass)	34.0 (5.5/33.0) cB	21.0 bB	0.0 aA	0.0 aA	0.0 aA	0.0 aA	54.5 C
Mean	15.6 (6.5/11.0) b	4.1 a	2.3 a	0.3 a	0.3 a	0.2 a	21.9

[1]*Colletotrichum* observed on the fruit body/peduncle

[2]Data followed by the same letter, lowercase in the row and uppercase in the column, do not differ from each other based on the non-parametric analysis and multiple proportions comparison test (p = 0.05) (Zar, 1999).

Table 7. Incidence (%) of postharvest pathogens in avocados from orchards in the State of São Paulo.

THANKS

The authors would like to thank the institution: Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, Process number: 2022/02694-9) for funding the work.

REFERENCES

AGROFIT. Ministério da Agricultura, Pecuária e Abastecimento. http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_ cons. Accessed: Feb. 2025.

AHIMERA, N. *et al*. Effects of single drop impactions and natural and simulated rains on the dispersal of *Botryosphaeria dothidea* conidia. **Phytopathology** 94:1189–1197, 2004.

ALAMA, L. *et al*. *Lasiodiplodia theobromae* afectando el cultivo de palto (*Persea Americana*) en las condiciones de Piura-Perú. **Universalia** 11:4-13, 2006.

AMARAL, D.D. *et al*. Frequency of quiescent fungi and post-harvest alternative management of stem end rot in papaya. **Revista Caatinga** 30:786–793, 2017.

ARJONA-GIRONA, I. *et al*. Identification, pathogenicity and distribution of the causal agents of dieback in avocado orchards in Spain. **Spanish Journal of Agricultural Research** 17:1-9, 2019.

AVENOT, H.F. *et al*. Prevalence, identity, pathogenicity, and infection dynamics of Botryosphaeriaceae causing avocado branch canker in California. **Phytopathology** 113: 1034–1047, 2023.

AVOCADO INFORMATION KIT, 2001. Disponível em: http://era.daf.qld.gov.au/id/eprint/1642/7/06-avoprobPartb.pdf. Accessed: Feb. 2025

BARNETT, H.L.; HUNTER, B.B. **Illustrated genera of imperfect fungi.** 4.ed. Saint Paul: American Phytopathology Society Press, 1998.

BEZUIDENHOUT, J.J.; KUSCHKE, E. Voorkoms en tendense van naoessiektes by Suid-Africaanse avokado's in 1982 by Rungis. **South African Avocado Growers' Association Yearbooks** 4:20-23, 1983.

BOWEN, J. *et al*. Postharvest Biology and Technology Maturity, storage and ripening effects on anti-fungal compounds in the skin of 'Hass' avocado fruit. **Postharvest Biology and Technology** 146:43–50, 2018.

CANTARELLA, H. *et al*. **Boletim 100**: Recomendação de adubação e calagem para o Estado de São Paulo. Campinas: Instituto Agronômico, 2022.

DANN E.K. *et al*. Foliar, fruit and soilborne diseases. In: SCHAFFER, B. *et al*. (Eds.) **The avocado**: Botany, production and uses. Wallingford, UK. CAB Intl. Press. pp. 380-423. 2013.

DUARTE, J.L.P. *et al*. Detecção molecular de *Lasiodiplodia* spp. associado a cancro e seca de ponteiros em pomares comerciais de abacateiro no Estado de São Paulo-SP, Brasil. 52 Congresso Brasileiro de Fitopatologia, 2021, p.1-2.

ESKALEN, A. *et al*. Spore trapping and pathogenicity of fungi in the Botryosphaeriaceae and Diaporthaceae associated with avocado branch canker in California. **Plant Disease** 97:329-332, 2013.

EVERETT, K.R, *et al*. Calcium, fungicide sprays and canopy density influence postharvest rots of avocado. **Australasian Plant Pathology** 36:22–31, 2007.

FIRMINO, A.C. *et al*. Identification of *Fusicoccum* species causing rot in avocado fruits. **Summa Phytopathologica** 42:100-102, 2016.

FISCHER, I.H.; FIRMINO, A.C. Main diseases of avocado in Brazil. **Revisão Anual de Patologia de Plantas** 19:106-130, 2023.

FISCHER, I.H. *et al*. Pós-colheita de abacates 'Fuerte' e 'Hass': características físicas e químicas, danos e controle de doenças. **Semina: Ciências agrárias** 32:209-220, 2011.

FISCHER, I.H. *et al*. Effect of conventional and alternative products on postharvest disease control in avocados. **Revista Brasileira de Fruticultura** 40:1-10, 2018.

FISCHER, I.H. *et al*. Detection and epidemiological progress of quiescent avocado diseases. **Ciência Rural** 49:1-10, 2019.

GUARNACCIA, V. *et al*. Characterisation and pathogenicity of fungal species associated with branch cankers and stem-end rot of avocado in Italy. **European Journal of Plant Pathology** 46:963–976, 2016.

HARTILL, W.F.T.; EVERETT, K.R. Inoculum sources and infection pathways of pathogens causing stem-end rots of 'Hass' avocado (*Persea americana*). **New Zealand Journal of Crop and Horticultural Science** 30:249–260, 2002.

HERNÁNDEZ, D. *et al*., Fungal pathogens associated with aerial symptoms of avocado (*Persea americana* Mill.) in Tenerife (Canary Islands, Spain) focused on species of the family Botryosphaeriaceae. **Microorganisms** 11:1-22, 2023.

HIRSCHI, K.D. The calcium conundrum both versatile nutrient and specific signal. **Plant Physiology** 136:2438–2442, 2004.

IBGE - Instituto Brasileiro de Geografia e Estatística. Produção de abacate. 2025. Disponível em: https://www.ibge.gov.br/explica/producao-agropecuaria/abacate/sp. Accessed: Feb. 2025.

JOHNSON, G.I; KOTZE, J.M. Avocado stem-end rot. In: PLOETZ, *et al*. (eds) **Compendium of Tropical Fruit Diseases**. The American Phytopathological Society, St. Paul, Minnesota, pp. 81–83, 1994.

LARACH, A. *et al*. Yield loss estimation and pathogen identification from Botryosphaeria dieback in vineyards of Central Chile over two growing seasons. **Phytopathologia Mediterranea** 59:537-548, 2020.

LAZZIZERA, C. *et al*. Morphology, phylogeny and pathogenicity of Botryosphaeria and Neofusicoccum species associated with drupe rot of olives in southern Italy. **Plant Pathology** 57:948-956, 2008.

LINS, S.R.O. *et al*. Controle alternativo da podridão peduncular em manga. **Summa Phytopathologica** 37:121-126, 2011.

MCDONALD, V.; ESKALEN, A. Botryosphaeriaceae species associated with avocado branch cankers in California. **Plant Disease** 95:1465-1473, 2011.

MENGE, J.A.; PLOETZ, R.C. Diseases of Avocado. In: PLOETZ, R.C. (ed.) **Diseases of Tropical Fruit Crops**. CAB International, Wallingford, UK, pp. 35–71, 2003.

MICHAILIDES, T.J. *et al*. Managing Botryosphaeria/Phomopsis canker and blight and anthracnose blight of walnut in California. Pages 299-317. In: **Walnut Research Reports**. California Walnut Board, Folsom, CA. 2014.

MILES, M.R. *et al*. International fungicide efficacy trials for the management of soybean rust. **Plant Disease** 91:1450-1458, 2007.

MÖLLER, H. *et al*. Branch canker battles: understanding and managing the *Botryosphaeriaceae* in avocado. **Phytoparasitica** 53:17, 2025.

MORAL, J. *et al*. Management of Botryosphaeria canker and blight diseases of temperate zone nut crops. **Crop Protection** 126:104927, 2019.

NAVARRO, B.L. *et al*. Penetration by Botryosphaeriaceae species in avocado, guava and persimmon fruit during postharvest. **Journal of Phytopathology** 170:57-68, 2022.

NETTO, M.S.B. *et al*. Analysis of phylogeny, distribution, and pathogenicity of Botryosphaeriaceae species associated with gummosis of *Anacardium* in Brazil, with a new species of *Lasiodiplodia*. **Fungal Biology** 121:437-451, 2017.

SLIPPERS, B.; WINGFIELD, M.J. Botryosphaeriaceae as endophytes and latent pathogens of woody plants: diversity, ecology and impact. **Fungal Biology Reviews** 21:90-106, 2007.

SLIPPERS, B. *et al*. Diversity in the Botryosphaeriales: Looking back, looking forward. **Fungal Biology** 121:307-321, 2017.

TEIXEIRA, L.A.J. *et al*. Frutíferas. In: CANTARELLA, H. *et al*. (eds.). **Boletim 100: Recomendação de adubação e calagem para o Estado de São Paulo**. Instituto Agronômico (IAC), Campinas, pp. 259-264, 2022.

TRAKUNYINGCHAROEN, T. *et al*. Phylogenetic study of the Botryosphaeriaceae species associated with avocado and par rubber in Thailand. **Chiang Mai Journal Science** 42:104-116, 2015.

TRIPATHI, R. *et al*. Plant mineral nutrition and disease resistance: A significant linkage for sustainable crop protection. **Front Plant Science** 20:883970, 2022.

TWIZEYIMANA, M. *et al*. Effect of fungicide application on the management of avocado branch canker (formerly Dothiorella canker) in California. **Plant Disease** 97:897-902, 2013a.

TWIZEYIMANA, M. *et al*. Identification and pathogenicity of fungal pathogens associated with stem-end rot of avocado in California. **Plant Disease** 97:1580-1584, 2013b.

URBEZ-TORRES, J.R. *et al*. Identification and distribution of *Botryosphaeria* spp. associated with grapevine cankers in California. **Plant Disease** 90:1490-1503, 2006.

VALENCIA, A.L. *et al*. Characterization and pathogenicity of Botryosphaeriaceae species obtained from avocado trees with branch canker and dieback and from avocado fruit with stem end rot in Chile. Plant Disease 103:996-1005, 2019.

VALENCIA, A.L. *et al*. Unveiling the predisposing factors for the development of branch canker and dieback in avocado: A case of study in chilean orchards. **Horticulturae** 8:1-17, 2022.

VIRET, O.; GINDRO, K. Disease Control. In: VIRET, O.; GINDRO, K. (ed.) **Science of Fungi in Grapevine**. Springer, Cham, pp. 401-461, 2025.

WILLINGHAM, S.L. *et al*. Effects of rootstock and nitrogen fertilizer on postharvest anthracnose development in Hass avocado. **Australasian Plant Pathology** 35:619-629, 2006.

YAHIA, E.M. Avocado. In: **Crop Post-Harvest**: Science and Technology, Perishables. D. Rees, G. Farrell and J. Orchard, eds. Wiley-Blackwell, Oxford, UK. 2012. p.159-179.

ZAR, J.H. **Biostatistical Analysis**. Prentice-Hall, New Jersey, USA. 1999. 663 p