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Checklist of *Colletotrichum* species associated with plant diseases in the Philippines

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Abstract

Fungal plant diseases account for more than half of the plant disease records in the Philippines. The fungal species in the genus *Colletotrichum* are among the most well-studied fungi due to their multifaceted lifestyle, ubiquitous nature, and, more importantly, their role as pathogens of economically important plants. *Colletotrichum* species are responsible for the destructive plant disease known as anthracnose. Successful management of anthracnose starts with accurately identifying the causative agent. This paper examined data from databases and scholarly outputs to provide a checklist of *Colletotrichum* species associated with plant diseases in the Philippines. Records show 55 *Colletotrichum* species (36 belonging to ten species complexes, two singleton species, and 17 morphospecies), and 12 unidentified *Colletotrichum* species, hosted by 106 plant species, with anthracnose as the primary disease. The *Colletotrichum gloeosporioides* species complex had the highest number of species reported. The checklist will be useful as a reference for students, lecturers, researchers, plant quarantine officers, growers, and decision/policy-makers. This checklist provides an understanding of the country's current diversity of *Colletotrichum* species, forms baseline information for future taxonomic studies in unexplored regions, and a reference for future discovery of new plant hosts.

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Introduction

Fungal plant diseases account for more than half of the plant disease records in the Philippines[1]. Some fungal diseases have placed the country on several 'international maps' of plant diseases. For instance, the island of Mindanao is known for having the dreaded Panama wilt in the banana cv. Cavendish caused by *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (TR4). A recent study also reported a novel fungal species, *Fusarium mindanaoense*, associated with the Fusarium wilt of banana[2]. Most recently, the fungus *Paramyrothecium folliicola* was reported for the first time as an eggplant pathogen[3]. Several *Colletotrichum* species have been reported in the Philippines in the last five years. For instance, *Colletotrichum fructicola, C. siamense,* and *C. tropicale* have been isolated from cassava leaf diseases[4], *C. siamense* in onion[5], and *C. nymphaeae* in tomato[6]. Fungal diseases threaten food production, safety, and growers' livelihoods by reducing yield, contaminating food products, and reducing income[7,8].

Fungal plant diseases may also undermine conservation efforts of valuable and endangered plant species, and seed collections by reducing healthy seedling populations and seed viability[9,10]. Hence, fungal diseases are not only threats to agricultural crop production but also a plant species conservation issue. This threat is exacerbated by long-range fungal spore dispersal and the illegal trade or movement of planting materials, which could harbor fungal inoculum. Some fungal pathogens can cross national borders[11−13]. Ubiquitous, highly sporulating fungal pathogens are easily dispersed by wind[14], and rain splashes[15]. These conditions are common in tropical and subtropical regions, like the Philippines.

The fungal species in *Colletotrichum* are among one of the most studied fungi globally because of their multifaceted lifestyle, ubiquitous nature, and, more importantly, their role as pathogens of economically important plants[16−25]. *Colletotrichum* species are responsible for the destructive plant disease known as anthracnose[26]. Species in *Colletotrichum* have been grouped into species complexes generally based on the partial internal transcribed spacer (ITS) region[16,17,22]. Most *Colletotrichum* species belong to the *C. gloeosporioides, C. acutatum,* and *C. boninense* species complexes[17,18,20]. In 2022, based on the phylogenetic analyses of multiple loci, there are 278 *Colletotrichum* species[17,18,20−22]. Then, in 2023, the number grew to 340 recognized *Colletotrichum* species from 20 species complexes, with the four new species complexes proposed by Talhinhas & Baroncelli[16]. Jayawardena et al.[27] identified 450 morphospecies based solely on morphological characters. As of September 2023, there are over 760 host plant species of these *Colletotrichum* species from the 3,400 host-species *Colletotrichum* species records[16] indexed and published in databases and scientific journals. This number increases as new reports are published and recorded. For instance, two novel species, *C. avicenniae* from *Avicennia marina* and *C. lumnitzerae* from *Lumnitzera racemose,* were discovered in mangrove forests in Prachuap Khiri Khan, Thailand[28].

Colletotrichum species play a significant role in agriculture and, without effective interventions, may reduce yield, grower income, and, subsequently, the economy; thus, consumers may also be affected. For instance, anthracnose can affect both the quantity and quality of the harvest, and the reduction in yield can reduce the supply of the products, which may increase the demand and price. Furthermore, there is a cost in controlling anthracnose, and successful management starts with accurately identifying the causative agent.

Fungal species within the genus *Colletotrichum* have been frequently reported in the last decade, and this genus has been associated with the destructive disease, anthracnose, that is affecting several important crops in the country. At least 55 *Colletotrichum* species are associated with more than a hundred plant species, with anthracnose as the primary disease. Many of the *Colletotrichum* species reported belong to the *C. gloeosporioides* species complex. This paper provides a checklist of the plant pathogenic *Colletotrichum* species recorded in the Philippines, and their host range.

Materials and methods

The information presented in this paper was based on reports published in various scientific journals (e.g., Crop Protection, New Disease Reports, Australasian Plant Pathology, etc.), listed in the US National Fungus Collections Fungus-Host Database of the US Department of Agriculture, Agricultural Research Service (https://fungi.ars.usda.gov), records found in the Host Index of Plant Diseases in the Philippines[29], and several other databases (e.g., Kew Botanic Gardens HerbIMI, and Global Biodiversity Information Facility). The legitimacy of the species was confirmed by cross-checking with MycoBank and Index Fungorom.

Documented *Colletotrichum* species and their host range

Fifty-five *Colletotrichum* species have been recorded and identified in the Philippines, there are also 12 unidentified *Colletotrichum* species. Of the 55, 36 belong to ten species complexes (Table 1), two are singleton species, and 17 are morphospecies (Table 2). These *Colletotrichum* species are responsible for various diseases (mainly anthracnose) in 106 host plant species.

Colletotrichum acutatum complex

Colletotrichum nymphaeae (Pass.) Aa

Colletotrichum nymphaeae was first reported in the Philippines on tomato fruits, causing post-harvest anthracnose[6]. The infected fruit shows sunken lesions and is sometimes covered with conidial masses. The fungus can infect wounded and unwounded tomato fruits in detached fruit experiments.

Colletotrichum scovillei Damm, P.F. Cannon & Crous

Colletotrichum scovillei was first reported in the Philippines on pepper fruits showing anthracnose symptoms[30]. Infected pepper fruits show anthracnose symptoms, characterized by dark, sunken lesions with a water-soaked appearance in some fruits. The fungus infects green (unripe) and red (unripe) fruits, either wounded or unwounded.

Colletotrichum acutatum

Alberto & Otanes[31] reported that a fungus attacked the fruits of guyabano (*Annona muricata*). Identification of the fungus was based on a molecular assay using the primer pair CaInt2/ITS4, which can detect *C. acutatum* at the species complex level; hence, the fungus they have isolated is herein referred to as *C. acutatum sensu lato*. Dela Cueva & Balendres[32] also detected *C. acutatum sensu lato* on pepper in several provinces in Southern Luzon.

Colletotrichum agaves complex

Colletotrichum agaves Cavara

Lee first reported *Colletotrichum* agaves in the Philippines in 1921[33], associated with anthracnose of *Agave cantata*.

Colletotrichum boninense complex

Colletotrichum heveae Petch

Colletotrichum heveae was first reported in the Philippines, causing leaf spot of *Hevea brasiliensis* by Soria[34].

Colletotrichum dematium complex

Colletotrichum circinans (Berk.) Voglino

Colletotrichum circinans has been associated with smudge in onion *(Allium cepa*), and was first reported in the country by Elayda[35].

Colletotrichum dematium (Pers.) Grove

Colletotrichum dematium has been associated with anthracnose in pepper[36], peanut[37], and *Hibiscus esculentus*[38] in the Philippines.

Colletotrichum dematium is a regulated non-quarantine pest in Egypt (2018) based on the EPPO Global Database (Table 3).

Colletotrichum gloeosporiodes complex

Colletotrichum asianum Prihastuti

Colletotrichum asianum was first detected and isolated from mango grown in Luzon and Guimaras Islands[39]. The colonies in potato dextrose agar medium appear grayish green to black and white at the edge. Three *C. asianum* isolates were also pathogenic to the mango cv. Carabao fruits in wounded and unwounded trials in controlled conditions.

Colletotrichum fructicola Prihastuti

Colletotrichum fructicola was first reported in the Philippines in 2021 on stems of dragon fruit[40], and mango[41]. It was also reported in imported persimmon fruits[42].

Colletotrichum musae (Berk. & M.A. Curtis) Arx

Colletotrichum musae is the banana anthracnose pathogen and has been reported several times in the Philippines. This fungal species causes anthracnose[43,44], fingertip rot[45], and crown rot[46] in *Musa* spp. It has also been reported to cause anthracnose in *Capsicum* spp.[36]. The first molecular characterization of a Philippine isolate of *C. musae* was made in 2020[44], further validating its identity.

Colletotrichum musae is a regulated non-quarantine pest in Egypt (2018), based on the EPPO global database (Table 3).

Colletotrichum siamense Prihast

Colletotrichum siamense was first reported in the country in 2023 and was found on leaves of *Nephelium lappaceaum,* showing leaf spots[47]. In 2024, *C. siamanse* was reported in red onion sold in a market in Laguna[5].

Colletotrichum theobromicola Delacr

Colletotrichum theobromicola was first reported in the Philippines in 2021 and was isolated from anthracnose-infected mango[41].

Colletotrichum tropicale Rojas

Colletotrichum tropicale was reported in three plant species in the Philippines. It was isolated from anthracnose-infected mango[41], anthracnose-infected stems of dragon fruit[48], and leaf spot-infected *N. lappaceaum*[47].

Colletotrichum gloeosporioides (Penz.) Penz. & Sacc

Most of the reports on *Colletotrichum gloeosporioides* were based on their morphology, and only a few were distinguished using multi-locus analysis. *Colletotrichum gloeosporioides sensu lato* has been reported in various plant species (Table 1), including fruit trees like mango and papaya.

Colletotrichum graminicola-Caudatum complex

Colletotrichum falcatum Went

Colletotrichum falcatum is responsible for red rot in *Sorghum halapense, S. bicolor,* and *Saccharum officinarum*. One of the earliest records of *Colletotrichum falcatum* was in the 1920s[49]. Ahmed & Divinagracia[50] characterized 13 *C. falcatum* isolates from the Philippines. They found variations within the collections, particularly in spore sizes. Variations in virulence were also observed,

Table 1. *Colletotrichum* species associated with plant diseases in the Philippines.

Species complex	Current species name	Host plant	Associated disease
Acutatum	*C. acutatum sensu lato*	*Capsicum* spp.	Anthracnose
		Annona muricata	Fruit deterioration
	C. nymphaeae	*Solanum lycopersicon*	Anthracnose
	C. scovillei	*Capsicum* sp.	Anthracnose
Agaves	*C. agaves*	*Agave cantuta*	Anthracnose
Boninense	*C. heveae*	*Hevea brasiliensis*	Leaf disease
Dematium	*C. circinans*	*Allium cepa*	Smudge
	C. dematium	*Capsicum* spp.	Anthracnose
		Arachis hypogaea	Anthracnose
		Zea mays	Seedborne rot
		Hibiscus esculentus	Anthracnose
Gloeosporioides	*C. asianum*	*Mangifera indica*	Anthacnose
	C. fructicola	*Selenicereus* spp.	Anthracnose
		Diospyrus kaki	Anthracnose
		Mangifera indica	Anthracnose
	C. gloeosporioides sensu lato	*Alchornea rugosa*	–
		Alstonia scholaris	–
		Hevea brasiliensis	–
		Annona muricata	Fruit deterioration
		Canavalia ensiformis	Anthracnose
		Citrus maxima	–
		Citrus sinensis	–
		Stylosanthes spp.	Anthracnose
		Bixa orellana	Anthracnose
		Gerbera jamesonii	Anthracnose
		Persea americana	Anthracnose
		Begonia spp.	Anthracnose
		Anthurium spp.	Anthracnose
		Anthurium spp.	Spadix rot
		Pachyrrhizos angulatus	Leafspot
		Codiaeum variegatum	Anthracnose
		Dieffenbachia spp.	Anthracnose
		Eugenia jambolana	Fruit disease
		Vitis vinifera	Anthracnose
		Vitis vinifera	Anthracnose
		Psidium guajava	Anthracnose
		Psidium guajava	Anthracnose
		Lansium domesticum	Leafspot
		Dioscorea hispida	Leafspot
		Nephelium lappaceum	Leaf blight
		Jasminum sambac	Anthracnose
		Schefflera odorata	Leaf blight
		Solanum lycopersicon	Leafspot
		Dioscorea alata	Leaf blight
		Chloropython elatum	Anthracnose
		Episcia cupreata	Anthracnose
		Dracaena fragrans	Anthracnose
		Euphorbia heterophylla	Leafspot
		Euphorbia hirta	Leafspot
		Sweitenia spp.	Blight
		Capsicum spp.	Anthracnose
		Philodendron spp.	Anthracnose
		Hevea brasiliensis	Anthracnose
		Hevea brasiliensis	Secondary leaf fall

(to be continued)

Table 1. (continued)

Species complex	Current species name	Host plant	Associated disease
		Solanum tuberosum	Leafspot
		Various orchid species	Anthracnose
		Various orchid species	Anthracnose
		Carica papaya	Anthracnose
		Carica papaya	Fruit rot
		Carica papaya	Fruit spot
		Carica papaya	Petiole browning
		Agathis spp.	Seedling dieback
		Basella Rubra	Leafspot/ Anthracnose
		Basella Rubra	Leafspot/ Anthracnose
		Theobromae cacao	Cherelle wilt
		Anacardium occidentale	Anthracnose
		Chrysanthemum spp.	Anthracnose
		Mangifera indica	Anthracnose
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Mangifera indica	Wither tip
		Lantana camara	Leafspot
		Polyaltha longifolia	Leaf blight
		Vitis vinifera	–
	C. musae	*Capsicum* spp.	Anthracnose
		Musa spp.	Anthracnose
		Musa spp.	Fingertip rot
		Musa spp.	Fingertip rot
		Musa spp.	Fingertip rot
		Musa spp.	Fingertip rot
		Musa spp.	Fingertip rot
		Musa spp.	Fingertip rot
		Musa spp.	Crown rot
		Musa spp.	Crown rot
		Musa sp.	Anthracnose
	C. siamense	*Nephelium lappaceum*	Leaf spot
		Allium cepa	Anthracnose
	C. theobromicola	*Mangifera indica*	Anthracnose
	C. tropicale	*Selenicereus monacanthus*	Anthracnose
		Mangifera indica	Anthracnose
		Nephelium lappaceum	Leaf spot
Graminicola-Caudatum	*C. falcatum*	*Sorghum halapense*	Red rot
		Sorghum bicolor	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot

(to be continued)

Table 1. (continued)

Species complex	Current species name	Host plant	Associated disease
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
		Saccharum officinarum	Red rot
	C. graminicola	*Leucaena leucocephala*	Seedborne rot
		Leucaena leucocephala	Seedborne rot
		Zea mays	Seedborne rot
		Zea mays	Storage rot
		Zea mays	Anthracnose
		Zea mays	Anthracnose
		Zea mays	Anthracnose
		Sorghum bicolor	Anthracnose
		Sorghum bicolor	Red leafspot
		Sorghum bicolor	Red leafspot
		Sorghum arundinaceaum	–
		Sorghum hakapense	Anthracnose
	C. gossypii	*Gossypium hirsutum*	Anthracnose
		Gossypium hirsutum	Pink boll rot
		Gossypium hirsutum	Seedling blight
		Gossypium hirsutum	Seedling blight
		Gossypium hirsutum	Seedling blight
		Gossypium hirsutum	Seedling blight
		Gossypium hirsutum	Seedling blight
Magnum	*C. brevisporum*	*Carica papaya*	Anthracnose
Orbiculare	*C. lindemuthianum*	*Phaseolus* spp.	Anthracnose
		Vigna radiata	Anthracnose
		Hibiscus esculentus	Anthracnose
		Stylosanthes guyanensis	Leafspot
		Phaseolus lunatus	Anthracnose
		Phaseolus lunatus	Anthracnose
		Phaseolus lunatus	Anthracnose
		Vigna spp.	Anthracnose
		Phaseolus vulgaris	Anthracnose
		Phaseolus vulgaris	Anthracnose
		Phaseolus vulgaris	Anthracnose
		Phaseolus vulgaris	Anthracnose
		Psophocarpus tetragonolobus	Anthracnose
		Ricinus communis	Anthracnose
		Vigna spp.	Anthracnose
Orchidearum	*C. orchidearum*	*Cymbidium sp.*	–
		Dendrochilum sp	–
		Eria ornata	–
		Pholidota imbricata	–
		Rhynchostylis sp.	–
Truncatum	*C. truncatum*	*Capsicum* spp.	Anthracnose
		Azadirachta indica	Seedling
		Medicago sativa	Anthracnose
		Trifolium pratense	Anthracnose
		Vicia villosa	Anthracnose
		Capsicum sp.	Anthracnose
		Carica papaya	Anthracnose
		Phaseolus lunatus	Anthracnose
		Lotus purshianus.	Anthracnose
		Melilotus alba	Anthracnose
		Vigna spp.	Seedborne rot
		Leucaena leucocephala	–
		Pterocarpus indicus	–

Source: Tangonan[97] and new reports. (–) not indicated.

whereby an isolate from a research station in Los Banos, Laguna, was more virulent than the other collected isolates. However, these isolates have not been preserved, and the current *C. falcatum* population in the field may now differ from those reported in 1973. In a follow-up work, Ahmed & Divinagracia[51] found that Philippine isolates grew well in sucrose and vitamins, e.g., biotin and thiamine, which can also induce sporulation.

Colletotrichum falcatum is a quarantine pest in Morocco (2018), and Mexico (2018), based on the EPPO global database (Table 3).

Colletotrichum graminicola (Ces. ex Sacc.) G.W. Wilson

Colletotrichum graminicola has been reported in *Leucaena leucocephala* causing seedborne rot, *Zea mays,* causing anthracnose[52], and *Sorghum bicolor*, causing anthracnose[53], and leaf spot[54].

Colletotrichum graminicola is a regulated non-quarantine pest in Egypt (2018), on the A1 list in Bahrain (2003), and a quarantine pest in Israel (2009), based on the EPPO Global Database (Table 3).

Colletotrichum gossypii Southw

Colletotrichum gossypii causes anthracnose[55], pink ball rot[56], and seedling blight[57] in *Gossypium hirsutum*.

Colletotrichum gossypii is on the A1 list in Egypt (2018), Bahrain (2003), Iran (2018), Kazakhstan (2017), Uzbekistan (2008), Azerbaijan (2007), Turkey (2016), and a quarantine pest in Morocco (2018), Israel (2009), and Belarus (1994), based on the EPPO global database (Table 3).

Colletotrichum magnum complex

Colletotrichum brevisporum Phouliv

Colletotrichum brevisporum causes anthracnose in papaya[58].

Colletotrichum orbiculare complex

Colletotrichum lindemuthianum (Sacc. & Magnus) Briosi & Cavara

Colletotrichum lindemuthianum is associated with anthracnose of *Vigna radiat*[59], *Phaseolus lunatus*[43], *Phaseolus vulgaris*[60], *Psophocarpus tetragonolobus*[61], and *Ricinus communis*[61].

Colletotrichum lindemuthianum is a regulated non-quarantine pest in Egypt (2018), based on the EPPO global database (Table 3).

Colletotrichum orchidearum complex

Colletotrichum orchidearum Allesch

Colletotrichum orchidearum has been associated with *Cymbidium* sp., *Dendrochilum* sp, *Eria ornata*, *Pholidota imbricata*, and *Rhynchostylis* sp.[57].

Colletotrichum truncatum complex

Colletotrichum truncatum (Schwein.) *Dendrochilum* sp. Andrus & W.D. Moore

Colletotrichum truncatum has been associated with anthracnose of *Capsicum* spp[61,62], *Medicago sativa*, *Trifolium pratense*, *Phaseolus lunatus*, *Lotus purshianus*, *Melilotus alba*, *Vicia villosa*[61], and *Carica papaya*[58].

Colletotrichum truncatum is a regulated non-quarantine pest in Egypt (2018). It is on the A1 list in Chile (2019) based on the EPPO global database (Table 3).

Singleton species

The two singleton species recorded in the country were *Colletotrichum coccodes* (Wallr.) S. Hughes [syn. *C. phomoides* (Sacc.) Chester], and *C. nigrum* Ellis & Halst. The former causes tomato and pepper anthracnose[63], and the latter causes anthracnose in *Averrhoa bilimbi* and fruit rot in pepper[64].

Morphospecies

There are 17 reported morphospecies of *Colletotrichum* from the Philippines (Table 2). Three of which, *C. elmeri, C. gliricidiae*, and

Table 2. Reported morphospecies of *Colletotrichum* from the Philippines.

Colletotrichum species	Host plant	Associated with	Ref.
C. pithecellobii Roldan	*Pithecolobium dulce*	–	[85]
C. alstoniae (Sacc.) Petr.	*Alstonia scholaris*	Dead leaves	[86]
C. arecae Syd. & P. Syd	*Areca cathecu*	Anthracnose	[87]
C. bakeri (Syd. & P.Syd.) Mundk.	*Ricinus communis*	Dead stem and petioles	[88]
C. coffeanum F. Noack	*Coffea* spp.	Anthracnose	[89]
		Berry blight	[90]
		Brown blight	[90]
		Dieack	[90]
C. conspicuum Syd. & P. Syd.	*Erythropalum scandens*	Living leaves	[91]
C. elmeri Syd	*Cyrtosperma merkusii*	Leaves	[92]
C. euchroum Syd. & P. Syd.	*Euphorbia neriifolia*	Leafspot	[93]
C. ficus Koord	*H. brasiliensis*	Anthracnose	[34]
C. gliricidiae Syd. & P. Syd.	*Gliricidia sepium*	Living leaves	[91]
C. lussoniense	*Manihot utilissima*	Dead branches	[94]
C. melongenae Av.-Saccá	*Solanum melongena*	Anthracnose	[43]
		Fruit rot	[95]
C. merilli (Syd. & P. Syd.) Quimio	*Ricinus communis*	Stems	[61]
C. pandani Syd. & P. Syd.	*Pandanus veitchii*	–	[93]
Gloeosporium lebbek Syd. & P. Syd (Obligate synonym: *C. lebbek*)	*Albizia lebbeck*	–	[86]
C. crassipes	*Agave rigida*	–	[96]
C. sumbaviae Syd. & P. Syd.	*Sumbavia rottleroides*	Living leaves	[57]

C. sumbaviae, have been associated with leaves, but whether they were diseased or healthy is unknown.

Unidentified *Colletotrichum* species

Twelve fungal isolates designated as *Colletotrichum* species were recorded from ten plants showing various symptoms (shoot blight, anthracnose, leaf spots, fruit rot, stalk rot, and grain mold). Infected plants were *Acacia mangiu*[65], *Manihot* sp.[66], *Corchorus olitorius*[67], *Lansium domesticum*[68], *Euphorbia pulcherrima*[69], *Wikstroemia lanceolota*[70], *Sorghum bicolor*[71], and *Dioscorea alata*[72].

Occurrences

The most frequently reported species complex is *Colletotrichum gloeosporioides sensu lato* (65), and the most frequently reported species is *Colletotrichum lindemuthianum* (15), followed by *C. truncatum* (14), *C. graminicola* (12), *C. musae* (11), and *C. falcatum* (11). Reports and occurrences of *Colletotrichum* species were highest during the 1970s, 1990s, and 1980s (Fig. 1). The plant families with the most reported number of *Colletotrichum* species are the Fabaceae and Solanaceae (Fig. 2)

Discussion

A checklist of *Colletotrichum* species associated with plant diseases in the Philippines has been provided. The *Colletotrichum gloeosporioides* species complex had the highest number of species reported. The earliest scientific records of *Colletotrichum* species associated with a plant disease in the country were in Reinking[43], reporting *C. musae* in banana, and *C. lindemuthianum* in *Phaseolus lunatus*. Pepper, mango, banana, and *Phaseolus vulgaris* had the most host reports (Table 1). The 'Host Index of Plant Diseases in the Philippines' by Tangonan[29] was particularly useful for extracting local reports. Still, validation of the current taxonomy of the reported species was necessary. The Mycobank and Index Fungurom have been useful for validating the current names of the

Table 3. Pest categorization of *Colletotrichum* species recorded in the Philippines based on the EPPO global database (2024)[1]

Colletotrichum species	EPPO categorization	EPPO code
C. asianum	No categorization	COLLAS
C. agaves	No categorization	GLOMCI
C. alstoniae	Not found in the database	–
C. arecae	Not found in the database	–
C. bakeri	Not found in the database	–
C. brevisporum	No categorization	COLLBV
C. coccodes	No categorization	COLLCC
C. coffeanum	A1[2] list in Argenina (2019), and Paraguay (1992)	COLLCO
C. conspicuum	Not found in the database	–
C. crassipes	No categorization	COLLKP
C. dematium	Regulated non-quarantine pest[3] in Egypt (2018)	COLLDE
C. elmeri	Not found in the database	–
C. euchroum	Not found in the database	–
C. falcatum	Quarantine Pest[4] in Morocco (2018), and Mexico (2018)	GLOMTU
C. ficus	Not found in the database	–
C. fructicola	No categorization	COLLFC
C. gliricidiae	Not found in the database	–
C. gossypii	A1 list in Egypt (2018), Bahrain (2003), Iran (2018), Kazakhstan (2017), Uzbekistan (2008) Azerbaijan (2007), Turkey (2016), quarantine pest in Morocco (2018), Israel (2009), and Belarus (1994)	GLOMGO
C. graminicola	Regulated non-quarantine pest in Egypt (2018), A1 list in Bahrain (2003), quarantine pest in Israel (2009)	COLLGR
C. heveae	Not found in the database	–
C. lindemuthianum	Regulated non-quarantine pest in Egypt (2018)	COLLLD
C. lussoniense	Not found in the database	–
C. melongenae	No categorization	GLOMCI
C. merilli	Not found in the database	–
C. musae	Regulated non-quarantine pest in Egypt (2018)	COLLMU
C. nigrum	No categorization	COLLNG
C. nymphaeae	No categorization	COLLNY
C. orchidearum	No categorization	COLLOR
C. pithecellobii	Not found in the database	–
C. pandani	Not found in the database	–
C. siamense	No categorization	COLLSM
C. sumbaviae	Not found in the database	–
C. theobromicola	No categorization	COLLTH
C. tropicale	No categorization	COLLTP
C. truncatum	Regulated non-quarantine pest in Egypt (2018), and A1 list in Chile (2019)	COLLDU

[1] Source: EPPO (2024) global database. https://gd.eppo.int [accessed September 24, 2024]. [2] A1 list—absent in the EPPO region. [3] RNQP – 'a non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party'. IIPPC (1997). [4] Quarantine pest —quarantine pests are absent from an area or present but under official control (EPPO).

fungi. In addition, the USDA Fungal Databases were also beneficial for researchers who want to compare country records of the *Colletotrichum* species and their hosts[73]. Nevertheless, the database did not cover other local reports, and the host index records were only available until 1999. Hence, the Google Scholar and SCOPUS databases were used to include new reports published since then. *Colletotrichum* species records from 1999 to the present, included in this checklist, can now be included in future updates of the host index.

The Philippines ranked third in the Southeast Asian region regarding the number of *Colletotrichum* species reported, trailing behind Thailand (151), and Malaysia (119) based on the records available in the USDA fungal databases. Interestingly, the Philippines, Malaysia, Thailand, and Indonesia have frequently reported *Colletotrichum* species associated with pepper, indicating pepper as a versatile host of anthracnose regardless of the associated *Colletotrichum* species. *Colletotrichum scovillei* and *C. truncatum* are found in all four countries. However, pepper anthracnose associated with *Colletotrichum dematium*[36], *C. coccodes* (reported as *C. phomoides* by Teodoro[57], and Ocfemia[63]), and *C. musae*[36] were only reported in the Philippines. Among these species, only *C. musae* has molecular data[44]. Hence, the other species should be restudied to confirm if they are indeed the species previously reported.

Among the important crops affected by *Colletotrichum* species were onion, pepper, papaya, mango, banana, sugarcane, tomato, sorghum, and corn. Information on the actual figures of the economic impact and losses is scarce. If it exists, it is limited to a few crops. Available reports indicate anthracnose plays a significant role in yield reduction, market demand for the harvests, and grower profit in the Philippines, as seen in other countries[74,75]. For instance, in pepper, anthracnose can wipe out an entire field. Dela Cueva & Balendres[32] reported a farm in Batangas where a grower abandoned the field because they failed to harvest healthy pepper fruits due to pepper anthracnose. When fruits were recovered from anthracnose-infected fields, some healthy fruits later developed anthracnose (due to latent infection) and were subsequently rejected or devalued during marketing. In such a case, the market could demand higher prices due to the limited product supply. From a consumer's perspective, this would be an additional household expense. For example, in December 2015, the price of siling 'labuyo' increased to Php 700 per kilo in some Metro Manila markets because of the low supply[76]. For those in the restaurant or food business, this may increase the meal price to compensate for the cost of food ingredients.

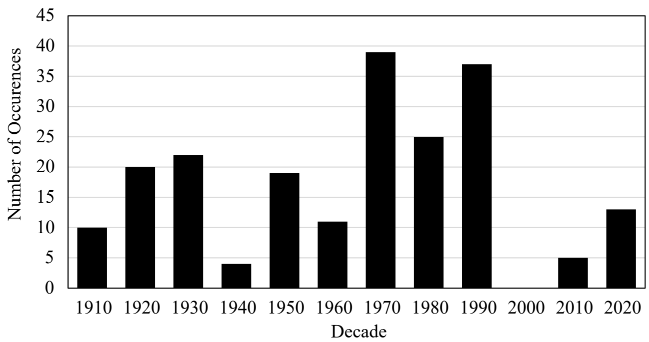

Fig. 1 Number of occurrences of *Colletotrichum* species reports in the Philippines.

Pepper anthracnose is not only a problem in the Philippines but also in Indonesia[77], Korea[78,79], Taiwan, China[80], Thailand[81,82], and Vietnam[83,84]. This problem was exacerbated by more aggressive and virulent strains of *Colletotrichum* species that had previously not been reported in pepper. These strains can also infect fruits without a wound or damage. For instance, pepper fruits infected by *C. scovillei* were more severe than those infected by other previously known species[30,32]. Infected fruits in the field are mummified; during marketing, some fruits are non-edible because of their appearance. It is clear that when the plant organ affected by anthracnose is the fruit, which is economically important, it is likely that the fruit will be devalued because the fruit becomes less appealing to the consumer.

In controlling plant diseases, including anthracnose, growers often use pesticides (or fungicides) as an immediate response. However, some growers use these fungicides when plants are severely infected; some fungicides are however not designed to cure the disease but to protect the plant from pathogen infection, thereby reducing the disease's incidence and severity below the economic injury level. From a production perspective, using pesticides to control anthracnose is an added cost to the inputs and reduces the grower's net income. From an environmental perspective, the use of pesticides may have a long-term effect on the health of non-target organisms in the field and the soil. Therefore, the impact of anthracnose is not only limited to the direct effect on the quantity and the quality of the harvest, but also indirectly on the cost of input and the environment. Research on alternative disease control approaches is needed to reduce the reliance on pesticides in anthracnose management.

Conclusions

This paper updates the knowledge of *Colletotrichum* species associated with plant diseases in the Philippines. Records show 55 *Colletotrichum* species (36 belonging to ten species complexes, two

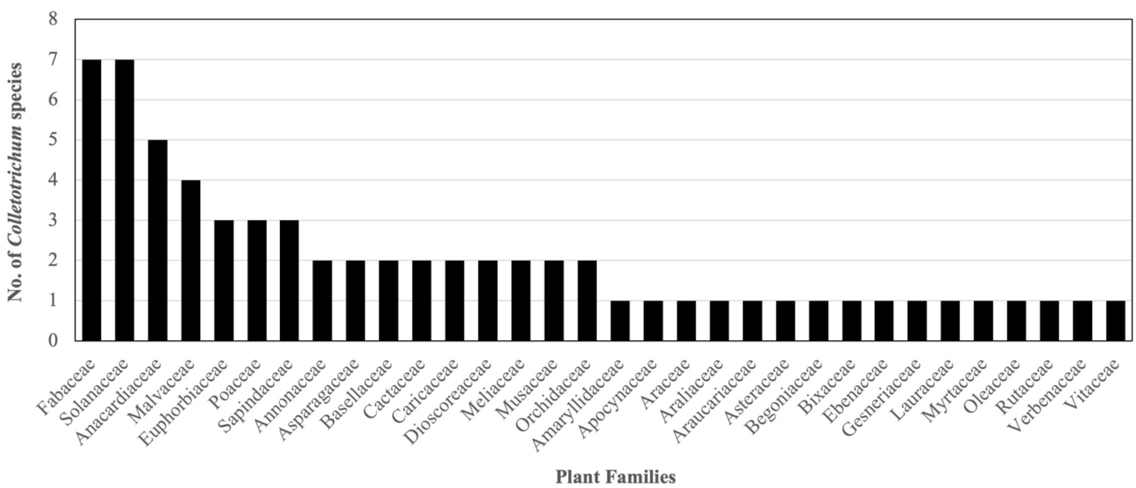

Fig. 2 Species richness of recorded *Colletotrichum* species across different plant families in the Philippines.

singleton species, 17 morphospecies), and 12 unidentified *Colletotrichum* species hosted by 106 plant species with anthracnose as the primary disease. The *Colletotrichum gloeosporioides* species complex had the highest number of species reported.

The checklist will be useful as a reference for students, lecturers, researchers, plant quarantine officers, growers, and decision-makers. This checklist provides an understanding of the country's current diversity of *Colletotrichum* species, forms baseline information for future taxonomic studies in unexplored regions, and a reference for future discovery of new plant hosts. Furthermore, government funding agencies, e.g., the Department of Science and Technology (DOST), and the Department of Agriculture (DA), also allocate resources and funds for future anthracnose research; this list will be a useful guide to identify key crops significantly affected by anthracnose and to direct allocations to key research questions and areas, e.g., sustainable disease management strategies.

Anthracnose poses a significant threat to economically important plants in the Philippines. This checklist offers valuable insights into the *Colletotrichum* species linked to anthracnose associated with particulate crops. Facilitating targeted monitoring efforts aids growers and farm managers anticipate outbreaks and implement effective preventive measures. Furthermore, the checklist supports assessing the vulnerability and susceptibility of different crops or varieties to anthracnose, enabling prioritization of interventions based on risk levels. Identifying the causative species also allows for the development of strategic sanitation practices to reduce pathogen load in the field. Understanding the life cycle of these pathogens encourages practices like crop rotation, which can disrupt their cycles and minimize disease incidence. Additionally, since fungal species respond variably to fungicides and biological control agents, this checklist can inform decisions on the most effective treatments, whether fungicides, botanical extracts, or biological controls, tailored to specific *Colletotrichum* species or complexes.

This paper also supports the ongoing efforts of the Bureau of Plant Industry's Plant Quarantine Offices and other related agencies in monitoring plant pathogens and diseases of interest. There may be collections of *Colletotrichum* species in museums and other research institutions. Molecular studies on these collections are warranted to confirm species identity. In the last decade, molecular assays have been used to identify the *Colletotrichum* species associated with plant diseases. Sequencing the recommended barcoding gene regions would validate these isolates' current taxonomic placement, especially the reported morphospecies, and contribute to the global effort of epitypification of these *Colletotrichum* cultures. This will also correct previous reports and those erroneously identified *Colletotrichum* species. Nevertheless, from a plant pathology perspective, these isolates must be assessed for their pathogenicity on original and known hosts, and Koch's postulates should be established.

Author contributions

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Data availability

No new data was produced for this work. All data generated or analyzed during this study are included in this published article.

Conflict of interest

The author declares that there is no conflict of interest.

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