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Morphological Diversity and Virulence of *Colletotrichum* spp. Causing Anthracnose in Chilli Pepper in Coastal Purworejo, Indonesia

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Abstract. Anthracnose, caused by *Colletotrichum* spp., is one of the most destructive diseases affecting chilli peppers and can result in significant yield losses, particularly in coastal agroecosystems where climatic factors favor the development and spread of this pathogen. This study examined the diversity and virulence of Colletotrichum populations in the coastal region of Purworejo Regency, Central Java, by investigating the severity of anthracnose as well as the morphological diversity and virulence of *Colletotrichum* spp. in the coastal region of Purworejo Regency, Central Java, Indonesia. Disease surveys were conducted in chilli-producing areas located in three subdistricts along the coast, followed by the isolation and morphological characterization of the pathogen, as well as an evaluation of its pathogenicity against healthy chilli fruits under laboratory conditions, using a purposive sampling design and a completely randomized design for laboratory testing. The results showed that anthracnose was widespread across all locations, with disease severity ranging from low (1%) in Grabag and Purwodadi subdistricts at Location 1 to very high (75%) in Purwodadi subdistrict at Location 2. Nineteen Colletotrichum isolates were isolated from fruit exhibiting symptoms. They showed significant variation in colony morphology—white, black, gray, and orange on the reverse side of Petri dishes—with textures ranging from cottony to sparse; conidia were oval, fusiform, and crescent-shaped; and conidiomata production was observed in some isolates. Pathogenicity tests showed that all isolates except two exhibited varying levels of virulence, ranging from moderate to high, with the highest virulence of 73.09% observed in the isolate from Purwodadi Subdistrict.

Keywords: chilli; disease severity; pathogenicity; plant disease; virulence

1. Introduction

Coastal areas have several environmental characteristics that can directly and indirectly affect plant pathogens. These characteristics include high humidity, rainfall, and the influence of sea breezes. Climate change causes long-term temperature changes, increased rainfall, drought, and the emergence of cyclones. One indication of climate change is changes in seasons and weather (Yulihastin et al., 2023). This also occurs in coastal areas and is felt more strongly. Climate change affects chilli productivity both directly through reduced growth and crop production, and indirectly through plant pathogen attacks (Widowati et al., 2023). Currently, chilli is widely cultivated by coastal farmers in coastal areas (Fivintari & Shofiyah, 2024; Ruslanjari et al., 2020), thus posing a threat to chilli cultivation in coastal areas.

Heavy rainfall provides surface water that can facilitate the spread of spores to nearby plants. Pathogenic spores can also be transported by sea breezes from one area to another (Grinn-gofroń et al., 2020). Anthracnose is considered one of the pathogens that causes significant damage to chilli plants worldwide, with a damage rate of 55% and resulting in yield reductions of 10-80% depending on the cultivation area and cultivation techniques used by farmers (Saxena et al., 2016; Suprapta, 2022), even resulting in crop failure during high rainfall (Abdila et al., 2022; Avianto & Handayani, 2023). This disease is very detrimental because it can cause serious damage to chilli fruit, both in the field and during storage (Filaila et al., 2021; Manda et al., 2020).

According to de Silva et al. (2019), the diversity of Colletotrichum species in chilli peppers includes *C. endopytichum*, *C. fructicola*, *C. javanense*, *C. karsti*, *C. makassarense*, *C. plurivorum*, *C. scovillei*,

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C. siamense, *C. tainanense*, and *C. tropicale*. Kim et al. (2025) reported that different Colletotrichum species affect different organs of chilli plants. *Colletotrichum* spp. has a pathogenicity mechanism involving enzymes and toxins. Pectinase is an enzyme that plays a role in the pathogenesis process (Armesto et al., 2019). Toxins produced by *Colletotrichum* spp. often show different colors as indicators of secondary metabolites and toxin activity. The production of these colored enzymes and toxins is a virulence factor for *Colletotrichum* spp. (Rovetto et al., 2023). In fact, this is a common occurrence in the field, where several Colletotrichum species with varying morphologies and virulence are found within a single disease symptom. This case has not been widely reported, especially in coastal areas of Indonesia.

Although the diversity of Colletotrichum species causing anthracnose in chili peppers has been widely reported in various Asian countries as well as in Indonesia (Anggrahini et al., 2020; de Silva et al., 2019; Hodiyah et al., 2024), most of these studies were conducted in lowland agroecosystems or conventional agricultural lands located far from the influence of coastal environments. To date, there have been very few studies specifically evaluating the population structure of Colletotrichum in coastal agroecosystems with distinct microclimatic characteristics. Coastal areas are characterized by higher air humidity, relatively small daily temperature fluctuations, higher wind speeds, deposition of marine salt aerosols, and rainfall dynamics influenced by ocean-atmosphere circulation. These factors have the potential to influence spore viability, the efficiency of conidia dispersal via wind and rain splash, infection success, and selection pressure on pathogen populations, thereby allowing for the formation of a different species composition and virulence levels of Colletotrichum compared to non-coastal agroecosystems (Connell et al., 2012; Grinn-gofroń et al., 2020; Saxena et al., 2016).

In previous studies, researchers have generally focused on species identification using morphological and molecular approaches or on evaluating the pathogenicity of isolates from various aquaculture regions without considering the influence of a landscape's ecological characteristics on pathogen population diversity (de Silva et al., 2019; Hodiyah et al., 2024; Suwannarat et al., 2017). Based on this gap, this study offers a novel approach by examining the morphological diversity and virulence of Colletotrichum isolates originating specifically from the coastal chili agroecosystem in Purworejo Regency, Central Java, and linking these characteristics to disease severity at each observation site. This approach provides preliminary information on how coastal environmental characteristics are associated with the diversity of the pathogen population causing anthracnose, which, to date, has been reported only very limitedly in Indonesia. The results of this study are expected to serve as a basis for further landscape-based epidemiological studies and the development of more specific anthracnose management strategies tailored to the characteristics of coastal agroecosystems. Therefore, this study was conducted with three specific objectives: (1) to evaluate the severity of chilli anthracnose in coastal agroecosystems of Purworejo Regency; (2) to characterize the morphological diversity of *Colletotrichum* spp. isolates associated with anthracnose symptoms collected from coastal chilli fields; and (3) to assess the virulence of these isolates and examine their relationship with disease severity across different sampling locations.

2. Materials and Methods

2.1 Description of Study Area

This survey was conducted along the coast of Purworejo Regency, a coastal area that produces chilli peppers year-round. Sampling was carried out from June to August 2025 to collect samples and assess

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anthracnose disease. The sampling technique used purposive sampling, targeting plants exhibiting characteristic symptoms of anthracnose at eleven chilli-growing sites in three subdistricts: Purwodadi, Ngombol, and Grabag.

2.2 Exploration and Severity of Anthracnose Disease

The Colletotrichum exploration was conducted through a survey. Sampling used a purposive random sampling design and focused on anthracnose-infected chilli plantations in the coastal area of Purworejo Regency, Indonesia. Eleven locations were selected as sampling points. The survey was conducted during the chilli planting season, sampling anthracnose-infected chilli fruit, which exhibits black spots on the fruit. Eleven to 20 samples were taken at each location, representing different symptoms (small lesions, large lesions, pigmented tissue, and rot). The samples were temporarily stored in sterile plastic bags labeled appropriately (location, date, and plant ID) and kept in a refrigerator with dry ice. A total of 10% of the chilli plant population was randomly selected using a zigzag sampling technique to determine the disease intensity in each city. Disease severity was calculated using the formula:

$$IP = \sum\left(\frac{(n\ x\ v)}{N\ x\ Z}\right) x\ 100\%$$

Description: IP: Disease intensity/severity percentage; n: number of samples at each attack level; v: scale at each attack level; N: number of samples observed; Z: highest score. Disease severity was assessed on a scale of 0 to 9. A total of 120 chillies were randomly selected to determine the severity of anthracnose disease in each city/district. Fruits with anthracnose symptoms were selected, preserved, and then sent to the laboratory for further analysis.

2.3 Isolation and Morphological Characterization

Isolation and purification of isolates were carried out based on the standards established by Joshi et al. (2023). The diseased tissue sections of infected chilli peppers were cut and sterilized. These sterilized fragments were inoculated on Potato Dextrose Agar (PDA) Himedia and incubated at 28°C for seven days. Five-millimeter diameter mycelial discs from 7-day-old cultures of each isolate were transferred to the center of a sterile Petri dish containing potato dextrose agar and incubated at 25±10°C. The tips of hyphae growing from the infected fragments were observed for pathogen characteristics under a light microscope and then transferred to a slanted PDA medium with the aid of a sterile needle. Thus, 19 pathogen isolates were obtained from chilli fruit parts. The isolates were purified using the hyphal tip technique, and the culture tubes were stored in a refrigerator at 4°C for subsequent virulence testing.

Macroscopic and microscopic characters were observed using 10-day-old pure isolates, identified according to (da Silva et al., 2020). Macroscopic observations were made using an Olympus CX 23 light microscope, while observations of the shape and size of conidia were made by observing the symptoms on chilli fruit. Microscopic measurements were carried out using a microscope lens calibrated with a micrometer, an Optilab microscope camera, and Image Raster 3 software. The isolates obtained were grouped based on the color at the top and bottom of the medium. Morphological identification of Colletotrichum spp isolates is not accurate enough to determine the species level. Therefore, molecular identification is necessary to determine the characteristics of the species found. This step will be carried out in the next stage of research.

2.4 Pathogenicity Test

Pathogenicity tests were conducted on 19 isolates obtained based on the modified method (de Silva et al., 2019). The isolates were inoculated into healthy Kalibri chili peppers to confirm the fungus's pathogenicity. The surface of freshly picked healthy chili peppers was sterilized using

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70% alcohol and then rinsed three times with sterile distilled water. The fruits were punctured with a sterile needle to a depth of 1 mm (6 punctures) within a 5-mm-diameter circle. Pathogen inoculation was performed by placing mycelium discs from a 5-day-old *Colletotrichum* spp. culture onto the punctured fruits, which were then covered with moistened sterile cotton. Next, the fruits were incubated in a closed container. Humidity was maintained by moistening the sterile cotton with sterile water inside the container. The diameter of the lesions, measured over ten days following inoculation, was determined diagonally at a point on the edge of the wound using a digital caliper. This pathogenicity test was designed using a completely randomized design with five replicates, and the experiment was conducted three times for validation.

2.5 Data analysis

Pathogenicity test data were collected five times, starting from day 2 after inoculation or after the appearance of the first anthracnose symptoms, and virulence was calculated based on the lesion area on infected chilli fruit. The lesion size against chilli anthracnose disease was analyzed using an analysis of variance (ANOVA) model with a 5% error rate estimated for each test and post hoc analysis with Duncan's Multiple Range Test (DMRT), which was significantly different using SAS software (SAS Institute, USA).

3. Results and Discussion

3.1 Symptoms of Disease in the Field

A chilli agroecosystem in a coastal area is shown in Figure 1A. Chilli plants grow well in sandy soil, which is poor in nutrients and has high porosity. Cultivation of cucumbers and chillies in sandy soil has been carried out (Jensen & Teran, 1971), as well as shallots, garlic, beans, ginger, spinach, cabbage, potatoes, eggplant, tomatoes, and carrots (Pangemanan et al., 2021). Good soil for cultivation is well-drained and rich in organic matter (Bertucci et al., 2024). Cultivation in sandy soil can grow well with additional nutrients and irrigation technology (Budiyanto, 2021; Fivintari et al., 2023; Jensen & Teran, 1971). Symptoms of anthracnose disease in chilli peppers are shown in Figure 1.B-D), blackish- brown necrosis symptoms with lesions with white conidia distribution on green chilli peppers (Figure 1B), black lesions are found on red chilli peppers (Figure 1C), and cayenne peppers with brownish-black lesions (Figure 1D). Typical symptoms of anthracnose disease in chilli peppers appear as circular or angular concave lesions. The lesions are characterized by the presence of black spots in mature concentric rings. Orange to pink conidia are visible on the surface of the fruit. The spots are acervuli that have hairs and pathogens (Saxena et al., 2016). According to Suwannarat et al. (2017), anthracnose symptoms appear differently in each Colletotrichum species. Symptoms caused by *C. gloeosporioides* show black concave lesions. Necrotic spots of *C. siamense* are orange and surrounded by black-brown necrotic tissue. The symptomatic lesions of *C. acutatum* and *C. capsici* produce similar sunken lesions, but the fruiting structures in the center of the lesions are orange and black.

3.2 Severity of Chilli Anthracnose Disease

The severity of chilli anthracnose disease on the Purworejo coast shows variations between regions (Figure 2). Based on the data, it appears that the severity level is low to high (1%-75%). The highest severity, namely more than 75%, occurred in Purwodadi District at location 2, and the lowest severity was in Purwodari District, location 1, and Grabag, location 3, with a severity of 1%. Variations in disease severity are caused by chilli varieties, location, plant age, cultivation practices, and Colletotrichum species (Khalimi et al., 2019).

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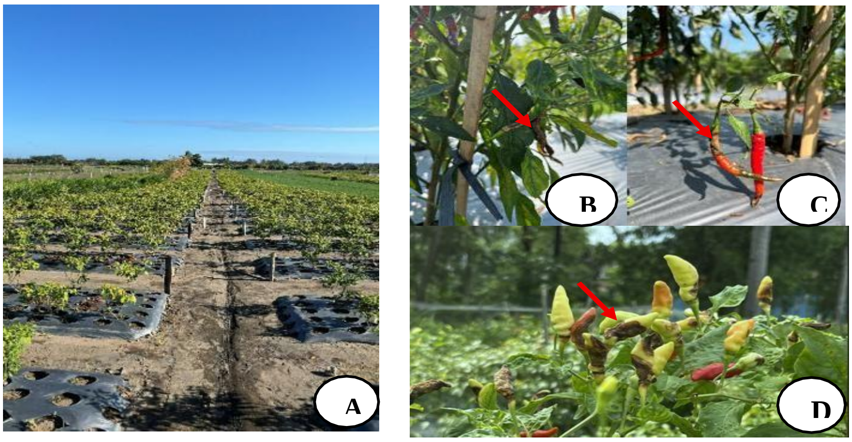

Figure 1. Anthracnose symptoms on chilli peppers on the Purworejo coast, Central Java Province, Indonesia. (A) chilli pepper planting ecosystem in the coastal area, (B) symptoms appearing on large green chilli peppers, (C) symptoms appearing on larger chilli peppers, (D) symptoms appearing on cayenne peppers. Arrows indicate symptoms.

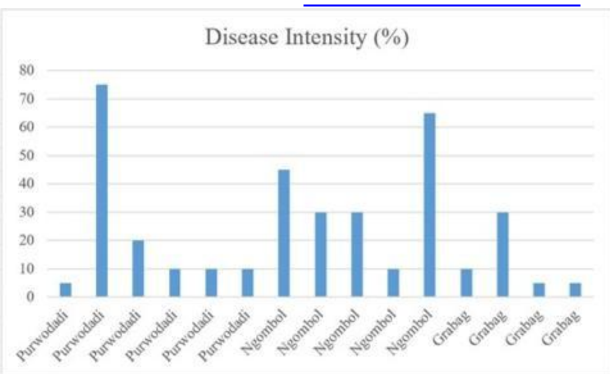

Figure 2. Severity of anthracnose disease in chilli peppers on the coast of Purworejo, Central Java, Indonesia

Pathogens have different lifestyles in terms of their host infection mechanisms. One of the lifestyles of *Colletotrichum* spp. is categorized as latent or dormant (Hyde et al., 2009). The pathogen Colletotrichum, which causes chilli anthracnose, can survive on plant debris as microsclerotia and as acervuli throughout the season (Hodiyah et al., 2024). Microsclerotia are small, black, spherical fungal survival structures. Microsclerotia are dormant structures during winter or when experiencing stress and can survive for years, germinating from root exudates (Lu et al., 2022). On the other hand, acervuli are small structures that produce conidia. Acervuli are formed from diseased plant parts and are spread under the cuticle and on the surface of the fruit. Conidia from acervuli can spread throughout the plant through rainwater splashes or irrigation water, thus influencing the spread of the disease (Kommula et al., 2017). This factor influences the severity of the disease even though the survey was conducted during the dry season.

Although the survey was conducted during the dry season, data on the severity of Chilli anthracnose disease indicate that most chilli plants in the Purworejo Coast were infected. Anthracnose disease was found in all chilli-producing areas in Bali, with an average severity of 63% and an average

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disease severity of 68%. Variations in disease severity are generally due to differences in chilli varieties, cultivation practices, climatic conditions, location, and Colletotrichum species (Khalimi et al., 2019).

3.3 *Colletotrichum* spp Isolates from the Coast of Purworejo, Central Java, Indonesia

Based on the severity of anthracnose disease, two chilli plant species are known: *Capsicum annum* and *C. frutescens*. These chilli varieties are grown in coastal areas due to their adaptability and high yield. The results of the isolation of *Colletotrichum* spp. on chilli fruit on the coast of Purworejo, Central Java, Indonesia, obtained 19 isolates with different characters. *Colletotrichum* spp. were obtained from *C. annum* and *C. frutescens* varieties with different symptoms. Wartono et al. (2023) identified the species *C. gloeosporioides* and *C. brevisporum*, Anggrahini et al. (2020) *C. scovillei*, Manda et al. (2020) *C. capsici*, and Welideniya (2019) obtained a more complex diversity of species, namely *C. fructicola*, *C. siamense*, *C. gloeosporioides*, *C. truncatum*, *C. acutatum*, *C. coccodes*, *C. queenslandicum*, and *C. simmondsii* in the *C. annum* variety. In the *C. frutescens* variety, *C. gloeosporioides* was identified (Budi et al., 2023). Mirza & Soraya (2020) identified it as *C. capsici* Sydow.

Table 1. *Colletotrichum* spp. isolates obtained from chillies with anthracnose symptoms on the coast of Purworejo Regency, Indonesia

Isolate	Host	District Location	Latitude	Longitude
PWJ L1 S2	*Capsicum annum*	Purwodadi	-7,88251967800	110,02380735100
PWJ L1 S3	*Capsicum annum*	Purwodadi	-7,88251967800	110,02380735100
PWJ L3 S1	*Capsicum annum*	Purwodadi	-7,87377100000	110,00215400000
PWJ L3 S4	*Capsicum annum*	Purwodadi	-7,87377100000	110,00215400000
PWJ L3 S6	*Capsicum annum*	Purwodadi	-7,87377100000	110,00215400000
PWJ L4 S4	*Capsicum frutescens*	Purwodadi	-7,86948700000	109,99120000000
PWJ L5 S1	*Capsicum annum*	Purwodadi	-7,86554897500	109,98195667800
PWJ L6 A S1	*Capsicum annum*	Purwodadi	-7,86219620400	109,97280766300
PWJ L6 A S2	*Capsicum annum*	Purwodadi	-7,86219620400	109,97280766300
PWJ L8 A S1	*Capsicum frutescens*	Ngombol	-7,85045958800	109,94462853700
PWJ L8 B S1	*Capsicum frutescens*	Ngombol	-7,85045958800	109,94462853700
PWJ L8 B S8	*Capsicum frutescens*	Ngombol	-7,85045958800	109,94462853700
PWJ L10 A S1	*Capsicum annum*	Ngombol	-7,84357800000	109,92656100000
PWJ L11 S1	*Capsicum frutescens*	Ngombol	-7,84296241500	109,92459365300
PWJ L11 S2	*Capsicum frutescens*	Ngombol	-7,84296241500	109,92459365300
PWJ L12 B S5	*Capsicum annum*	Grabag	-7,83654567700	109,90405718700
PWJ L13 S1	*Capsicum frutescens*	Grabag	-7,83484386100	109,89890907900
PWJ L14 A S4	*Capsicum annum*	Grabag	-7,82576112500	109,87002940900
PWJ L14 A S5	*Capsicum annum*	Grabag	-7,82576112500	109,87002940900

3.4 Morphological Characteristics

The macroscopic characteristics of each isolate show different diversity, as shown in Table 1 and Figure 3. The front colonies of the isolates appear soft like cotton, have a loose to dense texture with colors of white, grayish white, blackish white, orange, and bright yellow. The rear colonies show colors of white, brownish black, jet black, gray, and pale orange. Variations in color or pigment and texture may reflect genetic differences or differences in pigment production regulation among different Colletotrichum species. The genus Colletotrichum is capable of producing at least more than 100 secondary metabolites, including nitrogen-containing compounds, sterols, terpenes, pyrones, phenolics, and fatty acids (Kim & Shim, 2019). Riolo et al. (2023) identified metabolites such as acids,

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phenolics, pyrones, sterols, and terpenes in *Colletotrichum* spp. infected olives. These compounds affect colony color, texture, pigment production in reverse media, and the ability of pathogens to attack hosts and resist plant defenses (Kim & Shim, 2019).

In addition to secondary metabolites, *Colletotrichum* spp. produces cellulase, pectinase, protease, and laccase enzymes that function to degrade cell walls and break down plant tissues, break down host cell walls, facilitate penetration and colonization, and accelerate damage and decay of plant organs (Akinwunmi & Latunde-Dada, 2001). Different Colletotrichum species or internal strains can produce different pigment variations that have distinctive pigments that produce specific colony colors on the top (front side) or bottom (back side) of Petri dishes. The fungal genome determines pigment production, enzyme secretion, sporulation capacity, secondary metabolite production, and cell wall properties, all of which affect the appearance of colonies in culture media (da Silva et al., 2020).

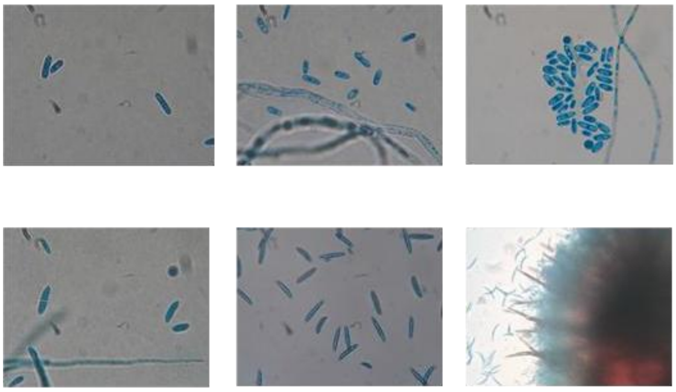

Figure 3. Microscopic characteristics of *Colletotrichum* spp on chilies from the coast of Purworejo Regency.

Colletotrichum isolated from chili peppers exhibits diverse morphological characteristics (Table 2). Morphological characteristics are highly dependent on the species and growth environment. The growth and characteristics of *C. lindemuthianum* depend on the media (Majumdar & Mandal, 2019; Nakrani et al., 2025; Rao et al., 2023) and the environment, such as temperature and pH, where it grows (Grahovac et al., 2012). Other studies have suggested that morphological differences are related to the host and the sampling location (Noireung et al., 2012).

Microscopic results (Figure 3) of *Colletotrichum* spp. isolates from chilli peppers show variation in conidia shape. Some appear fusiform or cylindrical with rounded or slightly tapered ends, while others are relatively shorter, blunt, or longer. The morphological variation of conidia found in local isolates from the southern coast of Central Java, Indonesia, indicates phytogenic diversity that directly identifies the dynamics of infection and host penetration ability. Species with slimmer conidia and higher sporulation rates, such as *C. scovillei*, generally have higher levels of aggressiveness and tissue invasion (rapid lesion expansion) compared to other species in the complex (de Silva et al., 2019). This difference indicates that conidia morphology can be an initial clue in species identification so that this study will be continued with molecular identification through DNA extraction (Mursyidin & Firnanda, 2024).

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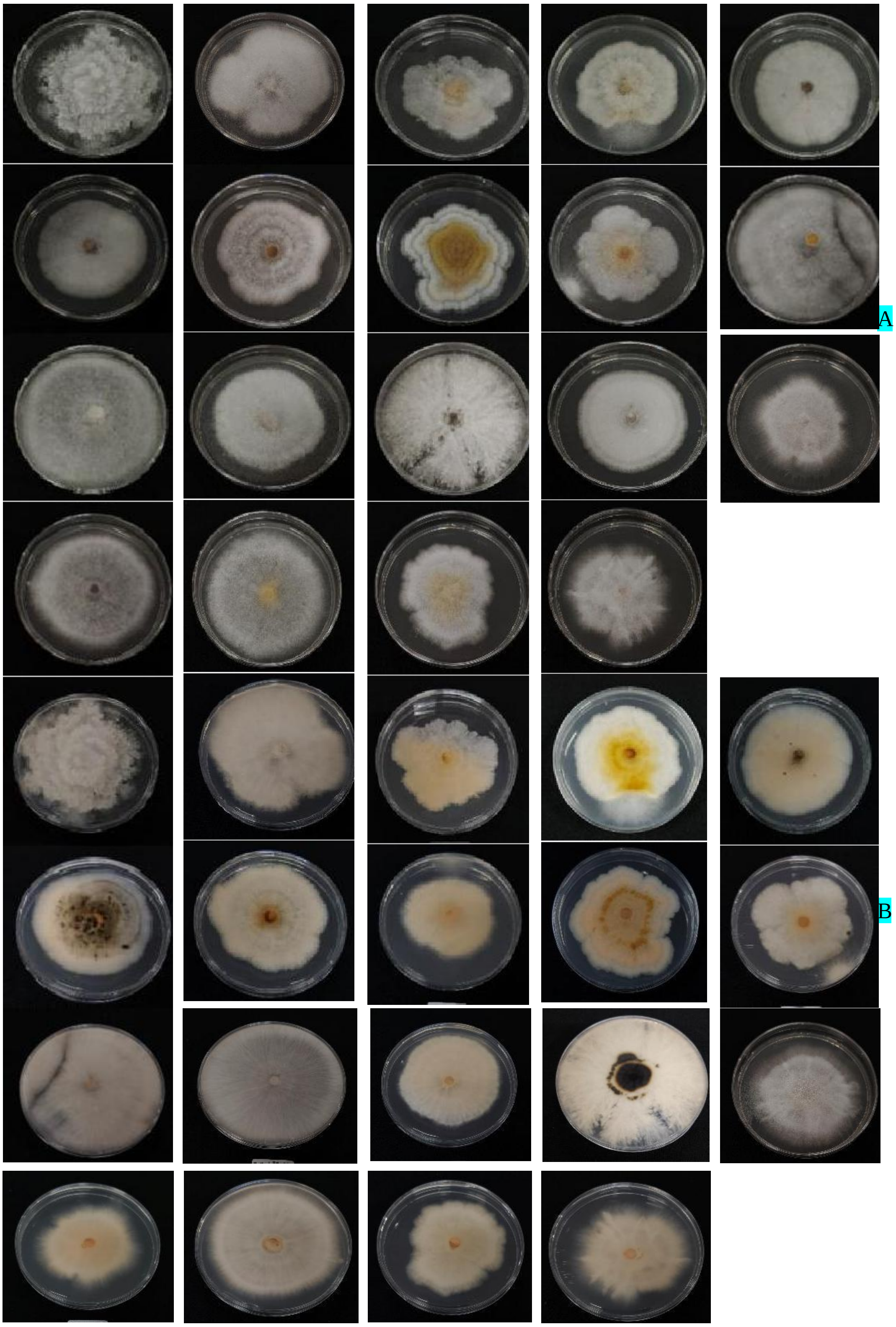

Figure 4. Appearance of 19 colonies of *Colletotrichum* spp. on PDA medium: A. front colony; B. Reverse colony: PWJL1S2, PWJL1S3, PWJL3S1, PWJL3S4, PWJL3S6, PWJL4S4, PWJ L5 S1, PWJ L6 A S1, PWJ L6 A S2, PWJ L8 A S1, PWJ L8 B S1, PWJ L8 B S8, PWJ L10 A S1, PWJ L11 S1, PWJ L11 S2, PWJ L12 B S5, PWJ L13 S1, PWJ L14 A S4, PWJ L14 A S5

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Table 2. Macroscopic and microscopic characteristics of *Colletotrichum* spp.

Isolates name	Colony texture	Front colony	Reverse colony	Conidio-mata	Shape and color of conidia
PWJL1S2	Cottony	White, circular with a slight gray center	Solid white	Present	Crescent shape with both ends pointed, transparent
PWJL1S3	Cottony	White with grey dots	White with a hint of grey	Present	Oval with blunt tip, transparent
PWJL3S1	Cottony	Pale yellow to salmon	Orange	Absent	Oval with blunt tip, transparent
PWJL3S4	Cottony	Pale white to salmon	Deep yellow	Present	Oval with blunt tip, transparent
PWJL3S6	Cottony	White with grey dots	Orange a little black	Present	Oval with blunt tip, transparent
PWJL4S4	Sparse	Grayish white	Black	Present	Oval with blunt tip, transparent
PWJL5S1	Cottony	Pale white with orange dots	Orange a little black	Absent	Fusiform with both ends blunt, transparent
PWJL6AS1	Cottony	Deep orange with white stripes	Orange	Absent	Crescent shape with both ends pointed, transparent
PWJL6AS2	Cottony	Pale yellow to salmon	Deep orange	Absent	Crescent shape with both ends pointed, transparent
PWJL8AS1	Sparse	Thin white with a hint of ash	Orange	Absent	Oval with blunt tip, transparent
PWJL8BS1	Sparse	Grayish white	White	Absent	Fusiform with both ends pointed, transparent
PWJL8BS8	Cottony	Solid white	Light gray	Present	Oval with blunt tip, transparent
PWJL10AS1	Cottony	Black and white combination	Pale orange	Absent	Oval with blunt tip, transparent
PWJ L11 S1	Cottony	Solid white with circular black lines	Black with a hint of white	Absent	Oval with blunt tip, transparent
PWJ L11 S2	Cottony	Solid white	white with a hint of gray	Absent	Fusiform with both ends blunt, transparent
PWJL12BS5	Sparse	Gray with a white tinge	Orange	Absent	Oval with blunt tip, transparent
PWJL13S1	Sparse	Gray with a white tinge	White	Absent	Fusiform with both ends blunt, transparent
PWJL14AS4	Cottony	Pale yellow	Pale yellow	Absent	Oval with blunt tip, transparent
PWJL14AS5	Cottony	Solid white	Pale orange	Absent	Oval with blunt tip, transparent

3.5 Pathogenicity Test

Pathogenicity tests showed that of the 19 isolates, 17 were found to be pathogenic with varying virulence categories, ranging from virulent to highly virulent (Table 3). Symptoms of the highly virulent isolates, namely PWJL5S1, PWJL11S2, PWJL14AS4, PWJL14AS5, and PWJL6AS1, appeared after 2 days. Colletotrichum species produce various enzymes capable of destroying structural components of plant tissue and killing plant cells. The enzymes found to destroy plant tissue structures include polygalacturonase, pectin lyase, and protease. These enzymes are capable of degrading carbohydrates, dissolving cell walls, and enzymes that hydrolyze cuticles (Wharton & Diéguez-Uribeondo, 2004).

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Table 3. Pathogenicity of *Colletotrichum* spp. isolates from the coast of Purworejo, Central Java, Indonesia

Isolate	PAL (%)		Isolate	PAL (%)		Isolate	PAL (%)	
control	0,00±0,00	o	PWJ L14 A S5	63,45±9,48	cd	PWJ L5 S2	56,22±6,55	e
PWJ L1 S2	0,00±0,00	o	PWJ L14 A S8	63,45±2,77	cd	PWJ L5 S3	57,03±7,16	e
PWJ L10 A S1	57,03±9,48	e	PWJ L14 B S1	57,83±4,46	e	PWJ L6 A 27	0,00±0,00	o
PWJ L11 S1	44,18±8,63	gh	PWJ L1S3	31,33±7,69	k	PWJ L6 A S1	63,45±6,07	cd
PWJ L11 S2	67,47±0,93	bc	PWJ L2 S1	42,57±4,78	gh	PWJ L6 A S2	40,16±4,33	hi
PWJ L11 S5	40,16±2,51	hi	PWJ L2 S3	12,05±0,35	n	PWJ L6 A S4	61,04±4,06	de
PWJ L12 A S3	39,36±3,17	hi	PWJ L2 S4	50,60±4,40	f	PWJ L6 A S7	20,08±5,03	l
PWJ L12 B S4	49,00±1,07	f	PWJ L2 S5	49,00±5,05	f	PWJ L6 B S2	61,04±2,28	de
PWJ L12 B S5	20,55±3,53	l	PWJ L2 S6	30,52±7,45	k	PWJ L8 A S1	39,36±6,78	hi
PWJ L13 S1	15,26±2,94	mn	PWJ L3 S1	58,63±2,37	e	PWJ L8 A S5	42,57±5,76	gh
PWJ L13 S2	36,14±5,67	ij	PWJ L3 S4	34,14±0,15	jk	PWJ L8 B S1	48,99±4,13	f
PWJ L13 S3	16,87±4,47	lm	PWJ L3 S6	43,37±5,14	gh	PWJ L8 B S2	46,59±8,82	fg
PWJ L14 A S1	32,93±7,97	jk	PWJ L4 S1	12,05±7,86	n	PWJ L8 B S4	73,09±4,79	a
PWJ L14 A S3	69,88±8,51	ab	PWJ L4 S4	57,03±6,45	e	PWJ L8 B S4 O	0,00±0,00	o
PWJ L14 A S4	65,86±5,39	bc	PWJ L5 S1	73,09±2,76	a	PWJ L8 B S8	0,00±0,00	o

Statistical analysis showed that 18 isolates exhibited differences in virulence compared to the control; however, isolate PWJL8BS8 was no different from the control, meaning that this isolate was not virulent in infecting chilli peppers. Based on the analysis results, the isolate with the highest virulence was PWJL5S1, with a virulence of 73.09%; however, statistically, PWJL5S1 did not differ from isolates designated by the same letter. According to Sangeeta & Devappa (2022), isolates can be grouped based on their virulence levels: infections of ≥ 40% are categorized as highly virulent, 30–40% as moderately virulent, and ≤ 30% as less virulent.

Pathogenicity is closely related to the aggressiveness of Colletotrichum isolates (de Silva et al., 2021). Species with slenderer conidia and higher sporulation rates, such as *C. scovillei*, generally exhibit higher levels of aggressiveness and tissue invasion rates (rapid lesion expansion) compared to other species (de Silva et al., 2019). The inclusion of wound inoculation is a factor influencing pathogen aggressiveness. This is in line with research results by de Silva et al. (2021) that found that most isolates were pathogenic on chilli fruit when inoculated with wounds, and were less aggressive without wounds. Anthracnose is a major disease of chilli plants that is currently difficult to control, necessitating effective control strategies. Identification of species diversity, pathogenicity, and aggressiveness is an important finding that can inform epidemiological studies to predict future disease occurrences. Further studies on its ability to survive in environmental conditions, especially in the air, are essential for developing anthracnose disease management.

4. Limitations and Future Directions

This study has limitations and shortcomings. The survey was conducted only once during a single growing season, so the data obtained are not comprehensive and cannot be linked to environmental factors in the region. Measuring damage intensity over a single growing season is necessary to determine the relationship between environmental factors, damage intensity, and other factors that influence pathogen virulence. Research should be conducted in coastal areas with similar environmental conditions that affect the intensity, spread, and diversity of the pathogen. A multi-

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season epidemiological study that integrates climate variables is needed. Since this is a long-term study, the number of pathogen species studied is limited, and molecular analysis is needed to identify the Colletotrichum pathogen species causing the infection.

5. Conclusion

Based on the results of a case study in the coastal region of Purworejo, Central Java, 19 isolates of the pathogen Colletotrichum were obtained, all with a high average virulence level; the highest virulence was found in Purwodadi Regency, at 73.09%. Variations in macroscopic and microscopic morphology indicate the presence of a diverse complex of *Colletotrichum* sp species with varying pathogenic capabilities. These findings expand our understanding of the population structure of *Colletotrichum* sp. in coastal chilli agroecosystems—a topic that remains under-researched in Indonesia—and provide a foundation for developing location-specific strategies for managing anthracnose, monitoring disease epidemics, breeding resistant varieties, and designing control programs that account for pathogen diversity in the field.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

In preparing this manuscript, the author employed artificial intelligence (AI) methodologies to facilitate language refinement and literature exploration. Subsequent to the utilization of this technological resource, the author meticulously reviewed and articulated the entirety of the manuscript as deemed necessary and assumed complete accountability for the scientific integrity, data analysis, and inferences articulated within this manuscript.

Authorship Contribution Statement

Concept: Wulansari, NK.; Design: Wulansari, NK.; Data Collection or Processing: Wulansari, NK.; Statistical Analyses: Wulansari, NK.; Literature Search: Wulansari, NK., Prihatiningsih, N., Djatmiko, HA., Mugiastuti, E.; Writing: Wulansari, NK.; Review and Editing: Prihatiningsih, N., Djatmiko, HA., Mugiastuti.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest with respect to the research, authorship, and or publication of this article.

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References

Abdila, W. P., Nugroho, B. D. A., & Setyawan, C. (2022). Effect of Extreem Rainfall Pattern on The Growth and Yield of Chili Peppers. *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, *11*(1), 117. https://doi.org/10.23960/jtep-l.v11i1.117-129

Akinwunmi, & Latunde-Dada. (2001). Pathogen profile Colletotrichum : tales of forcible entry, stealth , transient confinement and breakout. *Molecular Plant Pathology*, *2*(4), 187–198. https://doi.org/10.1046/j.1464-6722.2001.00069.x

Anggrahini, D. S., Wibowo, A., & Subandiyah, S. (2020). Morphological and Molecular Identification of *Colletotrichum* spp. Associated with Chili Anthracnose Disease in Yogyakarta Region. *Jurnal Perlindungan Tanaman Indonesia*, *24*(2), 161–174. https://doi.org/10.22146/jpti.58955

Armesto, C., Maia, F. G. M., Monteiro, F. P., & de Abreu, M. S. (2019). Exoenzymes as a pathogenicity factor for *Colletotrichum gloeosporioides* associated with coffee plants. *Summa Phytopathologica*, *45*(4), 368–373. https://doi.org/10.1590/0100-5405/191071

Avianto, D., & Handayani, I. E. (2023). Klasifikasi Penyakit Antraknosa Pada Cabai Merah Teropong ”Inko Hot” Dengan Metode Convolutional Neural Network. *SINTECH (Science and Information Technology) Journal*,

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i2.2846

6(2),76–88. https://doi.org/10.31598/sintechjournal.v6i2.1377

Budi, I. S., Mariana, & Fauziah, A. (2023). View of Resistance of cayenne pepper varieties (*Capsicum frutescens*) to anthracnose disease (*Colletotrichum gloeosporioides*) isolates from swampy areas.pdf. *Jurnal Ilmiah Pertanian*, *20*(3). https://doi.org/10.31849/jip.v20i3.16042

Connell, R. J. O., Thon, M. R., Hacquard, S., Amyotte, S. G., Kleemann, J., Torres, M. F., Damm, U., Buiate, E. A., Epstein, L., Alkan, N., Altmüller, J., Alvarado-balderrama, L., Bauser, C. A., Becker, C., Birren, B. W., Chen, Z., Choi, J., Crouch, J. A., Duvick, J. P., Vaillancourt, L. J. (2012). Lifestyle Transitions in Plant Pathogenic Colletotrichum Fungi Deciphered by Genome and Transcriptome Analyses. *Nature Publishing Group*, *44*(9). https://doi.org/10.1038/ng.2372

da Silva, L. L., Moreno, H. L. A., Correia, H. L. N., Santana, M. F., & de Queiroz, M. V. (2020). Colletotrichum: species complexes, lifestyle, and peculiarities of some sources of genetic variability. *Applied Microbiology and Biotechnology*, *104*(5), 1891–1904. https://doi.org/10.1007/s00253-020-10363-y

de Silva, D. D., Groenewald, J. Z., Crous, P. W., Ades, P. K., Nasruddin, A., Mongkolporn, O., & Taylor, P. W. J. (2019). Identification, prevalence and pathogenicity of Colletotrichum species causing anthracnose of *Capsicum annuum* in Asia. *IMA Fungus*, *10*(1), 1–32. https://doi.org/10.1186/s43008-019-0001-y

Filaila, N. F., Suryanti, S., & Widiastuti, A. (2021). Zero-Energy Cool Chamber in Anthracnose Disease Management of Postharvest Capsicum frutescens. *Jurnal Fitopatologi Indonesia*, *17*(3), 83–91. https://doi.org/10.14692/jfi.17.3.83-91

Fivintari, F. R., & Shofiyah, A. (2024). Red Chili Farming on Coastal Sand Land with Shower Irrigation System : A Review of Production Efficiency. *E3S Web of Conferences 595*, *01030*, 3–8. https://doi.org/10.1051/e3sconf/202459501030

Grahovac, M., Inđić, D., Vuković, S., Hrustć, J., Gvozdenac, S., Mihajlović, M., & Tanović, B. (2012). Morphological and ecological features as differentiation criteria for Colletotrichum species. *ŽEMDIRBYSTĖ=AGRICULTURE*, *99*(2), 189–196.

Grinn-gofroń, A., Çeter, T., Münevver, N., Bosiacka, B., & Çeter, S. (2020). Agricultural and Forest Meteorology Airborne fungal spore load and season timing in the Central and Eastern Black Sea region of Turkey explained by climate conditions and land use. *Agricultural and*

Hodiyah, I., Suryaman, M., Hartini, E., Juhaeni, A. H., Laksana, B. Y., Aisyah, & Benatar, G. V. (2024). Diversity of morphology, pathogenicity, and host range of *Colletotrichum* spp. associated with chili anthracnose in East Priangan, Indonesia. *Biodiversitas*, *25*(2), 533–541. https://doi.org/10.13057/biodiv/d250212

Hyde, K., Cai, L., McKenzie, E. H., Yang, Y., Zhang, J., & Prihastuti, H. (2009). Colletotrichum : a Catalogue of Confusion. *Fungal Diversity*, *March 2001*, 1–17.

Jensen, M. H., & Teran, M. A. (1971). Use of Controlled Environment for Vegetable Production in Desert Regions of the World. *Hort Science*, *6*(1), 33–36.

Joshi, R., Yenjerappa, S. T., Aswathanarayana, D. S., Chavan, S. S., Kisan, B., & Lakshmikant, M. (2023). Isolation and characterization of *Colletotrichum* spp. from infected chilli plant. *Biological Forum – An International Journal*, *15*(11), 469–472.

Khalimi, K., Agung, A., Darmadi, K., & Suprapta, D. N. (2019). First Report on the Prevalence of *Colletotrichum scovillei* Associated with Anthracnose on Chili Pepper in Bali , Indonesia. *International Journal Of Agricultural & Biology*, *22*, 363–368. https://doi.org/10.17957/IJAB/15.1072

Kim, H., Yoon, J., & Ju, H. (2025). Diagnosis Anthracnose of Chili Pepper Using Convolutional Neural Networks Based Deep Learning Models. *The Plant Pathology Journal*, *41*(1), 100–111. https://doi.org/10.5423/PPJ.OA.11.2024.0178

Kim, J. W., & Shim, S. H. (2019). The fungus

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i2.2846

Colletotrichum as a source for bioactive secondary metabolites. *Archives of Pharmacal Research*, *42*(53), 1–11. https://doi.org/10.1007/s12272-019-01142-z

Lu, X., Miao, J., Shen, D., & Dou, D. (2022). Proteinaceous Effector Discovery and Characterization in Plant Pathogenic Colletotrichum Fungi. *Frontiers in Microbiology*, *13*(May), 1–12. https://doi.org/10.3389/fmicb.2022.914035

M.B. Bertucci, Bilbo, T. R., Jennings, K. M., Meadows, I. M., Melanson, Rodrigues, C., Walgenbach, J. F., & Wszelaki, A. L. (2024). *Southeastern Vegetable Extension Workers* (J.M. Kemble (ed.); 1st ed.).

Majumdar, N., & Mandal, N. C. (2019). Influence of culture media on mycelial growth, sporulation and spore size of quiescent pathogen *Colletotrichum gloeosporioides* isolated from banana. *The Pharma Innovation Journal*, *8*(5), 385–390.

Manda, R. R., Pavithra, G., Addanki, V. A., & Srivastava, S. (2020). Anthracnose of *Capsicum annuum* L. (Chilli). *International Journal of Current Microbiology and Applied Sciences*, *9*(11), 749–756. https://doi.org/10.20546/ijcmas.2020.911.090

Mirza, M. A., & Soraya, R. (2020). Influence of biopesticides on growth (*Colletotrichum capsici Sydow*) Causes Antraknosa In Cayenne Pepper (*Capsicum frutescens* L .). *Jurnal Agroekoteknologi Tropika Lembab*, *2*(Nurhayati 2007), 105–110.

Mursyidin, D. H., & Firnanda, M. R. (2024). Genetic Diversity and Relationship of Native Phalaenopsis Orchids : A Case Study of Indonesian Archipelago. *Journal of Terkirdag Agricultural Faculty*, *21*(4), 844–853. https://doi.org/10.33462/jotaf.1247037

Nakrani, A. A., Fardhani, D. M., nnisa Khumaira, & Ika Afifah Nugraheni. (2025). Potensi bakteri rizosfer tanaman lamtoro sebagai agen pengendali jamur *Colletotrichum capsici* pada tanaman cabai rawit (*Capsicum frutescens*). *Prosiding Seminar Nasional Penelitian Dan Pengabdian Kepada Masyarakat*, 762–774.

Noireung, P., Phoulivong, S., Liu, F., Cai, L., Mckenzie, H. C., Chukeatirote, E., Jones, E. B. G., Bahkali, A. H., & Hyde, D. (2012). Novel Species of Colletotrichum Revealed by Morphology and Molecular Analysis Novel species of Colletotrichum revealed by morphology. *Cryptogamie, Mycologie*, *33*(3), 347–362.

Pangemanan, P. A., Kamagi, D., & Tumimomor, F. (2021). The use of Coastal Land for the Cultivation of Vegetable and Species on Small Islands in the Sub-District of Tatoareng Sangihe Regency. *International Journal of Environment, Agriculture and Biotechnology*, *6*(6), 214–218. https://doi.org/10.22161/ijeab

Rao, S. N., Bhattiprolu, S. L., & Kumari, V. P. (2023). Effect of Culture Media on Growth and Sporulation of *Colletotrichum lindemuthianum* (Sacc and Magn) Isolates Causing Anthracnose of Field Bean. *J. Res Angrau*, *51*(4), 59–70. https://doi.org/10.58537/jorangrau.2023.51.4.08

Riolo, M., Luz, C., Santilli, E., Meca, G., & Olga, S. (2023). Secondary metabolites produced by four Colletotrichum species in vitro and on fruits of diverse olive cultivars. *Fungal Biology*, *127*(7–8), 1118–1128. https://doi.org/10.1016/j.funbio.2023.06.003

Rovetto, E. I., Luz, C., Spada, F. La, Meca, G., Riolo, M., & Cacciola, S. O. (2023). Diversity of Mycotoxins and Other Secondary Metabolites Recovered from Blood Oranges Infected by Colletotrichum ,. *Toxins*, *1*(2). https://doi.org/10.3390/toxins15070407

Ruslanjari, D., Suryanto, P., & Alam, T. (2020). Optimization Management for Chilli (*Capsicum annum* L.) Production in Agroforestry Sistem With Coconut (*Cocos Nucifera* L.) on Local Protected Coastline Areas. *Indonesian Journal of Geography*, *52*(3), 397–
401. https://doi.org/10.22146/ijg.55241

Sangeeta, & Devappa. (2022). Variability and Virulence of *Colletotrichum gloeospoiroides* causing Antracnose of Mango Collected from Different Agro Climatic-zones of Karnataka. In V. D. Dinesh Singh, S. Jahangirdar, & H. R. G. and R. Aggarwal (Eds.), *Management of*

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i2.2846

Postharvest Disease and Value Addition of Horticultural Crops (1st ed., pp. 39–48). Today & Tomorrow's Printers.

Saxena, A., Raghuwanshi, R., Gupta, V. K., & Singh, H. B. (2016). Chilli anthracnose: The epidemiology and management. *Frontiers in Microbiology*, *7*(SEP), 1–18. https://doi.org/10.3389/fmicb.2016.01527

Silva, D. D. De, Ades, P. K., & Taylor, P. W. J. (2021). Pathogenicity of Colletotrichum species causing anthracnose of Capsicum in Asia. *Plant Pathology*, *January*, 875–884. https://doi.org/10.1111/ppa.13351

Suprapta, D. N. (2022). Biocontrol of Anthracnose Disease on Chili Pepper Using a Formulation Containing *Paenibacillus polymyxa* C1. *Frontiers in Sustainable Food Systems*, *5*(January), 1–7. https://doi.org/10.3389/fsufs.2021.782425

Suwannarat, S., Steinkellner, S., Songkumarn, P., & Sangchote, S. (2017). Diversity of *Colletotrichum* spp. isolated from chili pepper fruit exhibiting symptoms of anthracnose in Thailand. *Mycological Progress*, *16*(7), 677–686. https://doi.org/10.1007/s11557-017-1304-2

Wartono, Wawan, Susilowati, D., Sukamto, & Kosasih, J. (2023). *Colletotrichum* sp. Causes of Anthracnose Diseaseon Red Chilli Plants (*Capsicum annuum*) in Ciapus, Bogor, West Java. *Al-Kainiyah: Jurnal Biologi*, *16*(2.1), 81–90. https:

Welideniya, W. A. (2019). Characterization of fungal pathogens causing anthracnose in capsicum pepper (*Capsicum annuum* L.) and their seed borne nature. *Ceylon Journal of Science*, *48*(3), 261–269. https://doi.org/10.4038/cjs.v48i3.7650

Wharton, P. S., & Diéguez-Uribeondo, J. (2004). The biology of *Colletotrichum acutatum*. *Anales Del Jardin Botanico de Madrid*, *61*(1), 3–22. https://doi.org/10.3989/ajbm.2004.v61.i1.61

Widowati, I., Dhamira, A., Anggrasari, H., & Seleky, R. N. (2023). Climatic Factors and Its Effect on Chili Production: One Step Forward Combating Climate Change. *BIO Web of Conferences*, *69*, 1–7. https://doi.org/10.1051/bioconf/20236904001

Yulihastin, E., Taofiqurohman, A., Fathrio, I., Nauval, F., Andarini, D. F., Hatmaja, R. B., Fahim, A., Perdani, N. N., Satyawardhana, H., Ismail, M. F. A., Nugroho, D., Suaydhi, Sofiati, I., Avia, L. Q., & Ratnawati, H. I. (2023). Evolution of double vortices induce tropical cyclogenesis of Seroja over Flores, Indonesia. *Natural Hazards*, *117*(3), 2675–2692. https://doi.org/10.1007/s11069-023-05961-8