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A review of application of natural products as fungicides for chili

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Abstract

Anthracnose disease in chillies is a serious problem for farmers. So far, synthetic fungicides have been used as solution for the treatment of this disease. However, the side effects of synthetic fungicides to public health and environment raised awareness on alternative fungicides derived from natural resources. This paper aims to review plants that are potential as an alternative to fungicides for chili plantation, fabrication of test solutions, in vitro and in vivo fungicide test. Many plants were investigated as alternatives to plant-based fungicide. The utilization of leaves as samples including rhizomes, roots, tubers, weevils, seeds, fruit, flowers and other parts of the plant. The extract fabrication method used as a fungicide test include: maceration method, gradual fractionation method, and decoction method. The maceration method is the method most widely used to extract fungicidal active compounds from plants. Some studies that carried out in vitro tests were unable to compare with synthetic fungicides so it was not possible to determine their effectiveness for plant-based fungicide for chillies when compared to synthetic fungicides. In vitro extract of 80% alcohol and 10%/60% n-hexane of pacar cina *(Aglaia odorata* L.) leaves can be compared with the performance of propineb 0.2%. In addition, the 60% and 70% kirinyuh *(Chromolaena odorata* L.) leaf extracts were also able to match Acrobat 0.2% performance *in vitro*. Based on the in vivo test, suren *(Toona sureni* Merr) leaf extract and nut bulbs can be used as an alternative to vegetable / natural fungicides to help overcome the problem of anthracnose in chilies.

Keywords :
Chili anthracnose disease, in vitro test, in vivo test, natural fungicide

1 Introduction

One of the goals of the Sustainable development goals (SDGs) is to achieve food security and declare as sustainable agriculture. Chili is one of the food commodities whose production must be increased in order to realize food security in Indonesia. Every year, there are increased in demand for chilies which is in line with the growth in population and the development of food industry that require the chilies as raw material (Subagyono et al., 2010). In addition, there is always increase in the price of chili in particular month due to low productivity of chili harvest. The decrease in chili productivity can be caused by pests and plant diseases (Warisno Dahana, 2018). The pests attack the plants and causes chilies suffered severe damage and crop failure. The pests that can attack chili plants include: peach aphids, thrips pests, mites, fruit fly pests, and fruit borer pests. On the other hand, chili plant diseases include: anthracnose, phytophthora rot, fusarium wilt, cercospora leaf spot, bacterial wilt, yellow virus, mosaic disease (Piay et al., 2010). Therefore, control of plant pest organisms must be done in order to increase the production of chilies (Badan Pusat Statistik Republik Indonesia, 2019).

Anthracnose is a red chili plant disease caused by 2 types of fungi, namely: *Colletotrichum capsici* and *Colletotrichum gloeosporiodes*. *Colletotrichum capsisi* population is fewer than Colletotrichum gloeosporiodes. The *Colletotrichum capsica* fungus attacks ripen chilies that are reddish in color, while *Colletotrichum gloeosporiodes* which has 2 strains, namely: the R strain which only attacks ripe red chilies and the G strain which can attack all parts of the plant, including mature red chillies and those that are still unripe and green. These two types of pathogens are seed-borne diseases because they are able to survive in the seeds for a long time to form acervulus (Piay et al., 2010).

The use of chemical or synthetic pesticides is the most common control. Some examples of synthetic pesticides included: Pyraclostrobin, Azoxystrobin, Picoxystrobin, Difenoconazole, Thiophanate-methyl, Mancozeb (Gao et al., 2017), Metalaxyl-M (Esyanti et al., 2020), Orion 72 WP, Indofil Z-78 WP, Metarial 72 WP, Proven 250 EC, Folicure 5 EC, Propicon 250 EC, Fuji one 40 EC, Flowin HT, dan Winner 250EC (Naznin et al., 2016). The negative impact of usage chemical / synthetic fungicides continuously includes: 1) polluting / damaging the environment, 2) causing residues on plants thus endanger health, and 3) causing resistance on pathogens (Amelia et al., 2020). Therefore, to overcome the negative impact of usage synthetic fungicides, plant-based / natural fungicides can be used. The advantages of natural fungicides include: 1) relatively more environmentally friendly and safe for humans because they are made from natural materials that are easily biodegradable, and 2) cheaper, easy to obtained and easy to applied.

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Some plants that have the potential to be used as natural pesticides include: tembelekan/cherry pie *(Lantana camara)*, jarak tintir/coral plant *(Jatropha multifida)*, pacar cina/chinese rice *(Aglaia odorata* L.), mengkudu/noni *(Morinda citrifolia* L.), mimba/neem *(Azadirachta indica* A. Juss.), kenikir/compositae *(Cosmos caudatus Kunth.)*, sirih/betel *(Piper batle* L.), awar-awar *(Ficus septica)* and others. Basically, natural pesticides do not only come from plants, but also from bacteria, viruses, and fungi (Novizan, 2002). The purpose of this paper is to review: 1) plants that have the potential as an alternative natural fungicide for chili, 2) fabrication of solution for in vitro and in vivo test, 3) in vitro test as fungicide for chili, and 4) in vivo test as fungicide for chili.

2 Potential plants as alternative fungicide for chili

Many plants have been investigated on the potential as an alternatives to plant-based / natural fungicides for chili. Table 1 shows the names and parts of the plant and the method tested for fungicide. The part of plants that is widely used in research on finding alternative natural fungicides is the leaves. Few studies have used parts of rhizomes, roots, tubers, weevils, seeds, fruit, flowers or all parts of a plant (combination of flowers, leaves, stems, roots, and seeds). Betel leaf is a part of the plant that has been investigated both *in vitro* and *in vivo*. The researchers only used one plant type separately to determine its potential as natural fungicide. Only few researchers have combined 2 plants, for example: mixture of betel and tobacco leaf (Oktarina et al., 2017), (Anjani, 2018), (Nur Rohmah, 2017) and mixture of kenikir/compositae *(Cosmos caudatus* Kunth.) and betel (Maimunah et al., 2019).

In general, fungicide test methods used in many studies are divided into 2 categories, namely: 1) *in vitro* and 2) *in vivo*. There are researchers who only focus on using in vitro test methods or in vivo test methods. In addition, the researchers also used both test methods in combination . In the in vitro test method, many types of fungi that cause Anthracnose disease in chilies are used, for example: *Collectotrichum capsici, Colletotrichum gloesporioides* and *Colletotrichum acutacum* mushrooms. Several parameters that can be observed in the *in vitro* test include: percentage of inhibition, diameter of fungal colony growth, zone of inhibition, spore growth, spore germination and percentage of spore density. On the other hand, in the *in vivo* test more parameters can be observed which include: anthracnose disease severity, intensity of fungal attack on chilies, percentage of disease incidence, effectiveness of fungicides, diameter of chili spots, incubation period of fungi in chilies, plant height, number of fruit and the weight of the chilies. In this *in vivo* test, the success of the research is strongly influenced by environmental factors, for example: temperature, humidity and rainfall (Suwastini et al., 2020).

Table 1 Plants that have the potential as alternative fungicide for chili

Name of Plant	Scientific Name	Part of Plant	Test Method for Fungicide	Reference
Umbi Teki	*Cyperus rotundus* L.	Leaves	In vivo	(Sihite et al., 2020)
Urang Aring	*Eclipta alba* (L.) Hassk	-	In vitro	(Andreas et al., 2018)
Ketepeng Cina	*Cassia alata* Linnaeus	All parts of plant	In vitro	(Arneti & Sulyanti, 2017)
Forest Betel	*Piper aduncum* L.	Leaves	In vitro and In vivo	(Elfina, 2015)
Fragrant Lemongrass	*Cymbopogon nardus* L.	Leaves	In vitro and In vivo	(Elfina et al., 2016)
Tobacco	*Nicotiana tabacum* L.	Leaves	In vitro	(Isman Duila, 2017)
Mixture of Betel and Tobacco	*Piper betle* L. dan *Nicotina tobacum*	Leaves	In vitro and In vivo	(Oktarina et al., 2017)
Kunyit Temu Putih Temu Hitam	*Curcuma longa sensu* Val *Curcuma zedoaria* (Berg.) Roscoe *Curcuma aeruginosa* Roxb	Rhizome	In vitro and In vivo	(Sari et al., 2020a)
Putri Malu	*Mimosa pudica* L.	Root	In vitro and In vivo	(Septianing Ratri, 2017)
Soursop	-	Leaves	In vivo	(Zulkipli et al., 2018)
Betel	-	Leaves	In vivo	(Zulkipli et al., 2018)
Papaya	-	Leaves	In vivo	(Zulkipli et al., 2018)
Garlic	-	Tubers	In vivo	(Zulkipli et al., 2018)
Jarak Tintir	*Jatropha multifida*	Leaves	In vivo	(Suwastini et al., 2020)
Tembelekan	*Lantana camara* H. suaveolens (L.) Poit	Leaves	In vitro	(Chatri & Mansyurdin, 2015)
- Karamunting Purun Tikus Kirinyuh	 *Melastoma malabathricum* L. *Eleoharis dulcis* *Chromolaena odorata* L	 Leaves	 In vitro and In vivo	 (Suyanti et al., 2020)
Noni	*Morinda citrifolia*	Leaves	In vivo	(Marsuni, 2020)
Betel	*Piper batle* L.	Leaves	In vivo	(Juniar Dwi Cahya, 2019)
Tagetes	*Tagetes erecta*	Leaves	In vitro	(Satryawibowo et al., 2015)
Suren	*Toona sureni* Merr.	Leaves	In vivo	(Andriyani et al., 2020)
			In vitro	(Andriyani & Purwantisari, 2019)
Betel	*Piper betle*	Leaves	In vitro and In vivo	(Trisnawati, D., Nugroho, L. P. E., 2019)

Fragrant Lemongrass	*Cymbopogon nardus* L.	Leaves	In vitro and In vivo	(Syabana et al., 2015)
Papaya	*Carica papaya* Linnaeus	Leaves	In vitro	(Liswarni & Edriwilya, 2020)
Pacar Cina	*Aglaia odorata* L.	Leaves	In vitro and In vivo	(Efri et al., 2017)
Neem	*Azadirachta indica* A.	Juss	Leaves In vivo	(Aziziy et al., 2020)
Kepok Banana	-	Hump		
Noni	*Morinda citrifolia* L.	Leaves	In vitro	(Anggreini et al., 2016)
Neem	*Azadirachta indica* A. Juss.			
Kenikir	*Cosmos caudatus* Kunth.	Leaves	In vitro and In vivo	(Amelia et al., 2020)
Babadotan	*Ageratum conyzoides*	Leaves	In vitro	(Wulandari et al., 2015)
Awar-awar	*Ficus septica*	Leaves	In vitro and In vivo	(Sudirga, 2018)
Mixture of Betel and Tobacco	*Piper betle* L. dan *Nicotina tobacum*	Leaves	In vitro and In vivo	(Anjani, 2018)
Gelinggang	*Cassia alata* L.	Leaves	In vivo	(Supriati et al., 2016)
Jarak Pagar	*Jatropha curcas* L.	Seed	In vitro and In vivo	(Lestari et al., 2020)
Mixture of Betel and Tobacco	*Piper betle* L. dan *Nicotiana tabaccum* L.	Leaves	In vitro and In vivo	(Nur Rohmah, 2017)
Binahong	*Anredera cordifolia*	Leaves	In vitro and In vivo	(Yulia et al., 2019)
Neem	*Azadirachta indica* A. Juss.	Leaves	In vitro and In vivo	(Ali et al., 2012)
Noni	*Morinda citrifolia* L.	Fruits	In vitro and In vivo	(Ali et al., 2013)
Betel	*Piper betle* L	Leaves	In vivo	(Damiri, 2011)
Noni	*M. citrifolia*	Fruits	In vitro	(Septiana et al., 2013)
Betel	*Piper betle* L.	Leaves	In vitro	(Ningtyas et al., 2013)
Babadotan	*Ageratum conyzoide*			
Noni	*Morinda citrifolia*	Leaves, Flowers, and Fruits	In vivo	(Efri, 2010)
Jarak	*Jatropha curcas* L.	Leaves	In vivo	(Wanda et al., 2014)
Mimba	Azadirachta indica			
Betel	*Piper betle* L.	Leaves	In vivo	(Wati et al., 2014)
Babadotan	*Ageratum conyzoides* L.			
Babadotan	*A. conyzoides*	-	In vivo	(Gusmarini et al., 2014)
Siam	*C. odorata*	-		
Reed	*I. cylindrica*	-		
Teki	*C. rotundus*	-		
Camplong	*Callophyllum inophyllum*	Fruits	In vitro	(Sholehah, 2012)
Patchouli Oil	-	-	In vitro and In vivo	(Sakerebau & Wahyu, 2013)
Ubi Ungu	*Ipomoea batatas*	Leaves	In vitro and In vivo	(Saputri & Utami, 2020)
Mixture of Kenikir and Betel	*Cosmos caudatus* dan *Piper betle*	Leaves	In vitro	(Maimunah et al., 2019)
Putri Malu	*Mimosa pudica*	Leaves	In vivo	(Eviyanti, 2020)
Kirinyuh	*Euphatorium odoratum* L.	Leaves	In vitro and In vivo	(Indrawati, 2021)
Cinnamon	*Cinnamomum burmannii*	Leaves	In vitro	(Darmadi et al., 2021)
Neem	*Azardiachta indica*	Leaves	In vitro	(Rahman et al., 2019)
Garlic	*Allium sativum*	Rhizome	In vitro	(Rahman et al., 2019)
Zinger	*Zingiber officinale* Rhizome			
Termaric	*Curcuma longa*	Rhizome		
Tulsi	*Oscimum sanctum* Linn.	Leaves		
Mahogoni	*Swietenia mahogoni*	Leaves		
Mehendi	Leaves			

Table 2 Methods of extract preparation for *in vitro* and *in vivo* test

Plant	Method	Solvent	Sample : Solvent (w/v)	Result	Reference
Binahong Leaf	Maceration for 1 x 24 hours then concentrated using rotary evaporator	90% methanol	1 : 4	Sticky	(Yulia et al., 2019)
Banana Hump and Mimba Leaf	The sample was sieved with size of 25 mesh and macerated separately for 1 x 24 hours then concentrated with rotary evaporator to 250 mL	100% methanol	6 : 10	Condensed extract	(Tobing & Mulyaningsih, 2020)
Jarak Pagar Seed	Maceration for 48 hours then concentrated with rotary evaporator	96% ethanol	1 : 3 and 1 : 2	-	(Lestari et al., 2020)
Mixture of Betel and Tobacco Leaf	The sample was separately dried and then crushed by adding distilled water and then filtered	Distilled water	1 : 1	-	(Oktarina et al., 2017)
Leaf of Pasang Surut Weeds	Leaf powder is macerated for 2 x 24 hours then concentrated with rotary evaporator at a temperature of 40 - 70 °C and followed by evaporation process with water bath at temperature of 50 - 60 °C	96% ethanol	1 : 4	-	(Suyanti et al., 2020)
Awar Awar Leaf	Maceration for 72 hours then evaporated with rotary evaporator	Methanol	1 : 10	-	(Sudirga, 2018)
Babadotan Leaf	Graded fractionation	Water, methanol, ethyl acetate, and n-hexane	1 : 10	-	(Wulandari et al., 2015)
Noni Leaves and Fruit	Maceration for 3 x 24 hours then concentrated with rotary evaporator and waterbath at temperature of 60 °C	Methanol	1 : 3	Condensed extract	(Nurul et al., 2020)
Kenikir Leaf	Maceration for 2 x 24 hours: the first soaking for 6 hours, then stirring it then leaving it for 18 hours then concentrating it with rotary evaporator and then concentrating again with a waterbath at temperature of 40 °C	96% ethanol	1 : 3 and 1 : 2	-	(Amelia et al., 2020)
Noni and neem leaf	Using simple fractionation tool	Water	1 : 5	-	(Anggreini et al., 2016)
Pacar Cina Leaf Graded fractionation Distilled water, alcohol, and n-hexane - - (Efri et al., 2017)	The sample was added with sterile distilled water, blended until smooth and put in sterile erlenmeyer and covered with aluminum foil. extract was heated until boilling and then filtered	Distilled water	1 : 20	-	(Arneti & Sulyanti, 2017)
Ketepeng Cina Fragrant Lemongrass Leaf	The sample was heated in water at 90 °C for 30 minutes then concentrated on rotary evaporator	Water	-	Concentrated extract	(Syabana et al., 2015)
Suren Leaf	Maceration for 1x24 hours then concentrated with rotary evaporator	70% ethanol	1 : 3	Pure extract	(Andriyani & Purwantisari, 2019)
Tagetes Leaf	Using simple fractionation tool	Water, methanol, ethyl acetate, and n-hexane	-	-	(Satryawibowo, 2015)
Putri Malu Root	The maceration and then evaporated with rotary evaporator	Ethanol	9 : 10	Condensed extract	(Eviyanti, 2020)
Jarak Tintir and Tembelekan	The sample was separately extracted using simple fractionation tool and then evaporated with rotary evaporator	Water	1 : 5	Dry extract	(Suwastini et al., 2020)
Neem, Betel, and Clove Leaf	Maceration for 3 days and stirring 3 times a day then concentrated with rotary evaporator	96% ethanol	1 : 5	Concentrated extract	(Sitompul, 2017)

Curcuma spp. Rhizome	Maceration	Methanol	-	Condensed extract	(Sari et al., 2020b)
Urang aring	Maceration for 3 x 24 hours then evaporated with rotary evaporator at temperature of 40 °C	Ethanol	1 : 4	Concentrated extract	(Andreas et al., 2018)
Shallot and Garlic	Extraction and then extracted in centrifuge and filtered	Distilled water	1 : 1	Crude extract	(Sittisart et al., 2017)
Carica papaya L. Cv. Leaf and Maradol Seed	Maceration for 24 hours then the extract was filtered and centrifuged then evaporated with rotary evaporator	Ethanol	1 : 8, 1 : 10, 1 : 12	-	(Chávez-Quintal et al., 2011)
Noni Leaf	Using multilevel extraction	Water, alcohol, ethyl acetate	1 : 5	Dry extract	(Putra, 2017)
Galangal Rhizome, Clove Leaf, and Bangun Bangun	Maceration extraction for 24 hours then evaporated by rotary evaporator	95% ethanol	-	Condensed extract	(Harianto, 2018)

3 Preparation of extract

The preparation of test solutions for chilies fungicide was summarized in Table 2. In general, the method of extracts preparation used can be classified into 3 types, namely: 1) maceration method, 2) graded fractionation method, and 3) decoction method.

3.1 Maceration method

This method are most widely used to extract active compounds from certain plants for fungicide. Plants were prepared in the powder or flour form are added with a solvent and then are soaked for a designated time. The filtrate is separated from the dregs and the maceration process can be continued with new solvent until color filtrate is clear. The filtrate is concentrated using rotary evaporator with temperature control according to the type of solvent used until concentrated extract is free solvent (K Ngibad, 2019), (Khoirul Ngibad, 2019), (Wibowo et al., 2019). The solvents used in the extract preparation for test fungicide on chilies, including: water solvent (ultrapure water) and organic solvents (90% methanol, methanol, 70% ethanol, 96% ethanol, ethanol, ethyl acetate, and n-hexane). The usage of solvents in the maceration process is expected to be able to extract the large fraction of possible fungicidal active compounds. In addition, there are differences in the ratio of sample weight and volume of solvent used between researchers, ranging from 1: 1 to 1: 10. The greater the ratio of solvent volume and sample weight will maximize the extract or active fungicidal compound produced. However, it is necessary to pay attention to the effectiveness of usage the solvent volume.

3.2 Stratified fractionation method

Practices of the graded fractionation method have been carried out, for example: the fine powder of Chinese henna leaves was fractionated in stages using filter made of various sizes of paralon to form funnel containing activated charcoal as filter and adsorption of nonpolar compounds. The liquid-liquid solvent extraction method used cold distilled water. Then, it was followed by solution of alcohol or n-hexane with concentrations of 10, 20, 30, 40, 50, 60, 70, 80, and 90%, respectively (Efri et al., 2017). Then, babadotan/goatweed *(Ageratum conyzoide)* leaf powder was placed into simple fractionation tool, then the filtered residue was collected and air-dried. The filtrate or crude extract was added with methanol solvent then was collected and air-dried to obtain the methanol fraction of the babadotan leaf extract. In the same way, to get ethyl acetate and n-hexane extract (Wulandari et al., 2015). The water solvent is expected to be able to extract the active polar fungicide compound which is polar. Decreasing the level of polarity starting from methanol, ethyl acetate, and n-hexane solvents is expected to be able to separate the active fungicide compounds based on their polarity level.

3.3 Decoction method

Decoction method has been used to extract the fungicidal active compounds found in betel leaf. Samples were boiled in water with ratio of 1: 1 for 1 hour. The extract are filtered and sterilized using autoclave at temperature of 121 °C to obtain sterile betel leaf extract (Trisnawati et al., 2019). The boiling process of the Cassia alata Linnaeus sample which was blended with water was carried out for 15 minutes (Arneti Sulyanti, 2017). This decoction method is rarely used because it is feared that the active fungicidal compounds present in the sample could be damaged by heat treatment.

4 In vitro test as fungicide for chili

The review results of research related to in vitro fungicide test are summarized in Table 3. The concentration of the test solution was carried out in various ways. For example, the concentration of mixture of betel leaf and tobacco extract with concentration of 30% was made by mixing 7 ml of PDA (Potato Dextrosa Agar) and 3 ml of mixture of betel and tobacco extracts (Nur Rohmah, 2017). Another technique was found in preparation of kenikir leaf extract test solution which is done by mixing the extract with Tween 80 as emulsifier with ratio of 1: 1 (w / v) and diluted using sterile distilled water to get concentration of 5%, 10%, 15%, and 20% (Amelia et al., 2020). In other cases, the suren concentrated extract was assumed to be 100% concentration then the concentrated extract was diluted using distilled water into several concentrations (25%, 50%, and 75%) (Andriyani et al., 2020). Besides water, methanol was also used as solvent to make test solution for the Curcuma sp. rhizome with concentration of 4-12 ppm (Sari et al., 2020b).

The synthetic fungicide control used by several researchers in in vitro tests included: propineb 70%, 0.2% propineb, azoxistrobin, diphenoconazole, benomyl, anthracol, 0.2% acrobat and 0.2% carbendazim. The usage of synthetic fungicide controls is very useful as comparison against the plants being studied. Many studies do not use synthetic fungicide controls so that the potential of these plants is less known when compared to synthetic fungicide controls. On the other hand, the most widely used fungi for in vitro tests are Colletotrichum capsici and then Colletotrichum gloeosporioides.

Table 3 *In vitro* fungicide test on chili test

Plant	Concentration Test Solution	Synthetic Fungicide Control	Type of Mushroom	Test Results	Reference
Jarak Pagar Seed	10 - 40%	-	Collectotrichum capsici	The percentage of inhibition of fungal mycelium (%): 18.90 – 31.08	(Lestari et al., 2020)
Betel and Tobacco	30% with concentration ratio (1: 1), (1: 2), (2: 1), (1: 3) (3: 1)	-	Colletotrichum sp	Percentage of Colletotrichum sp colony inhibition (%): 0.56 - 30.44	(Nur Rohmah, 2017)
Betel and Tobacco	30% with ratio of 3: 1	-	Colletotrichum sp	Average of inhibition power (%): 45.08 - 15.68 Average of spore density (106spores / mL): 15.8 - 35.2	(Anjani, 2018)
Babadotan Seed	-	Propineb 70% 1 g/L	Colletotrichum capsici	**Colony diameter of C. capsici** Water extract: 99.28% Methanol extract: 76.81% Ethyl acetate extract: 137.20% N-hexane extract: 85.27% Propineb 70%: 0% **Number of spores** Extract water: 5.33×10^6 Methanol extract: 2.34×10^6 Ethyl acetate extract: 7.78×10^6 N-hexane extract: 4.90×10^6 70% propineb: 0.00×10^6	(Wulandari et al., 2015)
Noni Leaves and Fruit	5%	-	Colletotrichum capsici	Percentage of inhibition (%) Leaves: 2.27 Fruits: 2.78 Amount of conidium (conidium/mL) Leaves: 1.44 Fruits: 1.42	(Nurul et al., 2020)
Kenikir Leaf	5 – 20%	-	Colletotrichum sp	Percentage of inhibition (%) : 10.76 – 41.12	(Amelia et al., 2020)
Pacar Cina Leaf	Aquades extract and 10 - 90% alcohol extract	Propineb 0,2%	Colletotrichum capsici	Growth diameter of C. capsici on day 7 (cm): 5.85 - 1.00 Spore density of C. capsici: 15.77 - 0.88	(Efri et al., 2017)
	Aquades extract and 10 - 90% n-hexane extract		Colletotrichum capsici	Growth diameter of C. capsici on day 7 (cm): 2.16 - 0.5 Spore density of C. capsici: 4.8 – 0	
Papaya Leaf	1 – 5 %	-	Colletotrichum gloesporioides	Colony area and effectiveness: 41.32 - 20.11 and 6.13% - 64.04% Mushroom wet weight: 4.69 - 45.16% Mushroom dry weight: 8.33 - 54.16% Number of conidia: 27.5 - 82.5%	(Arneti & Sulyanti, 2017)
Suren Leaf	10 – 30%	-	Colletotrichum capsici	Percentage of inhibition of C. capsici colony diameter: 45.49 - 62.74	(Andriyani & Purwantisari, 2019)
Tagetes Leaf	Water, methanol, ethyl acetate, and n – hexane extracts)	Propineb 70%	Colletotrichum capsici	Percentage of colony diameter: 55.18 - 92.47% Percentage of Spore density: 7.20 - 36.88	(Satryawibowo, 2015)
Pasang Surut Weeds	Extract of purun tikus, extract of kirinyuh, and extract of karamunting	Azoxistrobin, difenoconazole, and benomyl	Colletotrichum sp	The percentage of inhibition: 6.99 - 79.54	(Suyanti et al., 2020)
Essential oil (Hyptis suaveolens L)	Young leaves 0.5 – 2.5% Mature leaves 0.5 - 2.5%)	-	Colletotricuhm gloeosporoides	Percentage of inhibition (%): 50 - 65	(Chatri & Mansyurdin, 2015)
Putri Malu	30 – 90%	-	Colletotrichum sp	Percentage of inhibitory power (%): 14.36 - 28.01 The average of spore density (10^6 spores / ml): 19.11 - 4.44	(Septianing Ratri, 2017)
Curcuma spp	4 – 12 ppm	-	Colletotrichum capsici	The average of colony growth diameter (cm): 1.50 - 0.58	(Sari et al., 2020b)

Betel and Tobacco Leaf	Biorational extract: (1:1), (1:2), (2:1), (1:3), (3:1)	-	Colletotrichum capsici	Percentage of inhibition of fungal colonies (%): 0.56 - 30.44 Average of spore density (10^6 spores/ ml): 31.9 - 7.6	(Oktarina et al., 2017)
Tobacco	25 – 100%	-	Colletotrichum sp	Percentage of inhibition (%): 6.56 - 33.78 Average of spore density (10^6spores / ml): 19.57 - 100	(Isman Duila, 2017)
Flour of fragrant lemongrass	50 – 250 g/l	-	Colletotrichum capsici	Percentage of inhibitory power (%): 17.47 - 34.43	(Elfina et al., 2016)
Ketepeng Cina	5%	-	Colletotrichum gloeosporioides	Percentage of inhibitory power (%) Root: 11.96 Seeds: 17.21 Interest: 30.68 Young leaves: 38.40 Stems: 56.37 Old leaves: 64.30	(Arneti & Sulyanti, 2017)
Urang Aring	5 - 25%	Antracol	Colletotrichum sp	Number of mushroom colonies on day 7: 125.75 - 72.75 Diameter of mushroom colonies on day 7: (1.254 - 1.38)	(Andreas et al., 2018)
Banana Hump and Mimba Leaf	15 – 45%	-	Colletotrichum capsici	Percentage of inhibition zone for fungal colonies: 10.76 - 6.58	(Tobing & Mulyaningsih, 2020)
Cinamon leaf Extract	0,5 - 1,50%	-	Colletotrichum capsici	Percentage of inhibition (%): 17 - 100% Percentage of spore density (%): 51 100	(Darmadi et al., 2021)
Leaf Extract of Ficus septica	1 – 5%	-	Colletotrichum acutacum	Colony diameter (mm): 29.72 - 81.39 Percentage of spore density (10^5spora / ml): 63.21 - 99.11 Percentage of spore density (10^5 spora / ml): 63.21 - 99.11	(Sudirga et al., 2014)
Kirinyuh Leaf Extract	10 – 70%	Acrobat 0,2%	Colletotrichum capsici	Average percentage of fungal colony growth (%): 100.00 - 0.00 Fungal inhibition zone on day 10: 1.59 - 1.10	(Indrawati, 2021)
Mansoa alliacea Extract	1 – 5%	-	Colletotrichum acutacum	Colony diameter (mm): 63.25 - 17.00 Spore growth (10^5 spores / mL): 4.19 - 0 Spore germination (10^5 spores / mL): 2.59 - 0	(Sudirga et al., 2019)
Akar Putri Malu	25 - 100%	-	Colletotrichum sp	Percentage of inhibition zone diameter (%): (70 - 10)	(Eviyanti, 2020)
Neem Seed Kernel Extract	Neem oil, garlic bulb extract, combinate application of neem, garlic, ginger, onion plant extract, and neem sed kernel extract (NSKE)	Carbendazim 0,2%	Colletotrichum capsici	Percentage of inhibition: 74.77-68.75	(Musakhan & Zacharia, 2017)
Purple Sweet Potato	5 – 40%	-	Fusarium sp	Average percentage of inhibitory power (%): 56.7 - 76.6	(Saputri & Utami, 2020)

Some of the parameters used in the in vitro test include: colony diameter, percentage of colony inhibition, density / number of spores, and colony area. Colony diameter is measured by making vertical and horizontal lines perpendicular to each other at the bottom of the petri dish as vertical and horizontal diameters. Then, the colony diameter is calculated using formula (Andreas et al., 2018) :

$$Colonydiameter(cm) = (D1 + D2)/2 \quad (1)$$

With :

D1 = diameter of horizontal colony
D2 = diameter of vertical colony

Observations are made by measuring the diameter of the growth of C. capsici colonies. The measurement of inhibition using the formula:

$$DH(\%) = (a-b)/ax100\% \quad (2)$$

With :
DH = Inhibition (percent)
a = diameter of C. capsici colony (mm) (negative control)
b = diameter of C. capsici colony (mm) (treatment)

Spore density was determined by taking 1 ml of spore suspension from isolate propagation treatment. Furthermore, the spore density was calculated using hemocytometer that had been dropped by the suspension under a double lens (binocular), which is one type of lens from a light microscope with a magnification of 400 times. (Herlinda et al., 2006). The spore density was calculated using Gabriel Riyatno formula (1989) (Gabriel Riyanto, 1989):

$$C = \frac{t}{nx0,25} X10^6 \quad (3)$$

With:
C = spore density per ml of solution
t = total number of spores in the sample box observed
n = number of sample boxes (5 large x 16 small boxes)
0.25 = correction factor for the use of a small-scale sample box on the haemacytometer

Colony area was measured using millimeter plotting paper by depicting the colony area on plastic glass (Liswarni Edriwilya, 2020). The plants studied as an alternative to natural fungicides for chili have the ability to inhibit the growth of anthrax-causing fungi in chilies by in vitro study, which include: Colletotrichum capsici, Colletotrichum gloeosporioides, and Colletotrichum acutacum. However, many in vitro studies do not compare with synthetic fungicides. So, it is not possible to know the effectiveness of the performance of natural fungicides for chilies when compared to synthetic fungicides. Based on Table 4, it can be seen that 80% alcohol extract and 10% n-hexane extract and 60% Chinese henna leaves is similar with the 0.2% propineb performance by in vitro study. In addition, the 60% and 70% kirinyuh leaf extracts were also able to match 0.2% acrobat performance by in vitro study.

Table 4 Comparison of effectiveness of natural fungicides for chilies with synthetic fungicides

Plants	Synthetic Fungicides	Explanation	Reference
Babadotan Leaf	70% Propineb	The effectiveness of the three extract fractions < propineb 70%	(Wulandari et al., 2015)
Pacar Cina Leaf	0.% Propineb	The effectiveness of 80% alcohol extract and 10% and 60% n-hexane extract is is comparable to 0.2% propineb	(Efri et al., 2017)
Tagetes Leaf	70% Propineb	Cannot match the effect of 70% propineb	(Satryawibowo, 2015)
Urang Aring	Antracol	Effectiveness of urang-aring < Antracol	(Andreas et al., 2018)
Kirinyuh Leaf Extract	0.2% Acrobat	The effectiveness of 60% and 70% kirinyuh leaf extract is is comparable to 0.2% acrobat	(Indrawati, 2021)
Neem Seed Kernel Extract	0.2% Carbendazim	The effectiveness of neem seed kernel extract < 0.2% carbendazim	(Musakhan & Zacharia, 2017)

5 In vivo test as fungicide for chili

In effort to find alternatives natural fungicides, the researchers focused not only on in vitro studies but also in vivo studies of various plants with certain concentrations as shown in **Table 5**. This in vivo test was directly applied to chili plants to be treated with natural fungicides with test conditions appropriate to the actual environment in chili farm.

Table 5 In vivo fungicide test for chili

Plants	Concentration of Test Solution	Synthetic Fungicide	Test Parameters	Test Results	Reference
Neem Leaf Extract	5 – 20%	-	Incubation period	9 – 12 days	(Sitompul, 2017)
Betel Leaf Extract	Incubation period	12 – 19 days	The severity of anthracnose (Sitompul, 2017)	8.84 – 8.43%	
			The severity of anthracnose	8.88 – 7.74%	
Clove Leaf	Extract		Incubation period	14 – 14.33 days	(Sitompul, 2017)
Putri Malu Root Extract	30 – 90%	-	Percentage of disease incidence	62.5 – 0%	(Eviyanti, 2018)
			Spot diameter	0 mm	
			Incubation period	12 days	
Suren Leaf Extract	25 – 100%	Mankozeb 1g/L	Percentage and fresh weight of healthy cayenne pepper affected by anthracnose	91.16 – 99.68%	(Andriyani et al., 2020)
			Morphometry of chili fruit	Length: 7.74 – 8.54 cm	

				Diameter : 1.14 – 1.48 cm	
			Chili plant height	122.8 – 131.6 cm	
			The severity of anthracnose	4 – 0%	
Extract of Umbi Teki	5 – 25%	Propineb	The severity of anthracnose	13.00 – 17.50%	(Sihite et al., 2020)
			Plant height	37.56 – 34.18 cm	
			Number of fruit	7.5 – 3.2 fruit	
			Fruit weight	6.2 – 3.8 gram	
Extract of Curcuma Longa Sensu	4 – 12 ppm	-	Symptoms of anthracnose in red chili	0.67 – 0.00 cm	(Sari et al., 2020b)
			Mycelium dry weight	80.53 – 0.00 mg	
Extract of Curcuma aeroginosa			Symptoms of anthracnose in red chili	0.88 – 0.00 cm	
			Mycelium dry weight	0.00 mg	
Extract of Curcuma zedoaria			Symptoms of anthracnose in red chilies	0.78 – 0.00 cm	
	Mycelium dry weight	69.00 – 0.00 mg			
Citronella Leaf Extract	50 – 250 g/L	-	When the early symptoms of anthracnose disease appear in red chilies	2.48 – 2.00 days	(Elfina et al., 2016)
			The intensity of the attack to C. capsici	19 - 20	
			Effectiveness and level of fungicidal ability	-11,76 until 17,65%	
Awar-Awar Leaf Extract	1 – 5%	-	Percentage of incidence of anthracnose in red chilies	41.00 – 0%	(Sudirga, 2016)
			Percentage of incidence of anthracnose in red chilies	41.00 – 0%	
			Disease intensity	38.21 – 0%	
			Yield / amount of red chilies (kg / plant)	0.163 – 0.587	
			Losing the salvaged yield of red chilies	59.51 – 88.76%	
Betel and Tobacco Leaf Extract	(1:2), (1:2), (2:1), (1:3), (3:1)	-	Anthracnose incidence rate	25 – 75%	(Oktarina et al., 2017)
			The incubation period for anthracnose	4 – 9 days	
Betel Extract	200 – 600 mL/L	-	Number of fruits / plants	33 – 36 fruits	(Juniar Dwi Cahya, 2019)
			Number of fruit / plot	75 – 76 fruitd	
			Fruit weight / plant	362.23 – 387.21 gram	
			Fruit weight / plot	757.80 – 777.93 gram	
			Number of healthy fruit / plant	21 – 24 fruits	
			Number of damaged fruit / plants	8 – 5 fruits	
			Percentage of healthy fruit / plot	88.15 – 97.46%	
			Percentage of damaged fruit / plot	12.24 – 2.56%	
			The intensity of the plant attacked	3.06 – 1.25%	
Extract of Putri Malu	30 – 90%	-	Incidence of anthracnose in red chilies	62.5 – 0%	(Eviyanti, 2018)
			Incubation period	6 – 12 days	
			Spot diameter	6.8 – 0 mm	
Betel Leaf Extract	-	-	Incidence of anthracnose in chilies	43 – 15%	(Trisnawati et al., 2019)
Neem Leaf Extract	15% - 45%	-	Average height of chili plants	25.41 – 22.79 cm	(Tobing & Mulyaningsih, 2020)

			Average width of fungal spots	25.02 – 22.80 cm	
			Interaction of average of plant leaf area	33.17 – 33.03 cm2	
			Average weight of chilies	5.97 – 4.89 gram	
			Interaction of the main branches of the chili plant	36.67 – 52.22%	
			Dry weight of chilies	20.79 – 15.07 gram	
			Wet weight of chilies	20.53 – 26.74 gram	
			The average of root wet weight	3.58 – 4.99 gram	
			The average of root dry weight	0.36 – 0.49 gram	
			Disease incidence in chilies	20.3 – 0.00%	
			The average of incidence of pest infestation	0.52 – 2.85%	
Banana Weevil Extract	15 - 45%	-	Average height of chili plants	23.57 – 25.49 cm	(Tobing & Mulyaningsih, 2020)
			Average width of fungal spots	24.58 – 23.50 cm	
			Interaction average leaf area of plants	28.99 – 40.21 cm^2	
			Average weight of chilies	5.42 – 5.83 gram	
			Interaction of the main branches of the chili plant	43.00 – 59.11%	
			Dry weight of chilies 22.17 –	19.63 gram	
			Wet weight of chilies 26.81 –	22.86 gram	
			The average weight of the wet roots	3.98 – 4.44 gram	
			The average dry weight of the roots	0.39 – 0.45 gram	
			Disease incidence in chilies	1.31 – 4.17%	
			The average incidence of pest infestation	2.94 – 1.17%	
Neem Leaf Extract	15 – 45%	-	Height of red chili plant	16.39 – 17.26 cm	(Aziziy et al., 2020)
			Number of red chili leaves	18.47 – 18.89 leaves	
			Number of productive branches	5.11 – 5.33	
			Fruit weight / pPlant	46.95 – 50.03 gram	
			Number of pieces / plant	12.83 – 13.83 fruits	
			Fruit length	10.63 – 10.37 cm	
			Fruit diameter	1.10 – 1.12 cm	
Banana Weevil Mole Extract	15 – 45%	-	Height of red chili plant	16.30 – 17.65 cm	(Aziziy et al., 2020)
			Number of red chili leaves	18.64 – 19.22 leaves	
			Number of productive branches	5.06 – 5.28	
			Fruit weight / plant 44.08 –	53.20 gram	
			Number of pieces / plant	12.19 – 13.89 fruits	
			Fruit length	10.37 – 10.62 cm	
			Fruit diameter	1.11 – 1.12 cm	
Noni Leaf Extract	4 mL/100 mL, 8 mL/100 mL, 12 mL/100 mL, 16 mL/100 mL aquadest	-	Anthracnose intensity	12.75%	(Marsuni, 2020)
Betel and Tobacco Extracts	(1:1), (1:2), (2:1), (1:3), (3:1)	-	Disease incidence rate	75 – 25%	(Nur Rohmah, 2017)
			Incubation period	4 – 9 days	
			Spot diameter	6 – 4 mm	
Kenikir Leaf Extract	5 – 20%	-	Incubation period	4.40 – 5.13 days	(Amelia et al., 2020)
			Disease incidence	72.5 – 52.5%	
			Percentage of incidence of anthracnose in chilies	72.5 – 87.5%	

Tobacco Extract	25 – 100%	-	Disease incidence	75 – 0%	(Isman Duila, 2017)
			Incubation period	4 – 13 days	
Extract of Jarak Pagar Seed	30% - 50%	-	Incubation period	2.57 – 5.4 days	(Lestari et al., 2020)
			The incidence of anthracnose in chilies	65 – 85%	
Extract of Forest Betel Leaf Flour	25 – 100 g/L	-	The appearance of early anthracnose symptoms	3.33 – 4.25 days	(Elfina et al., 2015)
			The intensity of fungal attack on chilies	18.00 – 10.00%	
			Effectiveness and level of fungicidal ability	14.00 – 52.00%	
Soursop, Betel, Papaya, and Garlic Leaf Extracts	-	-	The intensity of the attack	39%, 31%, 33%, 35%	(Zulkipli et al., 2018)
Fragrant Lemongrass Leaf Extract	0.1 – 0.5%	0.2 % b/v synthetic fungicides	Incubation period	5.0 – 6.0 days	(Syabana et al., 2015)
			The intensity of the attack	13.3 – 6.6%	
			Reduction in weight of chilies	13.9 – 7.4%	
			Average total yield	3.8 and 2.5 kg	

Several parameters that are often observed in in vivo tests include: 1) The percentage of incidence of anthracnose disease and 2) The percentage of severity of anthracnose disease or the intensity of disease / attack.

Determination of the percentage of disease occurrences is done by counting the number of symptomatic chilies in each plant with the following formula (Suwastini et al., 2020):

$$TP\frac{n}{N}x100\% \quad (4)$$

With :
TP = Occurrence of disease (%)
n = Number of infected (symptomatic) fruit per plant
N = Total number of fruits observed per plant

Anthracnose disease in chilli is characterized by the appearance of blackish brown spots that will expand into soft rot with black dots in the middle which are collection of seta and conidia of C. capcisi fungi. The attack of C. capsici fungi begins by attaching the spores to the fruit and then the spores will germinate. Furthermore, through the fungal hyphae inject the fruit tissue and take nutrients in it so that it can interfere with metabolism and even cause cell death. The more severe the disease attack, the more extensive the rotting area on the fruit will be, this is due to damage to the fruit tissue and even cell death which ultimately results in the fruit experiencing dry rot or shrinking. (Andriyani et al., 2020). Disease severity is the surface area of chilies that shows symptoms of disease. Disease severity can also be interpreted as the part of the plant affected by disease or the disease area of the sample plant. Determination of the percentage of disease severity can be calculated by the formula as follows (Suwastini et al., 2020):

$$TP\frac{\sum nxv}{NxV}x100\% \quad (5)$$

With :
KP = Disease severity (%)
N = The number of fruit observed per plant
n = The number of fruits in each attack category
v = Numeric value for each attack category
V = Highest score

Several studies have also identified other parameters in the in vivo test, for example: fruit weight, mycelium dry weight, spot diameter, yield / number of red chilies, number of fruits, effectiveness and level of fungicidal ability, incubation period of anthracnose disease, morphometry of cayenne pepper, period incubation, percentage and fresh weight of healthy cayenne pepper affected by anthracnose disease, when the early symptoms of anthracnose disease appeared in red chilies, and the height of chili plants. The plants studied for chilies had the effectiveness of being used as a natural fungicide. However, many in vivo studies do not compare with synthetic fungicides. So, it is not possible to know the effectiveness of the performance of natural fungicides for chilies when compared to synthetic fungicides. Table 6 shows that suren leaf extract and nut bulbs can be used as alternatives to natural fungicides to help overcome the problem of anthracnose in chilies.

Table 6 Comparison of the effectiveness of natural fungicides for chilies with synthetic fungicides

Plants	**Synthetic Fungicides**	**Explanation**	**Reference**
Suren Suren Leaf Extract	Mankozeb 1g/L	In general, the performance of suren leaf extract as natural fungicide > mankozeb fungicide	(Andriyani et al., 2020)
Extract of Umbi Teki	Propineb	The treatment of nut bulb flour with concentration of 5%, 15%, and 25% was comparable to the propineb fungicide which is effective in controlling anthracnose in chili plants.	(Sihite et al., 2020)
Fragrant Lemongrass Leaf Extract	0.2% w/v synthetic fungicide	In general, the performance of fragrant lemongrass leaf extract as natural fungicide < 0.2% w / v synthetic fungicide	(Syabana et al., 2015)

6 Conclusion

This paper reviews the potential plants as an alternative to chili fungicides, the preparation of test solutions, in vitro and in vivo fungicide tests. The part of the plant that is widely studied as fungicide for chilies is the leaves, while the parts of the plant that are rarely used as samples are the parts of the rhizome, roots, tubers, weevils, seeds, fruit, flowers or all parts of the plant. The methods of extract preparation used as fungicide test include: maceration method, stratified fractionation method, and decoction method. The plants studied had the ability to inhibit the growth of the Colletotrichum capsici, Colletotrichum gloeosporioides, and Colletotrichum acutacum. The 80% alcohol extract and 10% and 60% n-hexane extract of Chinese henna leaves can be equal with the performance of 0.2% propineb by in vitro study. In addition, the 60% and 70% kirinyuh leaf extracts were also able to match acrobat 0.2% performance by in vitro study. Two parameters that are often observed in the in vivo test are the percentage of anthracnose disease incidence and the percentage of anthracnose disease severity. Suren and nut bulbs leaf extract can be used as alternative to natural fungicides to help overcome the problem of anthracnose in chilies.

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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References

Ali, M., Puspita, F., Siburian, M. M. (2013). Uji Beberapa Konsentrasi Ekstrak Buah Mengkudu (Morinda Citrifolia L.) Terhadap Penyakit Antraknosa Yang Disebabkan Oleh Jamur Colletotrichum Capsici Pada Buah Cabai Merah Pascapanen. Jurnal Sagu, 11(2).

Ali, M., Venita, Y., Rahman, B. (2012). Uji Beberapa Konsentrasi Ekstrak Daun Mimba (Azadirachta Indica A. Juss.) Untuk Pengendalian Penyakit Antraknosa Yang Disebabkan Jamur Colletotrichum Capsisi Pada Buah Cabai Merah Pasca-Panen. Jurnal Sagu, 11(1).

Amelia, M., Marsuni, Y., Budi, I. S. (2020). Pengaruh Ekstrak Daun Kenikir (Cosmos Caudatus Kunth.) Terhadap Cendawan Colletotrichum Sp. Pada Buah Cabai Rawit. Jurnal Proteksi Tanaman Tropika, 3(1), 157–163.

Andreas, B., Ekowati, C. N., Yulianty, Y., Irawan, B. (2018). Uji Efektifitas Ekstrak Tumbuhan Urang Aring (Eclipta Alba (L.) Hassk) Terhadap Pertumbuhan Jamur Colletotrichum Sp. Penyebab Penyakit Antraknosa. Jurnal Ilmiah Biologi Eksperimen Dan Keanekaragaman Hayati (J_Bekh), 5(1), 49–56.

Andriyani, F., Nurchayati, Y., Haryanti, S. (2020). Pengaruh Ekstrak Suren (Toona Sureni Merr.) Terhadap Produksi Buah Cabai Rawit Yang Diserang Penyakit Antraknosa. Niche Journal Of Tropical Biology, 3(2), 89–98.

Andriyani, F., Purwantisari, S. (2019). Uji Potensi Ekstrak Daun Suren Dalam Menghambat Pertumbuhan Jamur Colletotrichum Capcisi Secara In Vitro. Jurnal Akademika Biologi, 8(1), 24–28.

Anggreini, S., Efri, E., Nurdin, M. (2016). Pengaruh Tingkat Konsentrasi Fraksi Ekstrak Daun Mengkudu Dan Mimba Terhadap Pertumbuhan Dan Sporulasi Colletotrichum Capsici. Jurnal Agrotek Tropika, 4(1).

Anjani, A. G. (2018). Efektivitas Lama Penyimpanan Campuran Ekstrak Sirih Dan Tembakau Pada Colletotrichum Sp. Penyebab Antraknosa Cabai. Universitas Muhammdiyah Jember.

Arneti, A., Sulyanti, E. (2017). Pengujian Ekstrak Sederhana Bagian Tumbuhan Cassia Alata Linnaeus Terhadap Colletotrichum Gloeosporioides Secara Invitro. Jpt: Jurnal Proteksi Tanaman (Journal Of Plant Protection), 1(2), 42–51.

Aziziy, M. H., Tobing, O. L., Mulyaningsih, Y. (2020). Studi Serangan Antraknosa Pada Pertumbuhan Cabai Merah (Capsicum Annuum L.) Setelah Aplikasi Larutan Daun Mimba Dan Mol Bonggol Pisang. Jurnal Agronida, 6(1), 22–32. Badan Pusat Statistik Republik Indonesia. (2019). Distribusi Perdagangan Komoditas Cabai Merah Indonesia 2019. Bps Ri/Bps-Statistics Indonesia.

Chatri, M., Mansyurdin, A. B. P. (2015). Potensi Minyak Atsiri Hyptis Suaveolens (L.) Poit Dalam Menghambat Pertumbuhan Colletotrichum Gloeosporoides, Penyebab Penyakit Antraknosa Pada Cabai. Semirata 2015, 4(1), 227-233.

Chávez-Quintal, P., González-Flores, T., Rodríguez-Buenfil, I., Gallegos-Tintoré, S. (2011). Antifungal Activity In Ethanolic Extracts Of Carica Papaya L. Cv. Maradol Leaves And Seeds. Indian Journal Of Microbiology, 51(1), 54–60.

Damiri, N. (2011). Efektivitas Ekstrak Daun Sirih Terhadap Infeksi Colletotrichum Capsici Pada Buah Cabai. Jurnal Dharmapala, 3(2), 54–59.

Darmadi, A. A. K., Suriani, N., Darmayasa, I. D. A. B. G., Bagus, I. D. A., Suaskara, M., Gari, N. I. M., Fudholi, A. (2021). Cinnamon Leaf Extract To Control Anthracnose Disease On Chilli Plants In Bali: A Novel And New Potential. International Journal Of Pharmaceutical Research, 13(1).

Efri, E. (2010). Pengaruh Ekstrak Berbagai Bagian Tanaman Mengkudu (Morinda Citrifolia) Terhadap Perkembangan Penyakit Antraknosa Pada Tanaman Cabe (Capsicum Annuum L.). Jurnal Hama Dan Penyakit Tumbuhan Tropika, 10(1), 52–58.

Efri, E., Aeny, T. N., Maryono, T., Roanlddi, E. (2017). Pengaruh Fraksi Ekstrak Daun Pacar Cina (Aglaia Odorata L.) Terhadap Pertumbuhan Colletotrichum Capsici Penyebab Penyakit Antraknosa Pada Cabai (Capsicum Annuum L.) Secara In Vitro. Jurnal Hama Dan Penyakit Tumbuhan Tropika, 17(2), 179–184.

Elfina, Y., Ali, M., Aryanti, L. (2015). Uji Beberapa Konsentrasi Ekstrak Tepung Daun Sirih Hutan (Piper Aduncum L.) Untuk Mengendalikan Penyakit Antraknosa Pada Buah Cabai Merah Pasca Panen. Jurnal Sagu, 14(2), 18–27.

Elfina, Y., Ali, M., Tampubolon, M. C. (2016). Uji Beberapa Konsentrasi Ekstrak Tepung Daun Serai Wangi (Cymbopogon Nardus L.) Untuk Mengendalikan Penyakit Antraknosa Pada Buah Cabai Merah Pasca Panen. Jurnal Sagu, 15(1), 1–11.

Elfina, Y. E. (2015). Uji Beberapa Konsentrasi Ekstrak Tepung Daun Sirih Hutan (Piper Aduncum L.) Untuk Mengendalikan Penyakit Antraknosa Pada Buah Cabai Merah Pasca Panen. Jurnal Sagu, 14(2), 18–27.

Esyanti, R. R., Farah, N., Faiz, M. F. (2020). The Effect Of Synthetic Fungicide On Disease Severity And Plant Growth Of Chili Pepper (Capsicum Annuum L.) Infected With Phytophthora Capsici. 49(2), 7–12.

Eviyanti, A. (2018). Gel Fungisida Nabati Dari Ekstrak Akar Putri Malu Untuk Penyakit Antraknosa Pada Tanaman Cabai Di Lahan Pasir Pantai Indonesia.

Eviyanti, A. (2020). The Implementation Of Mimosa Pudica Root Extract For Anthracnose Disease On Red Chili To Increase Productivity. Proceeding International Conference On Science And Engineering, 3, 31–33.

Gabriel, B., Riyanto, P. (1989). Metarhizium Anisopliae (Metch) Sor: Taksonomi, Patologi, Produksi Dan Aplikasinya. Direktorat Perlindungan Tanaman Perkebunan, Departemen Pertanian. Jakarta.

Gao, Y.-Y., He, L.-F., Li, B.-X., Mu, W., Lin, J., Liu, F. (2017). Sensitiv

ity Of Colletotrichum Acutatum To Six Fungicides And Reduction In Incidence And Severity Of Chili Anthracnose Using Pyraclostrobin. Australasian Plant Pathology, 46(6), 521–528.

Gusmarini, M., Nurdin, M., Akin, H. M. (2014). Pengaruh Beberapa Jenis Ekstrak Tumbuhan Terhadap Penyakit Antraknosa Pada Tanaman Cabai Besar (Capsicum Annuum L.) Di Lapangan. Jurnal Agrotek Tropika, 2(2). Harianto, R. (2018). Selektifitas Beberapa Fungisida Nabati Dalam Menghambat Penyakit Antraknosa (Collectroticum Capsici) Pada Tanaman Cabai (Capsicum Annum L.) Skala Laboratorium.

Herlinda, S., Utama, M. D., Pujiastuti, Y., Suwandi, S. (2006). Kerapatan Dan Viabilitas Spora Beauveria Bassiana (Bals.) Akibat Subkultur Dan Pengayaan Media, Serta Virulensinya Terhadap Larva Plutella Xylostella (Linn.). Jurnal Hama Dan Penyakit Tumbuhan Tropika, 6(2), 70–78.

Indrawati, A. (2021). Test Kirinyuh Leaf Extract (Euphatorium Odoratum. L) As Biofungicides Against Antracnose Disease (Colletotrichum Capsici) On Chili Plants (Capsicum Annum L). Budapest International Research In Exact Sciences (Birex) Journal, 3(1), 54–67.

Isman Duila, M. (2017). Ekstrak Tembakau (Nicotiana Tabacum L.) Sebagai Fungisida Nabati Pada Antraknosa Cabai Merah Yang Disebabkan Jamur Colletotrichum Sp Secara In Vitro. Juniar Dwi Cahya, A. (2019). Aplikasi Konsentrasi Dan Interval Penyemprotan Ekstrak Sirih (Piper Batle L.) Terhadap Penyakit Antraknosa Tanaman Cabai. Universitas Muhammadiyah Jember.

Lestari, W. D., Marsuni, Y., Budi, I. S. (2020). Uji Penghambatan Konsentrasi Biji Jarak Pagar (Jatropha Curcas L.) Terhadap Pertumbuhan Cendawan Colletotrichum Capsici Pada Buah Cabai. Jurnal Proteksi Tanaman Tropika, 3(2), 209–214.

Liswarni, Y., Edriwilya, R. (2020). Efektivitas Ekstrak Daun Pepaya Secara Invitro Terhadap Colletotrichum Gloeosporioides Penyebab Penyakit Antraknosa Pada Tanaman Cabai. Jpt: Jurnal Proteksi Tanaman (Journal Of Plant Protection), 4(1), 1–10.

Maimunah, M., Azwana, A., Pandala, C. (2019). The Effectiveness Of Kenikir And Betel Leaves Extract As Bio Fungicide To The Causes Of Anthracnose Disease (Colletotrichum Capsici) On Chili Plants (Capsicum Annum L.) With In Vitro. Budapest International Research In Exact Sciences (Birex) Journal, 1(2), 29–36.

Marsuni, Y. (2020). Pencegahan Penyakit Antraknosa Pada Cabai Besar (Lokal: Lombok Ganal) Dengan Perlakuan Bibit Kombinasi Fungisida Nabati. Prosiding Seminar Nasional Lingkungan Lahan Basah, 5(2), 113–116.

Musakhan, P. R., Zacharia, S. (2017). Effect Of Neem Based Plant Products And Plant Extracts Against Anthracnose Of Chilli (Capsicum Annuum L.). Journal Of Pharmacognosy And Phytochemistry, 6(5), 171–174.

Naznin, S., Khalequzzaman, K. M., Khair, A. (2016). Effect Of New Fungicides In Controlling Anthracnose/Die Back Disease Of Chilli. Asian Journal Of Applied Science And Engineering, 5(2), 117–124.

Ngibad, K. (2019). Efektivitas Kombinasi Ekstrak Etanol Daun Bunga Matahari (Helianthus Annuus) Dan Tanaman Anting-Anting (Acalypha Indica Linn) Sebagai Antimalaria Secara In vivo. Jurnal Farmasi Galenika (Galenika Journal Of Pharmacy), 5(1), 12–19.

Ngibad, K. (2019). Phytochemical Screening Of Sunflower Leaf (Helianthus Annuus) And Anting-Anting (Acalypha Indica Linn) Plant Ethanol Extract. Borneo Journal Of Pharmacy, 2(1), 24–30.

Ningtyas, I. R., Efri, E., Aeny, T. N. (2013). Pengaruh Berbagai Tingkat Fraksi Ekstrak Daun Sirih (Piper Betle L.) Dan Daun Babadotan (Ageratum Conyzoide) Terhadap Colletotrichum Capsici Penyebab Penyakit Antraknosa Pada Cabai (Capsicum Annum L.) Secara In Vitro. Jurnal Agrotek Tropika, 1(3).

Novizan, I. (2002). Membuat Dan Memanfaatkan Pestisida Ramah Lingkungan. Agromedia Pustaka. Jakarta. Nur Rohmah, W. (2017). Biorasional Ekstrak Sirih Dan Tembakau Sebagai Fungisida Nabati Pada Colletotrichum Sp Secara In Vitro. Universitas Muhammadiyah Jember.

Nurul, A., Gayuh, P. B., Anis, S. (2020). Uji Daya Simpan Ekstrak Daun Dan Buah Mengkudu (Morinda Citrifolia L.) Terhadap Pertumbuhan Jamur Colletotrichum Capsici Asal Cabai Merah Secara In Vitro. Prosiding Semnas Pertanian 2020.

Oktarina, O., Tripama, B., Rohmah, W. N. (2017). Daya Hambat Biorasionalekstrak Sirih Dan Tembakau Pada Colletotrichum Capsici Penyebab Penyakit Antraknosa Cabai. Agritrop: Jurnal Ilmu-Ilmu Pertanian (Journal Of Agricultural Science), 15(2).

Piay, S. S., Tyasdjaja, A., Ermawati, Y., Hantoro, F. R. P. (2010). Budidaya Dan Pascapanen Cabai Merah (Capsicum Annuum L.). Badan Penelitian Dan Pengembangan Pertanian Balai Pengkajian Teknologi Pertanian Jawa Tengah.

Putra, M. S. (2017). Efektivitas Fraksi Ekstrak Daun Mengkudu (Morinda Citrifolia L.) Terhadap Penyakit Antraknosa (Colletotrichum Capsici) Pada Tanaman Cabai (Capsicum Annum L.).

Rahman, M. S., Jahan, K., Islam, R., Sabuz, A. A., Akanda, A. M. (2019). In-Vitro Evaluation Of Some Plant Extracts And Fungicides Against Colletotrichum Capsici Causing Anthracnose Of Chilli. Bangladesh Phytopathological Society. 35(1), 1-8.

Sakerebau, D. R. M., Wahyu, B. P. W. S. P. (2013). Minyak Nilam Sebagai Biofungisida Untuk Pengendalian Penyakit Antraknosa Cabai. Jurnal Fitopatologi Indonesia, 9(3), 84.

Saputri, D. D., Utami, A. W. A. (2020). The Potency Of Purple Sweet Potato (Ipomoea Batatas) Leaf Extract As Biofungicide For Controlling Fusarium Rot On Chili. Journal Of Agriculture And Applied Biology, 1(1), 1–8. Sari, A. R. K., Rahmah, F. A., Djauhari, S. (2020a). Efektivitas Senyawa Nonatsiri Dari Curcuma Spp. Terhadap Penekanan Penyakit Antraknosa Pada Buah Cabai. Buletin Penelitian Tanaman Rempah Dan Obat, 31(1), 21–30.

Sari, A. R. K., Rahmah, F. A., Djauhari, S. (2020b). Effectiveness Of Nonessential Compounds From Curcuma Spp. On Reducing Anthracnose Disease Of Chilli Pepper Fruit. Buletin Penelitian Tanaman Rempah Dan Obat, 31(1), 21–30.

Satryawibowo, M. W. (2015). Pengaruh Fraksi Ekstrak Daun Tagetes (Tagetes Erecta) Saliara (Lantana Camara) Dan Sirih Hijau (Piper Betle) Terhadap Pertumbuhan Dan Sporulasi Colletotrichum Capsici Secara In Vitro. Fakultas Pertanian.

Satryawibowo, M. W., Efri, E., Aeny, T. N. (2015). Pengaruh Fraksi Ekstrak Daun Tagetes (Tagetes Erecta) Terhadap Pertumbuhan Dan Sporulasi Colletotrichum Capsici Secara In Vitro. Jurnal Agrotek Tropika, 3(2).

Septiana, W., Efri, E., Aeny, T. N. (2013). Pengaruh Berbagai Tingkat Fraksi Ekstrak Buah Mengkudu (M. Citrifolia) Terhadap C. Capsici Pada Cabai (C. Annum L.) Secara In Vitro. Jurnal Agrotek Tropika, 1(2).

Septianing Ratri, E. (2017). Ekstrak Putri Malu (Mimosa Pudica L.) Sebagai Fungisida Nabati Pada Antraknosa Cabai Yang Disebabkan Jamur Colletotrichum Sp. Secara In Vitro. Universitas Muhammadiyah Jember.

Sholehah, D. N. (2012). Uji Aktivitas Minyak Camplong (Callophyllum Inophyllum) Terhadap Pertumbuhan Jamur Colletotrichum Sp. Penyebab Penyakit Antraknosa Pada Tanaman Cabe. Rekayasa, 5(1), 66–70.

Sihite, D. M., Nurdin, M., Dirmawati, S. R., Akin, H. M. (2020). Uji Efektivitas Tepung Umbi Teki (Cyperus Rotundus L.) Dalam Mengendalikan Penyakit Antraknosa Pada Tanaman Cabai Dilapang. Jurnal Agrotek Tropika, 8(1), 11–17.

Sitompul, L. Y. (2017). Uji Efektivitas Beberapa Ekstrak Tanaman Terhadap Patogen Colletotrichum Capsici (Syd.) Ej Butler And Bisby Secara In vitro Dan In vivo Pada Tanaman Cabai Besar (Capsicum Annum L.).

Sittisart, P., Yossan, S., Prasertsan, P. (2017). Antifungal Property Of Chili, Shallot And Garlic Extracts Against Pathogenic Fungi, Phomopsis Spp., Isolated From Infected Leaves Of Para Rubber (Hevea Brasiliensis Muell. Arg.). Agriculture And Natural Resources, 51(6), 485–491.

Subagyono, K., Sisca Piay, S., Tyasdjaja, A., Ermawati, Y., Rudi Prasetyo Hantoro, F., Prayudi, B., Jauhari, S., Basuki, S. (2010). Budidaya Dan Pascapanen Cabai Merah (Capsicum Annuum L.). Bptp Jateng/Kan.

Sudirga, S. K. (2016). Isolasi Dan Identifikasi Jamur Colletotrichum Spp. Isolat Pcs Penyebab Penyakit Antraknosa Pada Buah Cabai Besar (Capsicum Annuum L.) Di Bali. Metamorfosa: Journal Of Biological Sciences, 3(1), 23–30.

Sudirga, S. K. (2018). Efektivitas Ekstrak Daun Awar-Awar (Ficus Septica) Sebagai Fungisida Nabati Terhadap Penekanan Penyakit Antraknosa Pada Tanaman Cabai Besar. Prosiding Seminar Nasional Pendidikan Biologi, 1(1), 369–374.

Sudirga, S. K., Ginantra, I. K., Darmayasa, I. B. G. (2019). Antifungal Activity Of Leaf Extract Of Mansoa Alliacea Against Colletotrichum Acutatum The Cause Of Anthracnose Disease On Chili Pepper. Iop Conference Series: Earth And Environmental Science, 347(1), 12058.

Sudirga, S. K., Suprapta, D. N., Sudana, I. M., Wirya, I. (2014). Antifungal Activity Of Leaf Extract Of Ficus Septica Against Colletotrichum Acutatum The Cause Of Anthracnose Disease On Chili Pepper. Journal Of Biology, Agriculture And Healtcare, 4(28).

Supriati, L., Oemar, O., Anwar, M. (2016). Pemanfaatan Trichoderma Harzianum Dan Ekstrak Daun Gelinggang (Cassia Alata L.) Untuk Mengendalikan Penyakit Antraknosa Pada Usaha Tani Cabai Rawit Di Kelurahan Kalampangan. Prosiding Seminar Nasional Inovasi Teknologi Pertanian Fak. Pertanian Universitas Palangkaraya.

Suwastini, M., Efri, E., Ivayani, I., Suharjo, R. (2020). Evaluasi Efektivitas Fraksi Ekstrak Jarak Tintir Dan Tembelekanuntuk Mengendalikan Penyakit Antraknosa Pada Cabai Merah. Jurnal Agrotek Tropika, 8(1), 19–26.

Suyanti, A. P., Mariana, M., Rosa, H. O. (2020). Pengaruh Pemberian Beberapa Ekstrak Gulma Lahan Pasang Surut Dalam Menghambat Colletotrichum Sp Penyebab Penyakit Antraknosa Pada Buah Cabai Rawit. Jurnal Proteksi Tanaman Tropika, 3(2), 215–225.

Syabana, M. A., Saylendra, A., Ramdhani, D. (2015). Aktivitas Anti Cendawan Ekstrak Daun Sereh Wangi (Cymbopogon Nardus L.) Terhadap Colletotrichum Sp Penyebab Penyakit Antraknosa Pada Buah Cabai (Capsicum Annum L.) Secara In vitro Dan In vivo. Agrologia, 4(1).

Tobing, O. L., Mulyaningsih, Y. (2020). The Reconditioning Growth And Production Of Chili Through The Banana Hump And Mimba Leaf Extract. Indonesian Journal Of Applied Research (Ijar), 1(3), 136–148.

Trisnawati, D., Nugroho, L. P. E., T. (2019). Pengaruh Ekstrak Daun Sirih Dan Metode Ekstraksinya Dalam Menghambat Penyakit Antraknosa Pada Cabai Pascapanen. Jurnal Fitopatologi Indonesia, 15(6), 213–227.

Trisnawati, D., Pujantoro, L., Nugroho, E., Tondok, E. T. (2019). Pengaruh Ekstrak Daun Sirih Dan Metode Ekstraksinya Dalam Menghambat Penyakit Antraknosa Pada Cabai Pascapanen Extract Of Piper Betle As An Inhibitor Of Anthracnose Postharvest Disease On Chili Pepper. Fitopatologi Indonesia, 15(November), 213–227. Https://Doi.Org/10.14692/Jfi.15.6.

Wanda, T. S., Efri, E., Aeny, T. N., Akin, H. M. (2014). Uji Keeektifanf Ekstrak Daun Jarak Dan Daun Nimba Terhadap Intensitas Penyakit Antraknosa Pada Tanaman Cabai (Capsicum Annum L.). Jurnal Agrotek Tropika, 2(3).

Warisno, S., Dahana, K. (2018). Peluang Usaha Dan Budi Daya Cabai. Gramedia Pustaka Utama.

Wati, I. F., Efri, E., Maryono, T. (2014). Keefektifan Ekstrak Daun Sirih Dan Daun Babadotan Mengendalikan Penyakit Antraknosa Pada Buah Cabai (Capsicum Annum L.). Jurnal Agrotek Tropika, 2(3).

Wibowo, C. H., Oktarina, E., Wardani, R. D., Ngibad, K. (2019). The Potential Of Walnut Seeds (Canarium Indicum L.) In Repairing The Genotoxicity Effect Of Mercury On Mice Erythrocytes. Borneo Journal Of Pharmacy, 2(2), 48–54.

Wulandari, S., Aeny, T. N., Efri, E. (2015). Pengaruh Fraksi Ekstrak Daun Babadotan (Ageratum Conyzoides) Terhadap Pertumbuhan Dan Sporulasi Colletotrichum Capsici Secara In Vitro. Jurnal Agrotek Tropika, 3(2).

Yulia, E., Muhadam, H. S., Widiantini, F., Kurniawan, W. (2019). Perlakuan Benih Ekstrak Anredera Cordifolia Menekan Kejadian Penyakit Antraknosa Benih Cabai Terinfeksi Colletotrichum Acutatum. Agrikultura, 30(2), 75–82.

Zulkipli, S., Marsuni, Y., Rosa, H. O. (2018). Uji Lapangan Beberapa Pestisida Nabati Untuk Menekan Perkembangan Penyakit Antraknosa Pada Tanaman Cabai Besar. Jurnal Proteksi Tanaman Tropika, 1(2), 32–35.