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The potency of Myrtaceae Family from Cibodas Botanic Gardens (Cianjur, Indonesia) as botanical pesticide

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Abstract. *Pratiwi RA, Nurlaeni Y. 2021. The potency of Myrtaceae Family from Cibodas Botanic Gardens (Cianjur, Indonesia) as botanical pesticide. Biodiversitas 22: 4648-4664.* Cibodas Botanic Gardens (CBG) is a biodiversity reservoir that can be explored for the discovery of new candidates for botanical pesticides. Myrtaceae has been reported to provide biological activity against pests or pathogens due to their essential oil contents. This research was conducted to inventory and categorize Myrtaceae collection in CBG that had the potency to be botanical pesticide. The list of Myrtaceae collection of CBG obtained from Unit Registration and Collection CBG per 2021. Database fulfilling regarding the bactericide/fungicide/herbicide/insecticide potency of the Myrtaceae of CBG's collection was carried out through digital references search. Our result showed that there were 73 species of Myrtaceae (from 18 genera) that are potential to be botanical pesticide sources. There were 17 species that are considerably had a high potency. Most of them belong to the *Eucalyptus* and *Melaleuca*, followed by *Backhousia*, *Leptospermum*, *Psidium*, and *Syzygium*. The data resulted from this study is expected to serve as baseline information for further research about the formulation, efficacy, and conservation management of botanical pesticides from Myrtaceae for sustainable use. Furthermore, the development of biological pesticides is a step to improve the quality of Indonesian export products so as to increase national competitiveness in the globalization era nowadays.

Keywords: Botanical pesticide, Cibodas Botanic Gardens's collection, essential oil, inventory, Myrtaceae

INTRODUCTION

The infestation of pests, weeds, and pathogens is responsible for the annual global food crop losses approximated at 45% (Sharma et al. 2019). Pesticides are extensively served as crop protection in agriculture to ensure food security. Pesticides are defined as chemical substances and other materials as well as microorganisms and viruses that are used to prevent or against pests, weeds, and pathogens exposing plants, pets, and humans; to minimalize or eliminate their presence in households, buildings, and transportation. Pesticides comprise herbicides, insecticides, nematicides, molluscicides, acaricides, rodenticides, bactericides, antimicrobials, fungicides, avicides, and larvicides; no matter if it is a synthesis or natural-based products (President of The Republic of Indonesia 1973).

Synthetic pesticide is preferred the most compared to other control methods because it is technically practical, rapid in controlling pests, and effective economically. Unfortunately, over time the massive exposure of high pesticide doses has been associated with the development of resistance mechanisms for pests and pathogens over these compounds. The synthetic pesticides also gets accumulated in the plant, soil, water, air, and non-target biota, enters the food chain, and finally has adverse risks on human beings (Sharma et al. 2019).

The exposure of synthetic pesticides to the ecosystem must be limited by switching them to other environmentally friendly alternatives. The Indonesian government has issued a national policy as outlined in Government Regulation Number 6 of 1995 concerning plant protection by promoting the use of biological control agents or natural pesticides in the integrated pest management system (President of The Republic of Indonesia 1995).

Plants have acquired natural defense mechanisms related to their various secondary metabolites derived from root, leaf, fruit, and seed that repel, inhibit growth or kill pests and pathogens (Kardinan 2011). The plant-based pesticide has been used as local wisdom by earlier farmers with notable success. Botanical pesticides are considered renewable and non-harmful compared with their synthetic counterparts due to their existence as plants in nature for millions of years without any undesirable effect on the ecosystem, especially on non-target organisms. Their phytochemical contents degraded quickly and did not leave hazardous residues (Ebadollahi 2013). However, the commercialization of botanical pesticides depends on the availability of plant sources, which often conflict with other needs, such as food and medicine (Lengai et al. 2020). So, the current screening that emphasizes the botanical pesticide alternatives is being a necessity.

One of the biodiversity reservoirs that can be relied on as botanical pesticide candidates is botanical garden. A total of 50 families (127 species) of Bogor Botanic Gardens were recorded as botanical pesticide candidates (Wardani and Yudaputra 2015). On the other hand, there are 116 species belong to 46 families of Cibodas Botanic Gardens (CBG) plant collections that were confirmed to harbor the pesticide features. Myrtaceae, the family with the largest number of potential species as botanical pesticides at CBG (Nurlaeni 2016) has not been an investigation in depth. The Myrtaceae in CBG consists of the genera of *Acca, Agonis, Backhousia, Callistemon, Corymbia, Decaspermum, Eucalyptus, Eugenia, Jambosa, Kunzea, Leptospermum, Lophostemon, Melaleuca, Myrcia, Myrciaria, Plinia, Psidium, Rhodamnia, Rhodomyrtus, Syzygium, Tristaniopsis*, and *Xanthostemom*. Meanwhile, the inventoried genera as a natural pesticide are limited to *Eucalyptus, Melaleuca*, and *Leptospermum* (Nurlaeni 2016).

This research was conducted to inventory and categorize Myrtaceae collection in CBG that potential to become a source of botanical pesticides in a detailed and comprehensive manner. The data resulted from this study is expected to serve as baseline information for further research about the formulation, efficacy, and conservation management for sustainable use. Furthermore, the development of biological pesticides is a step to improving the quality of Indonesian export products to increase national competitiveness in the globalization era nowadays.

MATERIALS AND METHODS

Study area

This research was conducted in Cibodas Botanical Garden (CBG) that located at Cianjur, West Java, Indonesia. CBG is a botanical garden managed by the National Research and Innovation Agency (BRIN), formerly the Indonesian Institute of Sciences (LIPI), that plays a role in *ex-situ* conservation, research, and utilization of plant collection.

Procedures

The investigation of pesticide potency on this research is limited to bactericide, fungicide, herbicide, and insecticide. The list of Myrtaceae collection of CBG obtained from Unit Registration and Collection CBG per 2021. Database fulfilling regarding the botanical pesticidal potency of the Myrtaceae of CBG's collection was carried out through digital references search. The keywords were tailored for collecting information such as "the potential of Myrtaceae (name of species mentioned) as bactericide/ fungicide/insecticide/herbicide, essential oils (EOs) of Myrtaceae, chemical compound of Myrtaceae" to retrieve the relevant articles in digital international journal repositories and publishers, such ScienceDirect (www.sciencedirect.com), Google Scholar (www.scholar.google.com), Pubmed (www.pubmed.ncbi.nlm.nih.gov), JSTOR (www.jstor.org), SciELO (www.scielo.org), BioOne Complete (www.bioone.org), Wiley Online Library (www.onlinelibrary.wiley.com), Springer (www.link.springer.com), MDPI (www.mdpi.com), Academic Journals (www.academicjournals.org), SAGE Journals (www.journals.sagepub.com), Taylor & Francis Online (www.tandfonline.com), Cambridge Journals (www.cambridge.org), Smujo (www.smujo.id), also national journal libraries indexed on Sinta Indonesia (www.sinta.ristekbrin.go.id) until June 2021. The language was limited to English and Indonesian. The data about Myrtaceae potency was retrieved manually from collected articles.

The scientific name of the plant species mentioned as a botanical pesticide was verified based on a digital database from Royal Botanic Garden Kew; Plants of The World Online (www.plantsoftheworldonline.org). The conservation status of the plant was determined based on the IUCN Red List of Threatened Species^{TM} (www.iucnredlist.org). The compilation data served as a table that contained followed information: number, scientific name, biological activity against pest or pathogen (as bactericide/fungicide/ herbicide/insecticide), score, major chemical compound, the part of the plant used, and references. For high potential Myrtaceae species, additional data are compiled, such as conservation status and origin. In addition, we inventoried the species of Myrtaceae that are not yet mentioned as botanical pesticides for further researches recommendations.

Data analysis

The potential plant as botanical pesticides were classified into four categories: bactericide, fungicide, herbicide, and insecticide. Each plant was assigned a score. Each type of potency (bactericide, fungicide, herbicide, or insecticide) has a score of 1. Thus, plants that have all four potencies have a score of 4 and are stated as high potential sources of botanical pesticide.

RESULTS AND DISCUSSION

The genera distribution of Myrtaceae with botanical pesticide properties

We found that CBG has 124 species of Myrtaceae. A number of 18 genera that consisted of 73 species of Myrtaceae collection of CBG are potential as botanical pesticides according to the literature research we conducted. The genus with the largest number of botanical pesticides is *Eucalyptus* (18 species), *Melaleuca* (15 species), and *Syzygium* (13 species). The distribution of genera that have botanical pesticide properties from CBG is shown in Figure 1.

The list of Myrtaceae from CBG that have a high potentially botanical pesticides

We summarize 73 species of Myrtaceae collection of CBG that have potency as biopesticides. For detailed information about its pesticide attributes, see Table 1. As many as 17 species are classified as high potential sources of botanical pesticide. Most of them belong to the *Eucalyptus* and *Melaleuca*, followed by *Backhousia, Leptospermum, Psidium*, and *Syzygium* (Table 2).

Table 1. List of Myrtaceae collection from CBG with botanical pesticide properties

Accepted name	Biological activity against pest/pathogen	Score	Major chemical constituent	Part	References
Agonis flexuosa (Willd.) Sweet	Bactericide: *Bacillus subtilis, Staphylococcus aureus* Fungicide: *Aspergillus niger, Rhizopus oryzae.*	2	Myrcene, α- thujene, limonene	Ae (EO)	(Saj and Thoppil 2011)
Backhousia citriodora F.Muell.	Bactericide: *S. aureus, Escherichia coli, Salmonella typhimurium, Mycobacterium phlei, Clostridium perfringens.* Fungicide: *Candida albicans, A. niger.* Herbicide: cytogenotoxic effect on meristematic cells of *Lactuca sativa.* Insecticide: *Crocidolomia binotalis.*	4	Epoxy-linalool oxide, isoprophyl 4-methyl-3-methylene-4-pentenoate, citral, geranial, neral	L (EO)	(Wilkinson et al. 2003; Garba 2016; de Andrade Santiago et al. 2017)
Corymbia calophylla (Lindl.) K.D.Hill & L.A.S.Johnson	Bactericide: *S. aureus, B. subtilis, Kocuria rhizophila.*	1	Flavonolol	K (Ex)	(Nobakht et al. 2017)
Corymbia citriodora (Hook.) K.D.Hill & L.A.S.Johnson	Bactericide: *Streptococcus pneumoniae, Haemophilus influenza.* Fungicide: *Pyricularia grisea, Aspergillus* spp., *Colletotrichum musae.* Insecticide: adulticide (*Bemisia tabaci*).	3	Citronellal, isopulegol, citronellol, 1,8-cineole	L (EO)	(Aguiar et al. 2014; Hussein et al. 2017; Miguel et al. 2018)
Corymbia maculata (Hook.) K.D.Hill & L.A.S.Johnson	Bactericide: *S. aureus, Streptococcus agalactiae, E. coli, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa, S. typhimurium.* Fungicide: *Trichophyton mentagrophytes.*	2	β-citronellol, β-pinene, 2,6-dimethyl-2,6-octadiene, α-pinene	L (EO)	(Takahashi et al. 2004; Ololade et al. 2017)
Corymbia torelliana (F.Muell.) K.D.Hill & L.A.S.Johnson	Bactericide: *P. aeruginosa, S. aureus.* Fungicide: *C. albicans.*	2	3,4',5,7-Tetrahydroxyflavanone	K (Ex)	(Nobakht et al. 2017)
Decaspermum fruticosum J.R.Forst. & G.Forst.	Bactericide: *S. aureus.*	1	n.a.	B, L (Ec)	(Chung et al. 2004)
Decaspermum parviflorum (Lam.) A.J.Scott	Bactericide: *Enterococcus faecalis, S. aureus, Acinetobacter baumannii, E. coli, K. pneumoniae, P. aeruginosa.*	1	n.a.	L (Ec)	(Paosen et al. 2017)
Eucalyptus alba Reinw. ex Blume	Bactericide: *S. aureus, E. coli, E. faecalis*. Fungicide: *C. albicans, Candida tropicalis, A. niger, T. mentagrophytes, Microsporus canis.* Insecticide: mosquito repellent.	3	1,8-cineole, limonene, α-terpineol, globulol, α-pinene	L (EO)	(Cimanga et al. 2002a; Tine et al. 2020)
Eucalyptus botryoides Sm.	Bactericide: *S. aureus*, MRSA, *Bacillus cereus, E. faecalis, Pseudomonas putida, Cutibacterium acnes.* Fungicide: *T. mentagrophytes.*	2	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004)
Eucalyptus camaldulensis Dehnh.	Bactericide: *S. aureus, C. acnes, B. cereus, E. faecalis, P. putida,* MRSA. Fungicide: *T. mentagrophytes.* Herbicide: inhibitory effect of growth and chlorophyll content of *Vigna radiata.* Insecticide: *Oryzaephilus surinamensis, Sitophilus oryzae.*	4	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Ibrahim, 2011; Ebadollahi and Setzer 2020)
Eucalyptus cinerea F.Muell. ex Benth.	Bactericide: *S. aureus, Streptococcus pyogenes, P. aeruginosa.* Fungicide: *C. albicans.* Herbicide: inhibitory effect of germination, seedling growth, net photosynthetic rates of *Sinapsis arvensis, Eruca vesicaria, Scorpiorus muricatus, Triticum durum, Vicia faba, Phaseolus vulgaris.* Insecticide: *Musca domestica.*	4	1,8-cineole, α-pinene, limonene, α-terpineol, α-terpinyl acetate	L, Fl, Fr (EO)	(Silva et al. 2011; Rossi and Palacios 2015; Grichi et al. 2016)

Eucalyptus deglupta Blume	Bactericide: *B. subtilis, Citrobacter diversus, E. coli, Klebsiella oxytoca, K. pneumoniae, P. mirabilis, Proteus vulgaris, S. aureus, P. aeruginosa, S. typhimurium, Shigella flexneri.* Fungicide: *C. albicans, C. tropicalis, A. niger, M. canis.* Insecticide: strong repellant activities against *Culex quinquefasciatus*.	3	1,8-cineole, cryptone, myrtenol	L (EO)	(Cimanga et al. 2002a; 2002b; Pujiarti and Fentiyanti 2017)
Eucalyptus diversifolia Bonpl.	Bactericide: *E. faecalis, E. coli, S. aureus, P. aeruginosa.*	1	1,8-cineole, transpinocarveol, globulol, viridiflorol	L (EO)	(Elaissi et al. 2012)
Eucalyptus dunnii Maiden	Insecticide: Adulticide on *Sitophilus zeamais.*	1	α-pinene, 1,8-cineole, aromadendrene, α-terpinol, globulol, viridiflorol	L (EO)	(Mossi et al. 2011)
Eucalyptus exserta F.Muell.	Bactericide: *Salmonella enteritidis, E. faecalis, E. coli, Lactobacillus plantarum, S. aureus, Listeria innocua, B. subtilis, Lactobacillus rhamnosus.* Fungicide: *A. niger, A. flavus.* Herbicide: inhibitory effect of *Raphanus sativus* and *L. sativa.* Insecticide: cytotoxic on *Spodoptera litura* cell.	4	Globulol, viridiflorol, spathulenol, α-eudesmol, α-eudesmol, d-piperitone	L (EO)	(Rensen and Pengwei 1997; Li and Xu 2012; Ambrosio et al. 2017; Oanh and Giang 2017)
Eucalyptus globulus subsp. *Maidenii* (F.Muell.) J.B.Kirkp.	Bactericide: *S. enteritidis, L. plantarum, E. faecalis, E. coli, L. rhamnosus, S. aureus, L. innocua, B. subtilis.* Fungicide: *T. mentagrophytes.* Herbicide: inhibitory effect of germination and radicle growth of *L. sativa* and *Agrostis stolonifera*. Insecticide: adulticide on *S. zeamais*.	4	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Mossi et al. 2011; Puig et al. 2013; Ambrosio et al. 2017)
Eucalyptus gr&is W. Hill ex Maiden	Bactericide: *S. aureus*, MRSA, *B. cereus, E. faecalis, Alicyclobacillus acidoterrestris, P. putida, C. acnes.* Fungicide: *T. mentagrophytes.* Insecticide: adulticidal and repellent on *Cx. quinquefasciatus*.	3	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Tian et al. 2011)
Eucalyptus haemastoma Sm.	Bactericide: *S. aureus.*	1	Alkaloids, flavonoids, steroids, terpenoids, tannin	Sap	(Akter et al. 2016)
Eucalyptus microcorys F.Muell.	Bactericide: *E. coli, Enterobacter aerogenes, Staphylococcus lugdunensis*. Fungicide: *Geotrichum candidum, Aspergillus brasiliensis, C. albicans.*	2	Phenolic, flavonoid, proanthocyanidins, saponins	L (Ec)	(Bhuyan et al. 2017)
Eucalyptus punctata DC.	Bactericide: *S. aureus, E. faecalis, A. acidoterrestris*, MRSA, *B. cereus, C. acnes*. Fungicide: *T. mentagrophytes.* Insecticide: lethal on *Ascia monuste*.	3	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Ribeiro et al. 2018)
Eucalyptus robusta Sm.	Bactericide: *S. aureus, E. faecalis, A. acidoterrestris*, MRSA, *B. cereus, C. acnes*. Fungicide: *T. mentagrophytes.* Insecticide: adulticide against *Callosobruchus chinensis*.	3	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Liu et al. 2014)
Eucalyptus saligna Sm.	Bactericide: *S. aureus, E. faecalis, A. acidoterrestris*, MRSA, *B. cereus, C. acnes*. Fungicide: *T. mentagrophytes.* Herbicide: inhibitory effect of germination, shoot, and root growth of *L. sativa, Amaranthus viridis, Eregrostis plana, Paspalum notatum.* Insecticide: Adulticide on *S. zeamais.*	4	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004; Mossi et al. 2011)

Eucalyptus tereticornis Sm.	Bactericide: *S. aureus, E. faecalis, A. acidoterrestris,* MRSA, *B. cereus, C. acnes.* Fungicide: *C. albicans, C. tropicalis, A. niger, T. mentagrophytes, M. canis.* Herbicide: inhibitory effect of germination, seed growth and chlorophyll content of *Echinochloa crus–galli.* Insecticide: *Cx. quinquefasciatus.*	4	p-cymene, cryptone, cuminaldehyde, α-terpineol	L (EO)	(Cimanga et al. 2002a; Takahashi et al. 2004; Vishwakarma and Mittal 2014; Pujiarti and Fentiyanti 2017)
Eucalyptus urophylla S.T.Blake	Bactericide: *B. subtilis, C. diversus, S. aureus, E. coli, K. oxytoca, K. pneumoniae, P. aeruginosa, P. mirabilis, P. vulgaris, S. typhimurium, S. flexneri.* Fungicide: *A. niger, Fusarium oxysporum.* Herbicide: inhibitory effect of germination and seedling growth of *Cryptocarya concinna, Machilus chinensis, Photinia benthamiana, Pygeum topengii, Diospyros morrisiana, Pterospermum lanceaefolium, Acacia confusa, Albizia lebbeck, Albizia falcataria.* Insecticide: *Cx. quinquefasciatus*	4	1,8-cineole, α-pinene, globulol	L (EO)	(Cimanga et al. 2002a; Fang et al. 2009; Pujiarti and Kasmudjo 2016; Pujiarti et al. 2018)
Eucalyptus viminalis Labill.	Bactericide: *S. aureus, E. faecalis, A. acidoterrestris,* MRSA, *B. cereus, C. acnes.* Fungicide: *T. mentagrophytes.* Insecticide: knockdown effect in first instars nymphs of *Blatella germanica.*	3	1,8-cineole, α-pinene	L (EO)	(Takahashi et al. 2004)
Eugenia uniflora L.	Bactericide: *S. aureus, Listeria monocytogenes.* Fungicide: *C. lipolytica, C. guilliermondii.* Insecticide: lethal effect, locomotor deficit, oxidative stress response signaling on *Drosophila melanogaster.*	3	Germacrenes, seline-1,3,7-(11)-trien-8-one oxide, curzerene, γ-elemene, atractylone, trans-β-lemenone	L (EO)	(Victoria et al. 2012; da Cunha et al. 2014)
Feijoa sellowiana (O.Berg) O.Berg	Bactericide: *S. aureus, E. faecalis, P. mirabilis, Enterobacter cloacae, P. vulgaris, S. typhii, E. aerogenes, Helicobacter pylori, K. pneumonia, P. aeruginosa.* Fungicide: *Rhizoctonia solani, Botrytis cinerea, C. albicans.* Insecticide: chitin synthesis inhibitor	3	4-cyclopentene-1,3-dione	Fr (Ec)	(Basile et al. 2010; Mokhtari et al. 2018)
Kunzea ericoides (A.Rich.) Joy Thomps.	Bactericide: *C. tropicalis, S. aureus, Streptococcus mutans, Streptococcus sobrinus, E. coli.* Fungicide: *Malassezia furfur, Trichosporon mucoides, C. albicans, C. tropicalis.* Insecticide: lethal on *Drosophila suzukii.*	3	α-pinene, p-cymene	Ae (EO)	(Van Vuuren et al. 2014; Chen et al. 2016; Park et al. 2017)
Leptospermum brachy&rum (F.Muell.) Druce	Fungicide: *Fussarium* spp.	1	α-pinene, b-caryophyllene, terpinen-4-ol	L (EO)	(Brophy et al. 1998)
Leptospermum madidum A.R.Bean	Bactericide: *B. cereus, S. aureus, E. coli*	1	α-pinene, β-pinene, α-humulene, 1,8-cineole	L (EO)	(Demuner et al. 2011)
Leptospermum petersonii F.M.Bailey	Bactericide: *S. aureus, Staphylococcus epidermidis, Mycobacterium smegmatis, E. faecalis, S. pyogenes, Streptococcus agalactiae, S. pneumonia, C. acnes, Brevibacillus brevis, Bacillus agri, Bacillus laterosporum, Moraxella catarrhalis, P. aeruginosa, K. pneumoniae.* Fungicide: *C. albicans.* Insecticide: *Plutela xylostella*	3	Citronellal, citronellol, neral, geranial	Ae (EO)	(Van Vuuren et al. 2014; Park et al. 2017)
Leptospermum polygalifolium Salisb.	Bactericide: contains potentially antibacterial compounds.	1	α-pinene, β-pinene, limonene, 1,8-cineole, γ-terpinene, p-cymene, terpinen-4-ol	L (EO)	(Brophy et al. 1998; Windsor and Brooks 2012)

Leptospermum scoparium J.R.Forst. & G.Forst.	Bactericide: *S. aureus, S. mutans, S. sobrinus, E. coli*. Fungicide: *M. furfur, T. mucoides, C. albicans, C. tropicalis*. Herbicide: inhibitory effect of growth and pigment content of *Amaranthus retroflexus, Abutilon theophrasti*, *Calendula arvensis, Sesbania exaltata, E. crus-galli*, and large crabgrass. Insecticide: larvacidal against *Aedes aegypti* larvae.	4	Leptospermone, calamenene, flavesone	L (EO)	(Dayan et al. 2011; Chen et al. 2016; Park et al. 2017)
Lophostemon confertus (R.Br.) Peter G.Wilson & J.T.Waterh.	Bactericide: contains potentially antibacterial compounds.	1	α-pinene, α-thujene	L (EO)	(Siani et al. 2016)
Lophostemon suaveolens (Sol. ex Gaertn.) Peter G. Wilson & J.T.Waterh.	Bactericide: *S. aureus.* Fungicide: *C. albicans.*	2	Aromadendrene, spathulenol, β-caryophyllene, α-humulene, α-pinene	L (Ec)	(Packer et al. 2015; Naz et al. 2016)
Melaleuca alternifolia (Maiden & Betche) Cheel	Bactericide: *Acinetobacter baumannii, Micrococcus luteus, Actinomyces viscosus, B. cereus, E. faecalis, Porphyromonas gingivalis, Enterococcus. faecium, E. coli, K. pneumonia*, MRSA, *P. vulgaris, S. epidermidis, P. aeruginosa*. Fungicide: *A. flavus, Aspergillus fumigatus, A. niger, C. albicans, Saccharomyces cerevisae.* Insecticide: Inhibitor of detoxifying enzymes, glutathione S-transferase (GST), carboxylesterase (CarE), and nerve conduction enzyme, acetylcholinesterase (AChE) of *S. zeamais*.	3	Terpinene-4-ol, γ-terpinene, α-terpinene	L (EO)	(Carson et al. 2006; Liao et al. 2016)
Melaleuca armillaris (Sol. ex Gaertn.) Sm.	Bactericide: *B. subtilis subsp. spizizenii, S. aureus, E. aerogenes, E. coli, Salmonella enterica, K. pneumonia, P. aeruginosa*. Fungicide: *A. niger, A. flavus, F. oxysporum, Fusarium solani, Penicillium digitatum.*	2	Eugenol methyl ether, p-cymene, α-terpineol	L (EO)	(Siddique et al. 2017)
Melaleuca bracteata F.Muell.	Bactericide: *S. typhimurium, S. epidermidis, B. subtilis, S. aureus, K. pneumonia, S. mutans.* Fungicide: *A. flavus.* Herbicide: inhibitory effect of germination, seedling development, and chlorophylls content of *Panicum virgatum, Digitaria longiflora, Stachytarpheta indica, Aster subulatus.* Insecticide: adulticidal against *Tribolium castaneum.*	4	Methyl eugenol, (E)-methyl cinnamate, methyl chavicol, elemicin	L (EO)	(Almarie et al. 2016; Goswami et al. 2017; Siddique et al. 2017; Yasin et al. 2021)
Melaleuca cajuputi Maton & Sm. ex R.Powell	Bactericide: *B. cereus, S. aureus, S. epidermidis.* Fungicide: *A. niger*. Herbicide: trigger the chlorosis to necrosis, inhibit the height of *E. crus-galli.* Insecticide: repellent effect, lethal effect on *Camponotus* sp.	4	1,4-naphthalenedione, 4H-1-benzopyran-4-one, ethanone, 1,8-cineole, α-pinene	L (EO)	(Al-Abd et al. 2015; Visheenta et al. 2018; Kueh et al. 2019; Wińska et al. 2019)

Melaleuca citrina (Curtis) Dum. Cours. (synonym *Callistemon citrinus*)	Bactericide: *S. faecalis, B. cereus, Serratia marcesens, P. aeruginosa, B. subtilis, E. coli, P. mirabilis, S. aureus, Agrobacterium tumefaciens, Erwinia carotovora, Pseudomonas syringae, Ralstonia solanacearum, Xanthomonas axonopodis pv. malvacearum, X. campestris pv. vesicatoria, X. oryzae pv. oryzae.* Fungicide: *Phaeoramularia angolensis.* Herbicide: competitive inhibitor of the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD) of *Xanthium strumarium, A. theophrasti, Ambrosia trifida, Chenopodium, Amaranthus, Polygonum, Digitaria, Echinochloa.* Insecticide: larvacidal against *Ae. aegypti, Cx. quinquefasciatus.*	4	1,8-cineole, α-pinene, carbohydrates, proteins,tannins, phytosterols, coumarins, quinones, flavanones, saponins	L (EO)	(Mitchell et al. 2001; Jazet et al. 2008; Kavitha and Satish 2013; Oyedeji et al. 2014; An et al. 2020)
Melaleuca decora (Salisb.) Britten	Bactericide: *K. pneumonia, B. cereus, E. coli, P. aeruginosa.* Fungicide: *S. cerevisae*	2	n.a.	Ae (Ec)	(Touqeer et al. 2014)
Melaleuca leucadendra (L.) L.	Bactericide: MRSA, *E. aerogenes, E. coli.* Fungicide: *F. oxysporum, Thanatephorus cucumeris, R. oryzae.* Herbicide: inhibitory effect of germination, growth, and chlorophyll content of *E. crus-galli, Cyperus rotundus, Leptochloa chinensis.* Insecticide: larvacidal on *Ae. aegypti, Cx. quinquefasciatus.*	4	α-eudesmol, guaiol, 1,8-cineole, α-terpineol, (E)-methyl cinnamate, (Z)-nerolidol	B, L (EO)	(Goyal, 2017; An et al. 2020; Patramurti et al. 2020)
Melaleuca linearis var. *linearis*(synonym *Callistemon rigidus*)	Bactericide: *S. aureus, E. coli, Pseudomonas* spp. Fungicide: *Phaeoramularia angolensis.* Insecticide: larvacidal on *Anopheles gambiae, Ae. aegypti, Cx. quinquefasciatus.*	3	1,8-cineole, α-terpineol, terpinen-4-01	L (EO)	(Saxena and Gomber 2006; Ji et al. 2011; Pierre et al. 2014)
Melaleuca lophantha (Vent.) Ined. (*synonym Callistemon salignus*)	Bactericide: *S. epidermidis.*	1	1,8-cineole, α-pinene, (E)-β-terpineol	L (EO)	(Saxena et al. 2008)
Melaleuca nodosa (Sol. ex Gaertn.) Sm.	Bactericide: contains potentially antibacterial compounds.	1	Leptospermone	L, TB (Ec)	(Senadeera, 2017)
Melaleuca polii (F.M.Bailey) Craven (synonym *Callistemon polii*)	Bactericide: *E. coli, S. aureus, B. cereus*	1	Terpinen-4-ol	L (EO)	(Silva et al. 2010)
Melaleuca quinquenervia (Cav.) S.T.Blake	Bactericide: *E. coli, S. typhimurium, S. aureus, A. faecalis.* Fungicide: *C. albicans.* Herbicide: inhibitory effect of growth of *Lemna aequinoctialis.* Insecticide: larvicidal and growth inhibitory against *Cx. quinquefasciatus, Ae. aegypti, Aedes albopictus*.	4	1.8 cineol, α-pinene, β-pinene, aterpineol, limonene, hydroxylated sesquiterpenoid, viridiflorol	L (EO)	(Allan and Adkins 2005; Wilkinson and Cavanagh 2005; Leyva et al. 2016)
Melaleuca rugulosa (Link) Craven (synonym *Callistemon coccineus*)	Bactericide: *S. aureus, S. epidermidis, S. mutans, E. faecalis, K. pneumoniae, P. aeruginosa, E. aerogenes, E. coli.* Fungicide: *C. albicans, Cryptococcus neoformans, A. flavus, A. niger, Sporothrix schenckii, Trichophyton.rubrum.*	2	1, 8-cineole, α-pinene, (E)-β-terpineol	L (EO)	(Maurya et al. 2009)
Melaleuca styphelioides Sm.	Bactericide: *S. aureus, Streptococcus faecalis, B. subtilis, E. coli, P. aeruginosa, S. epidermidis, K. pneumonia, P. vulgaris.* Fungicide: *A. niger, Rhizopus nigricans, P. digitatum.* Herbicide: inhibitory effect of radicle growth of *R. sativus, Lepidium sativum, S. arvensis, T. durum, Phalaris canariensis.* Insecticide: lethal effect on adults and nymphs of *Aphis gossypi, Aphis spiraecola, Myzus persicae.*	4	Methyl eugenol, spathulenol, caryophyllene oxide	L (EO)	(Amri et al. 2012; Albouchi et al. 2018; Laribi et al. 2021)

Melaleuca trichostachya Lindl.	Bactericide: *B. cereus, Bacillus pumilus, S. aureus, S. faecalis, E. cloacae, E. coli, K. pneumoniae, P. vulgaris, P. aeruginosa, S. marcescens.*	1	Terpinen-4-ol, γ-terpinene, 1,8-cineole, pcymene, α-terpinene, terpinolene, sabinene	L (EO)	(Oyedeji et al. 2014)
Myrciaria floribunda (H.West ex Willd.) O.Berg	Bactericide: *S. aureus, E. coli.* Insecticide: inhibitor of developmental stages and lethal effect on *Rhodnius prolixus* nymphs, estimated LD_{50} 19.51 μg/insect	2	1,8-cineole, linalool, α-Terpineol, β-selinene, β-curcumene, (E)-nerolidol, Selin-11-em-4-α-ol, (2Z,6E)-farnesol	L (EO)	(de Azevedo et al. 2019; Tietbohl et al. 2020)
Plinia cauliflora (Mart.) Kausel	Bactericide: *S. aureus, S. epidermidis, B. subtilis, E. coli.* Fungicide: *C. albicans, C. parapsilosis, C. tropicalis*. Insecticide: larvicidal against *Spodoptera frugiperda* larvae, inhibitor larvae and pupae developmental stages, reducing amount of female adult.	3	Gallic acid, gallocatechin, catechin, epicatechin, ellagic acid, salicylic acid	Fr, L (Ec)	(Souza-Moreira et al. 2010; Alves et al. 2014)
Psidium cattleyanum Sabine	Bactericide: *K. pneumonieae, S. epidermidis*. Fungicide: *C. albicans.* Herbicide: inhibitory effect of the germination and root growth of *L. sativa*	3	α-copaene, eucalyptol, δ-cadinene, α-selinene	L (EO)	(Scur et al. 2016; Antonelli et al. 2020)
Psidium guajava L.	Bactericide: *Bacillus stearothermophilus, Brochothrix thermosphacta, E. coli, L. monocytogenes, Pseudomonas fluorescens, S. enterica, S. aureus, Vibrio cholerae.* Fungicide: *T. rubrum, Trichophyton tonsurans, S. schenckii, M. canis, C. neoformans, C. parapsilosis, C. albicans*. Herbicide: inhibitory effect of germination, seedling development, chlorophylls and carotenoids content of *Parthenium hysterophorus.* Insecticide: lethal effect, locomotor deficit, oxidative stress response signaling on *D. melanogaster*.	4	Morin-3-O-lyxoside, morin-3-O-arabinoside, quercetin, quercetin-3-arabinoside	L (EO)	(Rattanachaikun-sopon and Phumkhachorn 2010; Beatriz et al. 2012; Pinho et al. 2014; Kapoor et al. 2019)
Psidium guineense Sw.	Bactericide: *Mycobacterium tuberculosis*, MRSA. Insecticide: repellent effect on *Anopheles arabiensis* adults.	2	Spathulenol, 1,8-cineole	L (EO)	(Chalannavar et al. 2013; do Nascimento et al. 2018)
Psidium oligospermum Mart. ex DC. (synonim *Psidium sartorianum*)	Fungicide: *T. rubrum, Trichophyton schoenleinii, T. mentagrophytes*.	1	n.a.	Fr (Ec)	(Camacho-Hernández et al. 2004)
Rhodamnia cinerea Jack	Fungicide: *Colletotrichum capsici*.	1		L (Ec)	(Diaguna et al, 2015)
Rhodomyrtus tomentosa (Aiton) Hassk.	Bactericide: *B. cereus, S. typhi, C. acnes.* Fungicide: *C. albicans.* Insecticide: ovicidal and adulticidal activity against *Ae. aegypti.*	3	Flavonoid, triterpenoid, carbohydrate	L, S, T, Fr (Ec)	(Kusuma 2016; Kasinathan et al. 2018)
Syzygium anisatum (Vickery) Craven & Biffin.	Bactericide: *A. faecalis, B. cereus, E. coli, K. pneumonia, P. mirabilis, P. fluorescens, S. aureus, S. epidermidis, Aeromonas hydrophila, S. pyogenes.* Fungicide: *Dekkera anomala, Schizosaccharomyces pombe, S. cerevisiae, C. albicans, Rhodotorula mucilaginosa, C. krusei.* Insecticide: contain potential insecticide compounds.	3	Gallotanin, ellagitannin, p-ropenylanisole, isoestragole	L (Ec)	(Blenau et al. 2012; Bryant and Cock 2016; Alderees et al. 2018)
Syzygium antisepticum (Blume) Merr. & L.M.Perry	Bactericide: *S. aureus*, MRSA.	1	β-caryophyllene	L (Ec)	(Yuan and Yuk,2018)

Syzygium aqueum (Burm.f.) Alston	Bactericide: *S. aureus, B. subtilis, E. coli, P. aeruginosa.*	1	Alkaloid, tannins, glycosides, formic acid, tartaric acid, flavonoids, steroids	Fr, L (Ec)	(Mapatac and Mamaoag 2014)
Syzygium australe (J.C.Wendl. ex Link) B.Hyl	Bactericide: *A. hydrophila, A. feacalis, B. cereus, B. subtilis, C. freundii, E. aerogenes, E. coli, K. pneumoniae, P. aeuroginosa, P. fluorescens, S. salford, S. marcescens, S. aureus, Y. enterocolitia.* Fungicide: *S. cerevisiae*	2	1-vinylheptanol, 2-ethyl-1-hexanol, 2-heptyl-1,3-dioxolane, 1-methyloctyl butyrate	Fr, L (Ec)	(Sautron and Cock 2014; Noé et al. 2019)
Syzygium cumini (L.) Skeels	Bactericide: *S. aureus, E. coli, P. aeruginosa, B. subtilis* Fungicide: *C. albicans.* Herbicide: inhibitory effect of growth of canary grass and wheat. Insecticide: *P. xylostella.*	4	n.a.	L, B, Sd (Ec)	(Yousaf et al. 2014; Elfadil et al. 2015; Minj et al, 2017)
Syzygium filiforme Chantaran. & J.Parn.	Bactericide: *E. coli, S. aureus, B. subtilis.*	1	Arjunolic acid, alphitolic acid, ursolic acid	SB (Ec)	(Ahmad, 2015)
Syzygium jambos (L.) Alston	Bactericide: *S. aureus, B. subtilis, E. coli, K. pneumoniae, P. vulgaris, P. aeruginosa, S. typhi, V. cholerae.* Fungicide: *C. albicans, Microsporum gypseum, T. rubrum, T. mentagrophytes.*	2	Tannin	B, L, Sd (Ec)	(Murugan et al. 2011; Noé et al. 2019)
Syzygium malaccense (L.) Merr. & L.M. Perry	Bactericide: *S. aureus, B. subtilis, E. coli, P. aeruginosa*	1	Flavonoid, tannin, quinone, phenol, steroid	L (Ec)	(Yuniarni et al. 2020)
Syzygium myrtifolium Walp.	Bactericide: *S. aureus, E. coli.*	1	Alkaloids, triterpenoids, steroids, saponins.	L (Ec)	(Haryati and Saleh 2015)
Syzygium nervosum A. Cunn. ex DC.	Bactericide: *E. faecalis.* Fungicide: *C. albicans.* Insecticide: larvacidal against *Ae. Aegypti*, *Cx. Quinquefasciatus* larvae.	3	(Z)-β-ocimene, caryophyllene oxide, (E)-caryophyllene, α-pinene	L (EO)	(An et al. 2020)
Syzygium polyanthum (Wight) Walp.	Bactericide: *S. aureus, E. coli, P. aeruginosa, B. subtilis.* Fungicide: *C. albicans.* Insecticide: larvacidal against *Aedes* spp. instar III-IV.	3	Alkaloid, carbohydrate, tannin, steroid, triterpenoid, flavonoid.	L, Fr (Ec)	(Kusuma et al. 2011; Ramadhania et al. 2018; Tri and Ilham 2020)
Syzygium polycephalum (Miq.) Merr. & L.M.Perry	Bactericide: *P. aeruginosa*	1	n.a.	L (Ec)	(Yuniarni et al. 2020)
Syzygium racemosum (Blume) DC.	Bactericide: *S. aureus, E. coli, S. typhii.* Fungicide: *Aspergillus ochraceus, P. digitatum.* Insecticide: synergistic effect with *Citrus sinensis*–chlorpyrifos caused mortality on *S. zeamais.*	3	Eugenol, myrcene, chavicol, limonene, 1,8-cineole	L (EO)	(Alitonou et al. 2012; Brito et al. 2020)
Xanthostemon chrysanthus (F.Muell.) Benth.	Bactericide: *B. cereus, P. aureus, S. pneumonia, P. aeruginosa, E. coli.*	1	n.a.	B (Ec)	(Setzer et al. 2001; Paosen et al. 2017)

Table 2. List of species of Myrtaceae from CBG that have a high potentially botanical pesticides

Genus	Species	Conservation status	Origin
Backhousia	*Backhousia citriodora* F. Muell.	-	Queensland
Eucalyptus	*Eucalyptus camaldulensis* Dehnh.	NT	Australia
	Eucalyptus cinerea F.Muell. ex Benth.	NT	New South Wales and Victoria
	Eucalyptus exserta F.Muell.	LC	Queensland and New South Wales
	Eucalyptus globulus subsp. *Maidenii* (F.Muell.) J.B.Kirkp.	LC	Victoria and Tasmania
	Eucalyptus saligna Sm.	LC	Queensland, New South Wales
	Eucalyptus tereticornis Sm.	LC	New Guinea and Australia
	Eucalyptus urophylla S.T.Blake	EN	Lesser Sunda Island
Leptospermum	*Leptospermum scoparium* J.R. Forst. & G.Forst.	LC	Australia and New Zealand
Melaleuca	*Melaleuca bracteata* F.Muell.	-	Australia
	Melaleuca cajuputi Maton & Sm. ex R.Powell	LC	Indo-China to North Northern Territory
	Melaleuca citrina (Curtis) Dum. Cours.	-	East and South East Australia
	Melaleuca leucadendra (L.) L.	-	Maluku to North Australia
	Melaleuca quinquenervia (Cav.) S.T.Blake	LC	New Guinea, New Caledonia and East Australia
	Melaleuca styphelioides Sm.	LC	South East Queensland to New South Wales
Psidium	*Psidium guajava* L.	LC	Tropical and Subtropical America
Syzygium	*Syzygium cumini* (L.) Skeels	LC	Tropical and Subtropical Asia to North Queensland.

Note: NT (near threatened), LC (least concern), EN (endangered)

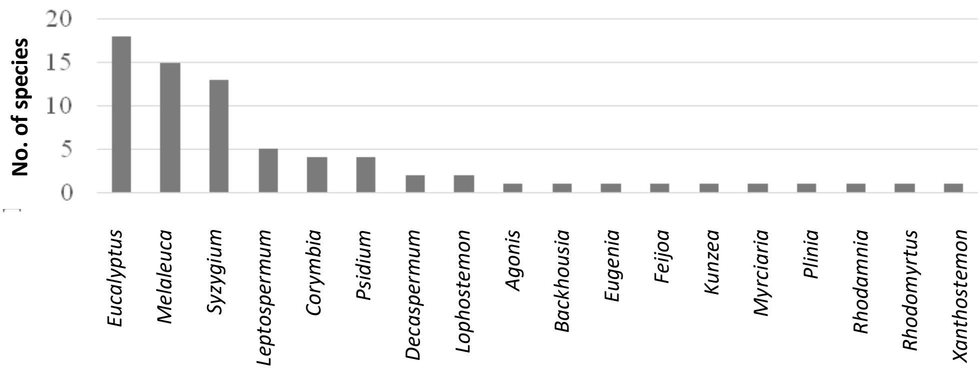

Figure 1. The distribution of genera of Myrtaceae from CBG that have botanical pesticide properties

Discussion

Myrtaceae can be distinguished from other families by scaly bark, scented leaves that contain oil gland dots, flat-leaf edges, inframarginal venation, numerous, brightly and conspicuous stamens, and inferior ovary position which is often fused with hypanthium (Singh 2010). Some of the valuable products from Myrtaceae include timber, EOs, spices, fruits, natural dyes, ornamental plants, animal feed, and folk medicines such as antibacterial, antidiabetic, antidiarrheal, and antioxidants) (Mitra et al. 2012; Kuspradini et al. 2019). The research about ethnobotany at Sesaot protected forest, West Nusa Tenggara, Indonesia revealed that Myrtaceae (represented by *Syzygium*; the highest important value's index in the primary forest of Sesaot) is the most widely family utilized by community as plant-based treatment for various diseases, source of food as edible fruits, drinks, or jelly, and building material (Hidayat 2017).

The promising biological activities of Myrtaceae attributed to its secondary metabolites contents in the form of EOs. Plants elicited a plentiful number of secondary metabolites as a strong defense response to counteract pest and pathogen attack, attractant of pollinators and symbionts, and plant-plant communication. An interesting study about *Ocimum kilimandscharicum* (Lamiaceae) found these plants increased the production of its secondary metabolites during *Helicoverpa armigera* infestation. Moreover, these metabolites have been studied able to retard larval growth and induce pupal deformities. However, many of the plant-related defense compounds are autotoxic to plant metabolism (Singh et al. 2014). Thus, Myrtaceae which have similar defense mechanisms, stored the secondary metabolites for long-term protection in separated cellular structures such as oil glands that avoid it contaminate the key physiological processes. Even in *E. brevistylis*, a novel finding was found that there are two foliar oil gland types, translucent and golden-brown, with different abundances which may reflect the different herbivores present (Goodger et al. 2018).

From Figure 1 and Table 2, it can be noticed that the *Eucalyptus* is the one that has received more attention in terms of its pesticide potency. Knowledge about EOs from *Eucalyptus* has been mapped. The observations regarding the folk utilization of eucalyptus oil against pathogens for hundreds of years have become the basis for the development of pesticides, as well as systematic screening followed by biological tests in order to determine the active compounds (Regnault-Roger and Philogène 2008). Major phytochemical content of eucalyptus oil such as 1,8-cineole, citronellal, citronellol, citronellyl acetate, p-cymene, eucamalol, limonene, linalool, a-pinene, g-terpinene, a-terpineol, alloocimene, and aromadendrene which act synergistically to bring a wide spectrum of fungicide, bactericide, insecticide, acaricide, and nematicide (Batish et al. 2008). EOs from *Eucalyptus* and Myrtaceae in general are relatively well-investigated experimentally and clinically as well as used extensively in modern pharmaceuticals and perfumery industries. Many studies evaluated their toxicity on mammals and put them on low-risk products (Ebadollahi 2013).

Eucalyptus oil, as well as *Melaleuca* and *Rhodamnia* extract can inhibit several types of pathogens such as bacteria and fungi that attack plant commodities, besides as inhibitors of microorganisms that cause disease in humans and animals. Some interesting examples include *Pectobacterium carotovorum* (formerly classified as *Erwinia carotopora*) which is a pathogen on cabbage, tomatoes, eggplant, and nepenthes (Lee et al. 2014), *Xanthomonas axonopodis* on citrus (Petrocelli et al. 2012), *X. campestris* on cruciferous plants (Vicente and Holub 2013), *X. oryzae* on rice (Lang et al. 2019), *Fusarium oxysporum* on banana (Maymon et al. 2020), *F. solani* on guava (Ingle 2017), *Agrobacterium tumefasciens* causing crown galls and hairy roots of over 20 different fruit trees (Smith and Townsend 2019), *Ralstonia solanacearum* on potato (Álvarez et al. 2019), *Rhizoctonia solani* (teleomorph: *Thanatephorus cucumeris*) on sugar beet (Windels et al. 1997), and *Colletotrichum capsici* on chili (Saxena et al. 2016). Thus, it is also expected to protect the collection of nepenthes and another plant collection belonging to CBG.

EOs from *E. urophylla, E. saligna, L. scoparium*, and *M. bracteata* as bioherbicides caused an inhibitory effect of seed germination, shoot and root growth, as well as reducing the amount of pigment content of *Acacia confusa*, *Amaranthus retroflexus*, *Amaranthus viridis*, and *Stachytarpetha indica*. Several species related with these weeds are familiar as invasive alien species (IAS) in CBG, including *Acacia farnesiana* (Junaedi and Mutaqien 2018), *Amaranthus spinosus* (Handayani et al. 2021), and *Stachytarpheta jamaicensis* (Handayani and Hidayati 2020). The EOs probably had a similar prospective to control the IAS in the CBG.

EOs as a botanical pesticide is most probably used under controlled environmental conditions only. It is unlikely for field-scale application considering the rapid volatility and low persistence in the environment due to the easy degradation of ultraviolet light or elevated temperatures (Ebadollahi 2013). Regarding the low toxicity, botanical pesticides from EOs of Myrtaceae are suitable for urban areas, hospitals, hotels, and offices (Kardinan 2011), such as for controlling mosquitoes (*Ae. aegypti, Ae. albopictus, A. gambiae, A. Arabiensis*, and *Cx. quinquefasciatus*), cockroach (*Blatella germanica*), and fruit flies (*D. melanogaster, D. suzukii*) although it requires a higher application rate and frequent reapplication (Isman, 2016). The application of EOs is also appropriate as a repellent for stored product pests. The EOs from *M. bracteata* leaves, as *Glycosmis lucida* (Rutaceae) and *Juniperus formosana* (Cupressaceae) do, was reported to contain significant repellent agent against *T. castaneum* and *Liposcelis bostrychophila* (Guo et al., 2016; 2017).

EOs application for pesticides can be used as a fumigant, in addition to being a repellent (Nattudurai et al., 2017). Their volatility in the case of aerosols to be used in urban environments is a blessing, in terms of attaching the pesticide vapor to the pest while at the same time quickly disappearing from the environment and leaving no harmful residue on surrounding objects, either plants, food, or humans (Lucia et al., 2009). Especially for controlling *Ae. aegypti*, volatile oil vapor extracted from various *Eucalyptus* (*E. gunnii, E. tereticornis, E. grandis, E. camaldulensis, E. dunnii, E. cinerea, E. saligna, E. sideroxylon, E. globulus* ssp. *globulus*, *E. globulus* ssp. *maidenii*, *E. viminalis* and hybrids of *E. grandis* x *E. tereticornis* and *E. grandis* x *E. camaldulensis*) are toxic to adult of *Ae. aegypti*, with the fastest knockdown time due to *E. viminalis* exposure (4.2 minutes), as good as dichlorvos, the standard knockdown agent (Lucia et al., 2009).

Although there are many literatures that explore the potency of Myrtaceae as a botanical pesticide, the development of plant-based pesticides is actually a long and challenging journey. The flow includes the discovery of plants with pesticide potency (active extraction compounds), optimization (biological evaluation), development (standardized formulation, toxicological assessment, environmental fate and safety), registration and regulatory approval, and commercialization (Luiz de Oliveira et al., 2018). For limited use, local farmers in Sumedang, Indonesia have succeeded in processing attractants from *Melaleuca* with a simple distiller they have made themselves. The EO yield is still in the form of a cloudy, but it is quite effective at trapping flies fruit (Kardinan 2011).

Recently, nanoemulsion technology has been developed as an efficient vehicle to overcome the problem of EOs stability. Nanoemulsion is a liquid dispersion system of two different immiscible liquids with nanometric sizes from 20 to 200 nm. The extremely small size of particles provides a wider surface contact area and resistance against gravity, resulting in a higher degree of delivery and absorption of particles to the target than bulk pesticides. In addition, the physicochemical properties of the coating agents can provide greater affinity with the target tissue and protection against particle degradation. The success stories of nano emulsified EOs in controlling pests included larvicides against *Cx. quinquefasciatus* from eucalyptus oil that emulsified by Tween® 80, as well as insecticides, repellents, acaricides, and anti parasites from EOs nanoemulsions derived from citronella, hairy basil, vetiver, cinnamomum, lavender, rosemary, and pepper tree (Echeverría and Albuquerque, 2019).

Registration and regulatory approval for EOs-based pesticides must follow the guidelines that have been developed in evaluating synthetic pesticides, even though they are considered as low-risk active substances. This includes data on product chemistry, environmental fate, and toxicity on laboratory animals and non-target organisms, including fish, wildlife, pollinator, crop, and ornamental plants. Even some regulatory agencies require efficacy data as well (Isman, 2016). Until the 1990s there was no successful commercialized repellent, let alone EOs-based pesticides, which were successfully commercialized, except for citronella (Isman, 2016). As technology advances, insecticides based on EOs from Myrtaceae along with rosemary oil, peppermint, cinnamon, thyme, and 2-phenethyl propionate have been developed into the commercial brand by EcoSMART® USA (https://ecosmart.com/). In China, eucalyptol has been registered as an insecticide and fungicide. 1,8-cineole from Eucalyptus has been approved as an insecticide in India. In Australia, EOs from tea tree (Melaleuca) are also approved as insecticides and miticides (Isman, 2016).

Even the EOs are harmless and effective, the price remains an important consideration while the EOs will be brought into the commercialization stage. The price of EOs varies and depends on quality, source, and geographic area (related to expenditure for land and labor) (Isman, 2016). In addition, the issue of EOs extraction which spent a huge amount of plant sources and cost should not be ignored (Ebadollahi 2013). In our research, several species of Myrtaceae have been tested from other parts, such as sap, kino exudate, or crude leaf extract. It is necessary to carefully calculate the cost of extracting these sources compared to EOs extraction to determine which method is the most efficient.

On the other hand, the attention of the high potency of the plant-derived pesticide risks the plant population's existence in the wild for the long term. Meanwhile, sustainability of the botanical resource in large volumes is the main requirement in the commercialization of pesticides (Isman 2005). In general, the risk of utilized plants can be evaluated based on the followed categories: low risk (high potential for sustainable use), medium risk, and high risk. The plants that utilized by fruit and foliage harvesting are categorized as low-risk plants because it is not destroying the plants seriously. The plants utilized by fruit and foliage harvesting are categorized as low-risk plants because it does not seriously destroy the plants. Logging the plants for building material and firewood put them at a high-risk of extinction (Hidayat 2017). Myrtaceae parts used as a source of EOs are mostly leaves, some fruits and flowers. Based on the categories above, the usability of Myrtaceae generally as botanical pesticide will drive them on low to moderate risk. However, this assessment may be different for Myrtaceae that have been classified as threatened plants, such as *E. urophylla* which is assigned by The RedList IUCN as endangered species (Hills 2019), *E. camaldulensis* (Fensham et al. 2019a) and *E. cinerea* as near-threatened species (Fensham et al. 2019b).

We offer several recommendations in following up on the information from our study. First, optimizing the usability of the high potential plants involving conservation consideration to assurance their sustainability. Various sets of conservation strategies for utilized plants are recommended, such as providing both *in situ* and *ex situ* conservation and formulating good agricultural practices. *In situ* conservation plays a great role because most of the particular biological properties of the plant mainly rely on secondary metabolites secretion as a response to natural environmental stimuli, which may not be expressed under culture conditions. As an *ex-situ* conservation institution, botanic gardens play important roles by developing the protocol for domestication, variety breeding, and cultivation, while the seed banks help store the genetic diversity of plants. Some implementation of good agricultural practices are organic farming and leaves and flower harvesting as a more sustainable resource instead of destructive root and whole-plant harvesting (Chen et al. 2016). Second, exploring many species listed here in order to avoid overexploitation of a particular species, such as *E. exserta, E. globulus, E. saligna, E. tereticornis, L. scoparium, M. cajuputi, M. quinquinervia, M. styphelioides, P. guajava,* and *S. cumini* whose populations were estimated quite stable. Although it is important to emphasize that *E. globules* (CABI 2015), *L. scoparium* (CABI 2012), *M. quinquinervia* (CABI 2007, 2013a), *P. guajava* (CABI 2013b), and *S. cumini* (CABI 2008) are invasive alien plants, so the risk analysis in their cultivation must to be considered. Third, investigating the 51 species of Myrtaceae at CBG whose potency is still not revealed due to limited research report, including *E. argillaceae, E. capitellata, E. deanei, E. dwyeri, E. foecunda, E. johnstonii, E. macandra, E. nigra, E. obtusiflora, E. pilularis, E. piperita, E. platyphylla,* and *E. racemosa* (*Eucalyptus*), *M. formosa, M. glauca,* and *M. williamsii* (*Melaleuca*), *S. acuminatissimum, S. acutangulum, S. ampliflorum, S. cerasiforme. S. claviflorum, S. cymosum, S. discophorum, S. formosum, S. furfuraceum, S. garciniifolium, S. glabratum, S. glomeratum, S. hemilamprum, S. laxiflorum, S. macromyrtus, S. magnolifolium, S. microcymum, S. nigricans, S. paucipunctatum, S. polycephaloides, S. pseudomalaccense, S. punctulatum, S. pycnanthum, S. rostratum, S. syzygioides, S. uniflorum,* and *S. versteegii* (*Syzygium*), *C. gummifera, C. leichhardtii* (*Corymbia*), *L. wooroonooran, L. javanicum* (*Leptospermum*), *Eugenia expansa, Jambosa anastomosans, Myrcia subcordata,* and *Tristaniopsis laurina*.

To conclude, CBG is a great source of germplasm for the development of botanical pesticides. Our result showed that 73 species of Myrtaceae (from 18 genera) from CBG are potential to be botanical pesticide sources. In addition, 17 species considerably have high potency. Most of them belong to the *Eucalyptus* and *Melaleuca*, followed by *Backhousia*, *Leptospermum, Psidium*, and *Syzygium*. The data resulted from this study is expected to serve as baseline information for further research about the formulation, efficacy, and conservation management of botanical pesticides from Myrtaceae for sustainable use. Furthermore, the development of biological pesticides is a step to improve the quality of Indonesian export products to increase national competitiveness in the globalization era nowadays.

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REFERENCES

Aguiar RW de S, Ootani MA, Ascencio SD, Ferreira TPS, Santos MM dos, Santos GR dos. 2014. Fumigant antifungal activity of *Corymbia citriodora* and *Cymbopogon nardus* essential oils and citronellal against three fungal species. Sci World J 2014: 1-8. DOI: 10.1155/2014/492138

Ahmad MH. 2015. Chemical Constituents and Biological Activities of *Syzygium filiforme* var. filiforme Stem Bark. [Thesis]. Universiti Teknologi MARA. [Malaysia]

Akter K, Barnes EC, Brophy JJ, Harrington D, Community Elders Y, Vemulpad SR, Jamie JF. 2016. Phytochemical profile and antibacterial and antioxidant activities of medicinal plants used by Aboriginal people of New South Wales, Australia. Evid-Based Complement Altern Med 2016: 1-14. DOI: 10.1155/2016/4683059

Al-Abd NM, Mohamed Nor Z, Mansor M, Azhar F, Hasan MS, Kassim M. 2015. Antioxidant, antibacterial activity, and phytochemical characterization of *Melaleuca cajuputi* extract. BMC Complement Altern Med 15 (1): 385. DOI: 10.1186/s12906-015-0914-y

Albouchi F, Ghazouani N, Souissi R, Abderrabba M, Boukhris-Bouhachem S. 2018. Aphidicidal activities of *Melaleuca styphelioides* Sm. essential oils on three citrus aphids: *Aphis gossypii Glover; Aphis spiraecola Patch* and *Myzus persicae* (Sulzer). S Afr J Bot 117: 149-154. DOI: 10.1016/j.sajb.2018.05.005

Alderees F, Mereddy R, Webber D, Nirmal N, Sultanbawa Y. 2018. Mechanism of action against food spoilage yeasts and bioactivity of *Tasmannia lanceolata, Backhousia citriodora* and *Syzygium anisatum* plant solvent extracts. Foods 7 (11): 179. DOI: 10.3390/foods7110179

Alitonou GA, Noudogbessi J-P, Sessou P, Avlessi F, Menut C, Sohounhloue DCK. 2012. Chemical composition and biological activities of essential oils of *Pimenta racemosa* (Mill.) J. W. Moore. from Benin. Intl J Biosci 2 (9): 1-12.

Allan SM, Adkins SW. 2005. Searching for a natural herbicide: The role of medicinal plants? Establishing the Scientific Base. Proc 4th World Cong Allelopath. Charles Sturt University, New South Wales, 21-26 August. [Australia].

Almarie A, Mamata A, Rukunudina I. 2016. Chemical composition and herbicidal effects of *Melaleuca bracteata* F. Muell. essential oil against some weedy species. Intl J Sci Eng Res 7 (1): 507-514.

Álvarez B, López MM, Biosca EG. 2019. Biocontrol of the major plant pathogen *Ralstonia solanacearum* in irrigation water and host plants by novel waterborne lytic bacteriophages. Front Microbiol 10 (2813): 1-17. DOI: 10.3389/fmicb.2019.02813

Alves APC, Corrêa AD, Alves DS, Saczk AA, Lino JBR, Carvalho GA. 2014. Toxicity of the phenolic extract from jabuticabeira (*Myrciaria cauliflora* (Mart.) O. Berg) fruit skins on *Spodoptera frugiperda*. Chil J Agric Res 74 (2): 200-204. DOI: 10.4067/S0718-58392014000200011

Ambrosio CMS, de Alencar SM, de Sousa RLM, Moreno AM, Da Gloria EM. 2017. Antimicrobial activity of several essential oils on pathogenic and beneficial bacteria. Ind Crops Prod 97: 128-136. DOI: 10.1016/j.indcrop.2016.11.045

Amri I, Mancini E, De Martino L, Marandino A, Lamia H, Mohsen H, Bassem J, Scognamiglio M, Reverchon E, De Feo V. 2012. Chemical composition and biological activities of the essential oils from three *Melaleuca* species grown in Tunisia. Intl J Mol Sci 13 (12): 16580-16591. DOI: 10.3390/ijms131216580

An NTG, Huong LT, Satyal P, Tai TA, Dai DN, Hung NH, Ngoc NTB, Setzer WN. 2020. Mosquito larvicidal activity, antimicrobial activity, and chemical compositions of essential oils from four species of Myrtaceae from Central Vietnam. Plants 9 (4): 544. DOI: 10.3390/plants9040544

Antonelli L, Morelli TM, Yockey K, Miyake B, Talia M, Sinclair T, Marahatta SP. 2020. Utilizing *Psidium cattleianum* leaves as a pre-emergent bio-herbicide: A Study on its allelopathic effects on the *in vitro* germination of *Lactuca sativa* seeds. Pac Agr Nat Resour 10 (1): 1-4.

Basile A, Conte B, Rigano D, Senatore F, Sorbo S. 2010. Antibacterial and antifungal properties of acetonic extract of *Feijoa sellowiana* fruits and its effect on *Helicobacter pylori* growth. J Med Food 13 (1): 189-195. DOI: 10.1089/jmf.2008.0301

Batish DR, Singh HP, Kohli RK, Kaur S. 2008. Eucalyptus essential oil as a natural pesticide. For Ecol Manag 2562008: 2166-2174. DOI: 10.1016/j.foreco.2008.08.008

Beatriz P-M, Ezequiel V-V, Azucena O-C, Pilar C-R. 2012. Antifungal activity of *Psidium guajava* organic extracts against dermatophytic fungi. J Med Plants Res 6 (41): 5435-5438. DOI:10.5897/JMPR12.240

Bhuyan DJ, Vuong QV, Chalmers AC, van Altena IA, Bowyer MC, Scarlett CJ. 2017. Phytochemical, antibacterial and antifungal properties of an aqueous extract of *Eucalyptus microcorys* leaves. S Afr J Bot 112: 180-185. DOI: 10.1016/j.sajb.2017.05.030

Blenau W, Rademacher E, Baumann A. 2012. Plant essential oils and formamidines as insecticides/acaricides: What are the molecule targets? Apidologie 43 (3): 334-347. DOI: 10.1007/s13592-011-0108-7

Brito VD, Achimón F, Pizzolitto RP, Ramírez Sánchez A, Gómez Torres EA, Zygadlo JA, Zunino MP. 2020. An alternative to reduce the use of the synthetic insecticide against the maize weevil *Sitophilus zeamais* through the synergistic action of *Pimenta racemosa* and *Citrus sinensis* essential oils with chlorpyrifos. J Pest Sci 94 (2): 409-421. DOI: 10.1007/s10340-020-01264-0

Brophy JJ, Goldsack RJ, Forster PI, Bean AR, Clarkson JR, Lepschi BJ. 1998. Leaf essential oils of the genus *Leptospermum* (Myrtaceae) in Eastern Australia. Part 1. *Leptospermum brachyandrum* and *Leptospermum pallidum* groups. Flavour Fragr J 13 (1): 19-25. DOI: 10.1002/(SICI)1099-1026(199801/02)13:1<19::AID-FFJ679>3.0.CO;2-9

Bryant K, Cock IE. 2016. Growth inhibitory properties of *Backhousia myrtifolia* Hook. & Harv. and *Syzygium anisatum* (Vickery) Craven & Biffen extracts against a panel of pathogenic bacteria. Pharmacogn Commun 6(4): 194-203. DOI: 10.5530/pc.2016.4.2

CABI. 2007. *Melaleuca quinquenervia* [original text by Nick Pasiecznik]. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

CABI. 2012. *Leptospermum scoparium* [original text by Ian Popay]. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

CABI. 2013a. *Melaleuca quinquenervia* [original text by Julissa Rojas-Sandoval & Pedro Acevedo-Rodríguez]. In: Invasive Species Compendium. CAB International, Wallingford, UK. www.cabi.org/isc.

CABI. 2013b. *Psidium guajava* [original text by Julissa Rojas-Sandoval & Pedro Acevedo-Rodriguez]. In: Invasive Species Compendium. CAB International, Wallingford, UK. www.cabi.org/isc.

CABI. 2015. *Eucalyptus globulus* [original text by Andrew Praciak]. In: Invasive Species Compendium. CAB International, Wallingford, UK. www.cabi.org/isc.

CABI. 2008. *Syzygium cumini* [original text by Nick Pasiecnik]. In: Invasive Species Compendium. CAB International, Wallingford, UK. www.cabi.org/isc.

Camacho-Hernández IL, Cisneros-Rodríguez C, Uribe-Beltrán MJ, Ríos-Morgan A, Delgado-Vargas F. 2004. Antifungal activity of fruit pulp extract from *Psidium sartorianum*. Fitoter 75 (3-4): 401-404. DOI: 10.1016/j.fitote.2004.01.004

Carson CF, Hammer KA, Riley TV. 2006. *Melaleuca alternifolia* (tea tree) oil: A Review of antimicrobial and other medicinal properties.

Clin Microbiol Rev 19 (1): 50-62. DOI: 10.1128/CMR.19.1.50-62.2006

Chalannavar RK, Hurinanthan V, Singh A, Venugopala KN, Gleiser RM, Baijnath H, Odhav B. 2013. The antimosquito properties of extracts from flowering plants in South Africa. Trop Biomed 30 (4): 559-569.

Chen C-C, Yan S-H, Yen M-Y, Wu P-F, Liao W-T, Huang T-S, Wen Z-H, David Wang H-M. 2016. Investigations of kanuka and manuka essential oils for *in vitro* treatment of disease and cellular inflammation caused by infectious microorganisms. J Microbiol Immunol Infect 49 (1): 104-111. DOI: DOI: 10.1016/j.jmii.2013.12.009

Chen S.-L, Yu H, Luo H-M, Wu Q, Li C-F, Steinmetz A. 2016. Conservation and sustainable use of medicinal plants: Problems, progress, and prospects. Chin Med 11 (37): 1-10. DOI: 10.1186/s13020-016-0108-7

Chung PY, Chung LY, Ngeow YF, Goh SH, Imiyabir Z. 2004. Antimicrobial activities of Malaysian plant species. Pharm Biol 42 (4-5): 292-300. DOI: 10.1080/13880200490511837

Cimanga K, Apers S, de Bruyne T, Van Miert S, Hermans N, Totté J, Pieters L, Vlietinck AJ, Kambu K, Tona L. 2002a. Chemical composition and antifungal activity of essential oils of some aromatic medicinal plants growing in the Democratic Republic of Congo. J Essent Oil Res 14 (5): 382-387. DOI: 10.1080/10412905.2002.9699894

Cimanga K, Kambu K, Tona L, Apers S, De Bruyne T, Hermans N, Totté J, Pieters L, Vlietinck AJ. 2002b. Correlation between chemical composition and antibacterial activity of essential oils of some aromatic medicinal plants growing in the Democratic Republic of Congo. J Ethnopharmacol 79 (2): 213-220. DOI: 10.1016/s0378-8741(01)00384-1

da Cunha FAB, Wallau GL, Pinho AI, Nunes MEM, Leite NF, Tintino SR, da Costa GM, Athayde ML, Boligon AA, Coutinho HDM. 2015. *Eugenia uniflora* leaves essential oil induces toxicity in *Drosophila melanogaster*: involvement of oxidative stress mechanisms. Toxicol Res 4 (3): 634-644. DOI: 10.1039/C4TX00162A

Dayan FE, Howell J, Marais JP, Ferreira D, Koivunen M. 2011. Manuka oil, a natural herbicide with preemergence activity. Weed Sci 59 (4): 464-469.

de Andrade Santiago J, das Graças Cardoso M, da Cruz FA, Palmieri MJ, de Souza RV, Soares LI, de Campos JMS, Andrade-Vieira LF. 2017. Cytogenotoxic effect of essential oil from *Backhousia citriodora* L. (Myrtaceae) on meristematic cells of *Lactuca sativa* L. S Afr J Bot 112: 515-520.

de Azevedo MML, Cascaes MM, Guilhon GMSP, Andrade EHA, Zoghbi M das GB, da Silva JKR, Santos LS, da Silva SHM. 2019. Lupane triterpenoids, antioxidant potential and antimicrobial activity of *Myrciaria floribunda* (H. West ex Willd.) O. Berg. Nat Prod Res 33 (4): 506-515. DOI: 10.1080/14786419.2017.1402311

Demuner AJ, Almeida LCB, Gonçalves CM, Da Silva CJ, Alvares CRM, Lelis PA. 2011. Seasonal variation in the chemical composition and antimicrobial activity of volatile oils of three species of *Leptospermum* (Myrtaceae) grown in Brazil. Mol 16 (2): 1181-1191. DOI: 10.3390/molecules16021181

Diaguna R, Inonu I, Kusmiadi R. 2015. Aplikasi ekstrak daun merapin (*Rhodamnia cinerea*) untuk menghambat *Colletotrichum capsici* pada benih cabai. Enviagro: J Pertan Lingkung 8(1): 1–9. [Indonesian]

do Nascimento KF, Moreira FMF, Alencar Santos J, Kassuya CAL, Croda JHR, Cardoso CAL, Vieira M do C, Góis Ruiz ALT, Ann Foglio M, de Carvalho JE, Formagio ASN. 2018. Antioxidant, anti-inflammatory, antiproliferative and antimycobacterial activities of the essential oil of *Psidium guineense* Sw. and spathulenol. J Ethnopharmacolog 210: 351-358. DOI: 10.1016/j.jep.2017.08.030

Ebadollahi A. 2013. Essential oils isolated from Myrtaceae family as natural insecticides. Annual Rev Res Biol 3 (3): 148-175.

Ebadollahi A, Setzer WN. 2020. Analysis of the essential oils of *Eucalyptus camaldulensis* Dehnh. and *E. viminalis* Labill. as a contribution to fortify their insecticidal application. Nat Prod Commun 15 (9): 1934578X2094624. DOI: 10.1177/1934578X20946248

Echeverría J, Albuquerque R. 2019. Nanoemulsions of essential oils: New tool for control of vector-borne diseases and *in vitro* effects on some parasitic agents. Med 6 (2): 42. DOI: 10.3390/medicines6020042

Elaissi A, Rouis Z, Mabrouk S, Salah KBH, Aouni M, Khouja ML, Farhat F, Chemli R, Harzallah-Skhiri F. 2012. Correlation between chemical composition and antibacterial activity of essential oils from fifteen eucalyptus species growing in the Korbous and Jbel Abderrahman arboreta (North East Tunisia). Mol 17 (3): 3044-3057. DOI: 10.3390/molecules17033044

Elfadil AG, Karamallah AA, Abualhassan AM, Hamid AA, Sabahelkhier MK. 2015. Antimicrobial activities of *Syzygium cumini* leave extracts against selected microorganisms. Nova J Med Biol Sci 4 (2): 1-10. DOI:10.20286/nova-jmbs-040245

Fang B, Yu S, Wang Y, Qiu X, Cai C, Liu S. 2009. Allelopathic effects of *Eucalyptus urophylla* on ten tree species in south China. Agrofor Syst 76 (2): 401-408. DOI: 10.1007/s10457-008-9184-8

Fensham R, Laffineur B, Collingwood T. 2019a. *Eucalyptus camaldulensis*. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/.

Fensham R, Laffineur B, Collingwood T. 2019b. *Eucalyptus cinerea*. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/.

Garba J. 2016. Identification of Malaysian Lemon Myrtle (*Backhousia citriodora* f. Muell) Chemical Constituents Responsible for Insecticidal Activity using GC-MC-based Metabolomics. [Thesis]. Universiti Putra Malaysia [Malaysia].

Goodger JQD, Senaratne SL, Nicolle D, Woodrow IE. 2018. Differential metabolic specialization of foliar oil glands in *Eucalyptus brevistylis* Brooker (Myrtaceae). Tree Physiol 38 (10): 1451-1460. DOI: 10.1093/treephys/tpy077

Goswami P, Verma SK, Chauhan A, Venkatesha KT, Verma RS, Singh VR, Darokar MP, Chanotiya CS, Padalia RC. 2017. Chemical composition and antibacterial activity of *Melaleuca bracteata* essential oil from India: A natural source of methyl eugenol. Nat Prod Commun 12 (6): 965-968. 10.1177/1934578X1701200633

Goyal G. 2017. Phytotoxic potential of essential oil of *Melaleuca leucadendra* against some agricultural weeds. Annals Plant Sci 6 (11): 1799. DOI:10.21746/aps.2017.6.11.14

Grichi A, Nasr Z, Khouja ML. 2016. Phytotoxic effects of essential oil from *Eucalyptus cinerea* and its physiological mechanisms. J New Sci 31 (13): 1289-1296.

Guo S, Zhang W, Liang J, You C, Geng Z, Wang C, Du S. 2016. Contact and repellent activities of the essential oil from *Juniperus formosana* against two stored product insects. Mol 2 1(4): 504. DOI: 10.3390/molecules21040504

Guo S-S, Zhang W-J, Yang K, Liang J-Y, You C-X, Wang C-F, Li Y-P, Geng Z-F, Deng Z-W, Du S-S. 2017. Repellence of the main components from the essential oil of *Glycosmis lucida* Wall. Ex Huang against two stored product insects. Nat Prod Res 31 (10): 1201–1204. DOI: 10.1080/14786419.2016.1226825

Handayani A, Hidayati S. 2020. Utilization of Invasive Alien Species (IAS) by communities around Cibodas Biosphere Reserve (CBR): A recommendation for invasive alien species management and policy. IOP Conf Ser Earth Environ Sci 533: 012017. DOI:10.1088/1755-1315/533/1/012017

Handayani A, Zuhud EAM, Junaedi DI. 2021. Assessing the utilization of naturalized alien plant species by community to inform its management strategy: A case study in Cibodas Biosphere Reserve, West Java, Indonesia. Biodivers J Biol Divers 22 (7): 2579-2588. DOI: 10.13057/biodiv/d220705

Haryati NA, Saleh C, Erwin E. 2015. Uji toksisitas dan aktivitas antibakteri ekstrak daun merah tanaman pucuk merah *(Syzygium myrtifolium Walp.)* terhadap bakteri *Staphylococcus aureus* dan *Escherichia coli*. J Kimia Mulawarman 13 (1): 35-40. [Indonesian]

Hidayat S. 2017. The use by local communities of plants from Sesaot Protected Forest, West Nusa Tenggara, Indonesia. Biodivers J Biol Divers 18 (1): 238-247. DOI: 10.13057/biodiv/d180130

Hills R. 2019. *Eucalyptus urophylla*. The IUCN Red Li*st of Threatened Species*. https://www.iucnredlist.org/.

Hussein HS, Salem MZM, Soliman AM. 2017. Repellent, attractive, and insecticidal effects of essential oils from *Schinus terebinthifolius* fruits and *Corymbia citriodora* leaves on two whitefly species, *Bemisia tabaci*, and *Trialeurodes ricini*. Sci Hortic 216: 111-119. DOI : 10.1016/j.scienta.2017.01.004

Ibrahim S. 2011. Biocontrol and allelopathic effects of *Eucalyptus camaldulensis* Dehnh. leaf litter on the growth of green gram (*Vigna radiata* L.) with farmyard manure. Intl J Biol Biotechnol 8 (1): 107-113.

Ingle AP. 2017. Diversity and identity of *Fusarium* species occurring on fruits, vegetables and food grains. Nusant Biosci 9 (1): 44-51. DOI: 10.13057/nusbiosci/n090108

Isman MB. 2005. Problems and opportunities for the commercialization of botanical insecticides. In: Regnault-Roger C, Philogene BJR, Vincent

C (eds) Biopesticides of Plant Origin. Paris, Lavoisier, and Andover, U.K.

Isman MB. 2016. Pesticides Based on Plant Essential Oils: Phytochemical and Practical onsiderations. In V. D. Jeliazkov (Zheljazkov) & C. L. Cantrell (Eds.), ACS Symp Ser 1218: 13-26.

Jazet P, Tatsadjieu LN, Ndongson BD, Kuate J, Zollo A, Menut C. 2009. Correlation between chemical composition and antifungal properties of essential oils of *Callistemon rigidus* and *Callistemon citrinus* of Cameroon against *Phaeoramularia angolensis*. J Med Plants Res 3 (1): 9-15. DOI: 10.5897/JMPR.9000413

Ji X, Pu Q, Garraffo HM, Pannell LK. 1991. The essential oil of the leaves of *Callistemon rigidus* R. Br. J Essent Oil Res 3 (6): 465-466. DOI: 10.1080/10412905.1991.9697989

Junaedi DI, Mutaqien Z. 2018. Predicting invasion probability from botanic gardens using exotic species traits. Biosaintifika: J Biol Biol Education 10 (3): 539-545. DOI: 10.15294/biosaintifika.v10i3.15500

Kapoor D, Rinzim, Tiwari A, Sehgal A, Landi M, Brestic M, Sharma A. 2019. Exploiting the allelopathic potential of aqueous leaf extracts of *Artemisia absinthium* and *Psidium guajava* against *Parthenium hysterophorus*, a widespread weed in India. Plants 8 (12): 552. DOI: DOI: 10.3390/plants8120552

Kardinan A. 2011. Penggunaan Pestisida Nabati sebagai Kearifan Lokal dalam Pengendalian Hama Tanaman Menuju Sistem Pertanian Organik. Pengemb Inov Pertan 4 (4): 262-278. [Indonesian]

Kasinathan M, Subramaniam J, Elanchezhiyan C, Kanthammal S, Vijay M. 2018. Adulticidal and ovicidal activities of *Rhodomyrtus tomentosa* leaf extracts against dengue vector *Aedes aegypti*. Intl J Zool Appl Biosci 3 (2): 224-230.

Kavitha KS, Satish S. 2013. Antibacterial activity of *Callistemon lanceolatus* DC. against human and phytopathogenic bacteria. J Pharm Res 7 (3): 235-240. DOI: 10.1016/j.jopr.2013.03.020

Kueh BWB, Yusup S, Osman N, Ramli NH. 2019. Analysis of *Melaleuca cajuputi* extract as the potential herbicides for paddy weeds. Sustain Chem Pharm 11: 36-40. DOI: 10.1016/j.scp.2018.12.004

Kuspradini H, Putri AS, Egra S, Yanti Y. 2019. Short Communication: *In vitro* antibacterial activity of essential oils from twelve aromatic plants from East Kalimantan, Indonesia. Biodivers J Biol Divers 20(7): 2039-2042. DOI: 10.13057/biodiv/d200733

Kusuma IW. 2016. Search for biological activities from an invasive shrub species rose myrtle (*Rhodomyrtus tomentosa*). Nusant Biosci 8 (1): 55-59. DOI: 10.13057/nusbiosci/n080110

Kusuma IW, Kuspradini H, Arung ET, Aryani F, Min Y-H, Kim J-S, Kim Y. 2011. Biological activity and phytochemical analysis of three Indonesian medicinal plants, *Murraya koenigii*, *Syzygium polyanthum* and *Zingiber purpurea*. J Acupunct Meridian Stud 4 (1): 75-79. DOI: 10.1016/S2005-2901(11)60010-1

Lang JM, Pérez-Quintero AL, Koebnik R, DuCharme E, Sarra S, Doucoure H, Keita I, Ziegle J, Jacobs JM, Oliva R, Koita O, Szurek B, Verdier V, Leach JE. 2019. A pathovar of *Xanthomonas oryzae* infecting wild grasses provides insight into the evolution of pathogenicity in rice agroecosystems. Front Plant Sci 10 (507): 1-15. DOI: 10.3389/fpls.2019.00507

Laribi B, Amri I, Bettaieb T, Hamrouni L. 2021. Phytochemical evaluation and *in vitro* antifungal activities of *Melaleuca styphelioides* leaves: comparison between volatile and non-volatile extracts. Plant Biosyst 155 (1): 54-63. DOI: 10.1080/11263504.2020.1727986

Lee DH, Kim J-B, Lim J-A, Han S-W, Heu S. 2014. Genetic diversity of *Pectobacterium carotovorum* subsp. *Brasiliensis* isolated in Korea. Plant Pathol J 30 (2): 117–124. DOI: 10.5423/PPJ.OA.12.2013.0117

Lengai GMW, Muthomi JW, Mbega ER. 2020. Phytochemical activity and role of botanical pesticides in pest management for sustainable agriculture crop production. Sci Afr 7 (e00239). DOI: 10.1016/j.sciaf.2019.e00239

Leyva M, French-Pacheco L, Quintana F, Montada D, Castex M, Hernandez A, Marquetti M del C. 2016. *Melaleuca quinquenervia* (Cav.) S.T. Blake (Myrtales: Myrtaceae): Natural alternative for mosquito control. Asian Pac J Trop Med 9 (10): 979-984. DOI: 10.1016/j.apjtm.2016.07.034

Li J, Xu H. 2012. Bioactive compounds from the bark of *Eucalyptus exserta* F. Muell. Ind Crops Prod 40: 302-306. DOI: 10.1016/j.indcrop.2012.03.032

Liao M, Xiao J-J, Zhou L-J, Liu Y, Wu X-W, Hua R-M, Wang G-R, Cao H-Q. 2016. Insecticidal activity of *Melaleuca alternifolia* essential oil and RNA-Seq analysis of *Sitophilus zeamais* transcriptome in response to oil fumigation. PLOS ONE 11 (12): e0167748. DOI: 10.1371/journal.pone.0167748

Liu XC, Liu QZ, Shi WP, Liu ZL. 2014. Evaluation of insecticidal activity of the essential oil of *Eucalyptus robusta* Smith leaves and its constituent compound against overwintering *Cacopsylla chinensis* (Yang et Li) (Hemiptera: Psyllidae). J Entomol Zool Stud 2 (4): 27-31.

Lucia A, Licastro S, Zerba E, Audino PG, Masuh H. 2009. Sensitivity of *Aedes aegypti* adults (Diptera: Culicidae) to the vapors of Eucalyptus essential oils. Bioresour Technol 100 (23): 6083-6087. DOI: 10.1016/j.biortech.2009.02.075

Luiz de Oliveira J, Ramos Campos EV, Fraceto LF. 2018. Recent developments and challenges for nanoscale formulation of botanical pesticides for use in sustainable agriculture. J Agric Food Chem 66 (34): 8898-8913. DOI: 10.1021/acs.jafc.8b03183

Mapatac LC, Mamaoag NR. 2014. Efficacy of three varieties *of Syzygium aqueum* (tambis) as antimicrobial agent and its bioactive component. Intl J Sci Clin Lab 9 (1). DOI: 10.7828/csuj.v1i1.370

Maurya A, Shrivastava K, Gupta S, Srivastava SK, Luqman S, Saxena M, Kumar A, Syamsundar KV, Darokar MP,. Ram T, Gupta S. 2009. Antimicrobial activity and chemical composition of *Callistemon macropunctatus* leaf essential oil from the northern plains of India. Intl J Essent Oil Therapeutics 3: 9-12.

Maymon M, Sela N, Shpatz U, Galpaz N, Freeman S. 2020. The origin and current situation of *Fusarium oxysporum* f. Sp. *Cubense* tropical race 4 in Israel and the Middle East. Sci Rep 10 (1): 1590. DOI: 10.1038/s41598-020-58378-9

Miguel M, Gago C, Antunes M, Lagoas S, Faleiro M, Megías C, Cortés-Giraldo I, Vioque J, Figueiredo A. 2018. Antibacterial, antioxidant, and antiproliferative activities of *Corymbia citriodora* and the essential oils of eight eucalyptus species. Med 5(3): 61. DOI: 10.3390/medicines5030061

Minj N, Calistus Jude AL, Sowmya SRI. 2017. Larvicidal and anti-feedant activity of *Phyllanthus emblica* and *Syzygium cumini* extracts on the diamond back moth: *Plutella xylostella*. Intl J Biol Res 2 (4): 97–100.

Mitchell G, Bartlett DW, Fraser TE, Hawkes TR, Holt DC, Townson JK, Wichert RA. 2001. Mesotrione: A new selective herbicide for use in maize. Pest Manag Sci 57: 120-128. DOI: 10.1002/1526-4998(200102)57:2<120::AID-PS254>3.0.CO;2-E

Mitra SK, Irenaeus TKS, Gurung MR, Pathak PK. 2012. Taxonomy and importance of Myrtaceae. Acta Hortic 959: 23-34. DOI: 10.17660/ActaHortic.2012.959.2

Mokhtari M, Jackson MD, Brown AS, Ackerley DF, Ritson NJ, Keyzers RA, Munkacsi AB. 2018. Bioactivity-guided metabolite profiling of feijoa (*Acca sellowiana*) cultivars identifies 4-cyclopentene-1, 3-dione as a potent antifungal inhibitor of chitin synthesis. J Agric Food Chem 66 (22): 5531-5539. DOI: 10.1021/acs.jafc.7b06154

Mossi AJ, Astolfi V, Kubiak G, Lerin L, Zanella C, Toniazzo G, Oliveira D de, Treichel H, Devilla IA, Cansian R, Restello R. 2011. Insecticidal and repellency activity of essential oil of *Eucalyptus* sp. against *Sitophilus zeamais* Motschulsky (Coleoptera, Curculionidae). J Sci Food Agr 91 (2): 273-277. DOI: 10.1002/jsfa.4181

Murugan S, Devi PU, Parameswari NK, Mani KR. 2011. Antimicrobial activity of *Syzygium jambos* against selected human pathogens. Intl J Pharm Pharm Sci 3 (2): 44-47.

Nattudurai G, Baskar K, Paulraj MG, Islam VIH, Ignacimuthu S, Duraipandiyan V. 2017. Toxic effect of *Atalantia monophylla* essential oil on *Callosobruchus maculatus* and *Sitophilus oryzae*. Environ Sci Pollut Res 24 (2): 1619-1629. DOI: 10.1007/s11356-016-7857-9

Naz T, Packer J, Yin P, Brophy JJ, Wohlmuth H, Renshaw DE, Smith J, Elders YC, Vemulpad SR, Jamie JF. 2016. Bioactivity and chemical characterisation of *Lophostemon suaveolens* - an endemic Australian Aboriginal traditional medicinal plant. Nat Prod Res 30 (6): 693-696. DOI: 10.1080/14786419.2015.1038260

Nobakht M, Trueman SJ, Wallace HM, Brooks PR, Streeter KI, Katouli M. 2017. Antibacterial properties of flavonoids from kino of the eucalypt tree, *Corymbia torelliana*. Plants 6 (4): 39. DOI: 10.3390/plants6030039

Noé W, Murhekar S, White A, Davis C, Cock IE. 2019. Inhibition of the growth of human dermatophytic pathogens by selected Australian and Asian plants traditionally used to treat fungal Infections. J Mycol Méd 29 (4): 331-344. DOI: 10.1016/j.mycmed.2019.05.003

Nurlaeni Y. 2016. Tumbuhan koleksi Kebun Raya Cibodas sebagai pestisida nabati. Prosiding Kongres Teknologi Nasional “Inovasi

Teknologi untuk Kejayaan Bangsa dan Negara. Badan Pengkajian dan Penerapan Teknologi, Jakarta, 25-27 Juli 2016. [Indonesian]

Oanh LTH, Giang VH. 2017. Study on antifungal activity of *Aspergillus flavus* and *Aspergillus niger* of eucalyptus and lemongrass essential oils. VNU Sci J Earth Environ Sci 33 (1S): 63-68. DOI: 10.5219/554

Ololade ZS, Olawore NO, Olasoji SO, Anosike SO. 2017. Chemical composition and bactericidal activities of the leaf essential oil of *Eucalyptus maculata* Hook. Nat Prod Chem Res 5 (2): 1-4.

Oyedeji OO, Oyedeji AO, Shode FO. 2014. Compositional variations and antibacterial activities of the essential oils of three *Melaleuca* species from South Africa. J Essent Oil Bearing Plants 17 (2): 265-276. DOI: 10.1080/0972060X.2013.813221

Packer J, Naz T, Harrington D, Jamie JF, Vemulpad SR. 2015. Antimicrobial activity of customary medicinal plants of the Yaegl Aboriginal community of northern New South Wales, Australia: A preliminary Study. BMC Res Notes 8 (1): 276. DOI: 10.1186/s13104-015-1258-x

Paosen S, Saising J, Septama, AW, Voravuthikunchai SP. 2017. Green synthesis of silver nanoparticles using plants from Myrtaceae family and characterization of their antibacterial activity. Mater Lett 209: 201-206. DOI: 10.1016/j.matlet.2017.07.102

Park CG, Jang M, Shin E, Kim J. 2017. Myrtaceae plant essential oils and their β-triketone components as insecticides against *Drosophila suzukii*. Mol 22 (7): 1050. DOI: 10.3390/molecules22071050

Patramurti C, Amin R, Nastiti CMRR, Hariono M. 2020. A Review on the potency of *Melaleuca Leucadendron* leaves solid waste in wood preservation and its *in silico* prediction upon biological activities. Intl J For Res 2020: 1-13. DOI: 10.1155/2020/8885259

Petrocelli S, Tondo ML, Daurelio LD, Orellano EG. 2012. Modifications of *Xanthomonas axonopodis* pv. Citri Lipopolysaccharide affect the basal response and the virulence process during citrus canker. PLoS ONE 7 (7): e40051. DOI: 10.1371/journal.pone.0040051

Pierre DYS, Okechukwu EC, Nchiwan NE. 2014. Larvicidal and phytochemical properties of *Callistemon rigidus* R. Br. (Myrtaceae) leaf solvent extracts against three vector mosquitoes. J Vector Borne Dis 51: 216-223.

Pinho AI, Wallau GL, Nunes MEM, Leite NF, Tintino SR, da Cruz LC, da Cunha FAB, da Costa JGM, Douglas Melo Coutinho H, Posser T, Franco JL. 2014. Fumigant activity of the *Psidium guajava* var. Pomifera (Myrtaceae) essential oil in *Drosophila melanogaster* by means of oxidative stress. Oxidative Med Cell Longev 2014: 1-8. DOI: 10.1155/2014/696785

POWO 2019. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org/"

President of The Republic of Indonesia, Government Regulation of the Republic of Indonesia No. 7/1973, 1973. [Online]. Available: http://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=5256&p_country=IDN&p_classification=14.01.

President of The Republic of Indonesia, Government Regulation of the Republic of Indonesia Number 6 of 1995, 1995. [Online]. Available: https://www.informea.org/en/legislation/government-regulation-no-6-1995-re-crop-Prot

Puig CG, Álvarez-Iglesias L, Reigosa MJ, Pedrol N. 2013. *Eucalyptus globulus* leaves incorporated as green manure for weed control in maize. Weed Sci 61 (1): 154-161. DOI: 10.1614/WS-D-12-00056.1

Pujiarti R, Fentiyanti PK. 2017. Chemical compositions and repellent activity of *Eucalyptus tereticornis* and *Eucalyptus deglupta* essential oils against *Culex quinquefasciatus* mosquito. Thai J Pharm Sci 40 (4): 1-6.

Pujiarti R, Kasmudjo K. 2016. Chemical compositions and insecticidal activity of *Eucalyptus urophylla* essential oil against *Culex quinquefasciatus* mosquito. J Korean Wood Sci Technol 44 (4): 494-504. DOI: 10.5658/WOOD.2016.44.4.494

Pujiarti R, Nurjanto HH, Sunarta S. 2018. Antifungal activity of *Eucalyptus urophylla* oil against *Aspergillus niger* and *Fusarium oxysporum*. AGRIVITA J Agric Sci 40 (1): 55-62. DOI: 10.17503/agrivita.v40i1.990

Ramadhania NR, Purnomo AS, Fatmawati S. 2018. Antibacterial activities of *Syzygium polyanthum* Wight leaves. The 3rd International Seminar on Chemistry: Green Chemistry And Its Role For Sustainability. AIP Publisher, Surabaya, 18-19 July 2018. DOI: 10.1063/1.5082429 [Indonesian]

Rattanachaikunsopon P, Phumkhachorn P. 2010. Contents and antibacterial activity of flavonoids extracted from leaves of *Psidium guajava*. J Med Plants Res 4 (5): 393-396. DOI: 10.5897/JMPR09.485

Regnault-Roger C, Philogène BJR. 2008. Past and current prospects for the use of botanicals and plant allelochemicals in integrated pest management. Pharm Bio 46 (1-2): 41-52. DOI: 10.1080/13880200701729794

Rensen Z, Pengwei LI. 1997. Allelopathic effects of *Eucalyptus exserta* and *E. urophylla*. J South Chin Agric Universit 18 (1): 6-10.

Ribeiro AV, Farias E de S, Santos AA, Filomeno CA, Santos IB dos, Barbosa LCA, Picanço MC. 2018. Selection of an essential oil from *Corymbia* and *Eucalyptus* plants against *Ascia monuste* and its selectivity to two non-target organisms. Crop Prot 110: 207-213. DOI:10.1016/j.cropro.2017.08.014

Rossi YE, Palacios SM. 2015. Insecticidal toxicity of *Eucalyptus cinerea* essential oil and 1,8-cineole against *Musca domestica* and possible uses according to the metabolic response of flies. Ind Crops Prod 63: 133-137. DOI: 10.1016/j.indcrop.2014.10.019

Saj O, Thoppil J. 2011. Chemical composition and antimicrobial properties of essential oil of *Agonis flexuosa.* Intl J Inst Pharm Life Sci 1 (2): 12-17.

Sautron C, Cock IE. 2014. Antimicrobial activity and toxicity of *Syzygium australe* and *Syzygium leuhmannii* fruit extracts. Pharmacogn Commun 4 (1): 53-60. DOI: 10.5530/pc.2014.1.8

Saxena A, Raghuwanshi R, Gupta VK, Singh HB. 2016. Chilli anthracnose: The epidemiology and management. Front Microbiol 7 (1527): 1-18. DOI: 10.3389/fmicb.2016.01527

Saxena M, Shrivastava K, Srivastava SK, Luqman S, Kumar A, Darokar MP, Syamsundar KV, Ram T, Khanuja SPS. 2008. Antimicrobial activity and chemical composition of *Callistemon Pinifolius* and *C. Salignus* leaf essential oils from the northern plains of India. Nat Prod Commun 3 (9): 1934578X0800300.0300926. DOI: 10.1177/1934578X0800300926

Saxena S, Gomber C. 2006. Antimicrobial potential of *Callistemon rigidus*. Pharm Biol 44 (3): 194-201. DOI: 10.1080/13880200600685899

Scur MC, Pinto FGS, Pandini JA, Costa WF, Leite CW, Temponi LG. 2016. Antimicrobial and antioxidant activity of essential oil and different plant extracts of *Psidium cattleianum* Sabine. Braz J Biol 76 (1): 101-108. DOI: 10.1590/1519-6984.13714

Senadeera SPD. 2017. Investigation of Anti-infective Compounds within the Flowers of Myrtaceae. [Disertation]. Griffith University [Australia].

Setzer MC, Setzer WN, Jackes BR, Gentry GA, Moriarity DM. 2001. The medicinal value of tropical rain forrest plants from Paluma, North Queensland, Aust Pharm Biol 39 (1): 67–78. DOI: 10.1076/phbi.39.1.67.5944

Sharma A, Kumar V, Shahzad B, Tanveer M, Sidhu GPS, Handa N, Kohli SK, Yadav P, Bali AS, Parihar RD, Dar OI, Singh K, Jasrotia S, Bakshi P, Ramakrishnan M, Kumar S, Bhardwaj R, Thukral AK. 2019. Worldwide pesticide usage and its impacts on ecosystem. SN Appl Sci 1 (11): 1-16. DOI: 10.1007/s42452-019-1485-1

Siani AC, Nakamura MJ, Neves GP das, Monteiro S da S, Ramos MFS. 2016. Leaf essential oil from three exotic mytaceae species growing in the Botanical Garden of Rio de Janeiro, Brazil. Am J Plant Sci 7 (6): 834-840. DOI: 10.4236/ajps.2016.76079

Siddique S, Parveen Z, -e-Bareen F, Butt A, Chaudhary M, Akram M. 2017. Chemical composition and insecticidal activities of essential oils of myrtaceae against *Tribolium castaneum* (Coleoptera: Tenebrionidae). Pol J Environ Stud 26 (4): 1653-1662. DOI: 10.15244/pjoes/73800

Siddique S, Parveen Z, -e-Bareen F, Chaudhary MN, Mazhar S, Nawaz S. 2017. The essential oil of *Melaleuca armillaris* (Sol. ex Gaertn.) Sm. leaves from Pakistan: A potential source of eugenol methyl ether. Ind Crops Prod 109: 912-917. DOI: 10.1016/j.indcrop.2017.09.048

Silva CJ, Barbosa LCA, Demuner AJ, Montanari RM, Pinheiro AL, Dias I, Andrade NJ. 2010. Chemical composition and antibacterial activities from the essential oils of myrtaceae species planted in Brazil. Químic Nova 33 (1): 104-108. DOI: 10.1590/S0100-40422010000100019

Silva SM, Abe SY, Murakami FS, Frensch G, Marques FA, Nakashima T. 2011. Essential oils from different plant parts of *Eucalyptus cinerea* F. Muell. ex Benth. (Myrtaceae) as a source of 1,8-cineole and their bioactivities. Pharm 4 (12): 1535-1550. DOI: 10.3390/ph4121535

Singh G. 2010. Plant systematics: An integrated approach (3rd ed). Science Publishers.

Singh P, Jayaramaiah RH, Sarate P, Thulasiram HV, Kulkarni MJ, Giri AP. 2014. Insecticidal potential of defense metabolites from *Ocimum kilimandscharicum* against *Helicoverpa armigera*. PLoS ONE 9 (8): e104377. DOI: 10.1371/journal.pone.0104377

Smith EF, Townsend CO. 1907. A plant tumor of bacterial origin. Sci 25 (643): 671-673. DOI: 10.1126/science.25.643.671

Souza-Moreira TM, Moreira RRD, Sacramento LVS, Pietro RCLR. 2010. Histochemical, phytochemical and biological screening of *Plinia cauliflora* (DC.) Kausel, Myrtaceae, leaves. Rev Bras de Farmacogn 20 (1): 48-53. DOI: 10.1590/S0102-695X2010000100011

Takahashi T, Kokubo R, Sakaino M. 2004. Antimicrobial activities of eucalyptus leaf extracts and flavonoids from *Eucalyptus maculata*. Lett in Appl Microbiol 39 (1): 60-64. DOI: 10.1111/j.1472-765X.2004.01538.x

Tian YH, Zhou XC, Zhou XL, Huang Q. 2011. Insecticidal and repellent activities of essential oil from leaves of *Eucalyptus grandis* against *Culex pipiens quinquefasciatus*. Adv Mater Res 233–235: 82–86. DOI: 10.4028/www.scientific.net/AMR.233-235.82

Tietbohl LAC, Mello CB, Silva LR, Dolabella IB, Franco TC, Enríquez JJS, Santos MG, Fernandes CP, Machado FP, Mexas R, Azambuja P, Araújo HP, Moura W, Ratcliffe NA, Feder D, Rocha L, Gonzales MS. 2020. Green insecticide against Chagas disease: Effects of essential oil from *Myrciaria floribunda* (Myrtaceae) on the development of *Rhodnius prolixus* nymphs. J Essent Oil Res 32 (1): 1–11. DOI: 10.1080/10412905.2019.1631894

Tine Y, Diallo A, Diop A, Costa J, Boye CSB, Wélé A, Paolini J. 2020. The essential oil of *Eucalyptus alba* L. growing on the salt zone of fatick (Senegal) as a source of 1,8-cineole and their antibacterial activity. J Drug Deliv Ther 10 (1-s): 140–143. DOI: 10.22270/jddt.v10i1-s.3918

Touqeer S, Saeed MA, Adnan S, Mehmood F, Ch MA. 2014. Antibacterial and antifungal activity of *Melaleuca decora* and *Syngonium podophyllum*. Res J Pharm Technol 7 (7): 776-778.

Tri W, Ilham R. 2020. *Syzygium polyanthum* Wight leaf extract evaluation on *Aedes* spp instar III-IV larvae. Asian J Pharm Res Dev 8 (2): 7-9. DOI: 10.22270/ajprd.v8i2.678

Van Vuuren SF, Docrat Y, Kamatou GPP, Viljoen AM. 2014. Essential oil composition and antimicrobial interactions of understudied tea tree species. S Afr J Bot 92: 7-14. DOI: 10.1016/j.sajb.2014.01.005

Vicente JG, Holub EB. 2013. *Xanthomonas campestris* pv. *campestris* (cause of black rot of crucifers) in the genomic era is still a worldwide threat to brassica crops: *Xanthomonas campestris* pv. *campestris*. Mol Plant Pathol 14 (1): 2-18. DOI: 10.1111/j.1364-3703.2012.00833.x

Victoria FN, Lenardão EJ, Savegnago L, Perin G, Jacob RG, Alves D, Silva WP da, Motta A de S da, Nascente P da S. 2012. Essential oil of the leaves of *Eugenia uniflora* L.: Antioxidant and antimicrobial properties. Food Chem Toxicol 50 (8): 2668-2674. DOI: 10.1016/j.fct.2012.05.002

Visheentha M, Appalasamy S, Nivaarani A, Weeraya K, Charoen P. 2018. The action of gelam (*Melaleuca cajuputi*) stem crude extract as natural insecticide for *Camponotus* Sp. J Biodivers Bioprospect Dev 5 (2): 1-6. DOI: 10.4172/2376-0214.1000173

Vishwakarma GS, Mittal S. 2014. Bioherbicidal potential of essential oil from leaves of *Eucalyptus tereticornis* against *Echinochloa crus-galli* L. J Biopestic 7: 47-53.

Wardani FF, Yudaputra A. 2015. Inventory of Bogor Botanic Gardens Collections that have potency as botanical pesticides. Pros Semin Nas Masy Biodivers Indones, Masyarakat Biodiversitas Indonesia, Juni 2015. [Indonesia].

Wilkinson JM, Cavanagh HMA. 2005. Antibacterial activity of essential oils from Australian native plants. Phytother Res 19 (7): 643-646. DOI: 10.1002/ptr.1716

Wilkinson JM, Hipwell M, Ryan T, Cavanagh HMA. 2003. Bioactivity of *Backhousia citriodora*: antibacterial and antifungal activity. J Agric Food Chem 51 (1): 76-81. DOI: 10.1021/jf0258003

Windels CE, Kuznia RA, Call J. 1997. Characterization and pathogenicity of *Thanatephorus cucumeris* from sugar beet in Minnesota. Plant Dis 81(3): 245–249. DOI: 10.1094/PDIS.1997.81.3.245

Windsor SAM, Brooks P. 2012. Essential oils from *Leptospermums* of the Sunshine Coast and Northern Rivers Regions. Chem Cent J 6 (1): 38. DOI: 10.1186/1752-153X-6-38

Wińska K, Mączka W, Łyczko J, Grabarczyk M, Czubaszek A, Szumny A. 2019. Essential oils as antimicrobial agents - myth or real Altern.? Mol 24 (11): 2130. DOI: 10.3390/molecules24112130

Yasin M, Younis A, Ramzan F, Javed T, Shabbir R, Noushahi H A, Skalicky M, Ondrisik P, Brestic M, Hassan S, EL Sabagh A. 2021. Extraction of essential oil from river tea tree (*Melaleuca bracteata* F. Muell.): antioxidant and antimicrobial properties. Sustain 13 (9): 4827. DOI: 10.3390/su13094827

Yousaf M, Shahzadi H, Anjum A, Zahoor AF, Khan ZI, Idrees S, Hamid S, Mubeen Z. 2014. Constitutional composition and allelopathic potential of jaman (*Syzygium cumini*) leaves against canary grass and wheat. Pak J Weed Sci Res 20 (3): 323-334.

Yuan W, Yuk H-G. 2018. Antimicrobial efficacy of *Syzygium antisepticum* plant extract against *Staphylococcus aureus* and methicillin-resistant *S. aureus* and its application potential with cooked chicken. Food Microbiol 72: 176-184. DOI: 10.1016/j.fm.2017.12.002

Yuniarni U, Sukandar EY, Fidrianny I. 2020. Antibacterial activity of several Indonesian plant extracts and combination of antibiotics with *Syzygium malaccense* extract as the most active substance. Intl J of Res in Pharm Sci 11 (3): 3300-3308. DOI: 10.26452/ijrps.v11i3.2456