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Potential of house yard plants as an alternative for dengue vector control in the tsunami area settlement of Banda Aceh City

Elita Agustina[1,2*], Amin Setyo Leksono[3], Zulfaidah Penata Gama[3], Bagyo Yanuwiadi[3], Mauliza Sukma[2]

[1]Doctoral Program, Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia.
[2]Department of Biology Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia.
[3]Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia..

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ABSTRACT

The rebuilding of settlements after the 2004 Aceh tsunami has created a new home environment. Human activities and behavior in managing new home environments have inadvertently contributed to creating new habitats for *Aedes*. One of the factors that support and limit the presence of *Aedes* is the plants around the house. Plants also influence mosquitoes in a place; they are known as mosquito-attracting plants and mosquito-repellent plants. This study aimed to determine the potential of house yard plants as an alternative to dengue hemorrhagic fever vector control in the tsunami settlement area of Banda Aceh City. This research is an explorative survey using 200 house yards in the tsunami area settlement of Banda Aceh City. The result of the study found two species of *Aedes* (*Aedes aegypti* and *Aedes albopictus*) and 63 families of house yard plants with 150 species in the tsunami area settlement of Banda Aceh City. Totally, 63 families have the potential as dengue vector repellents and 17 as dengue vector attractants. Plants in the tsunami settlements of Banda Aceh City have the potential as an alternative for controlling dengue vectors.

INTRODUCTION

Aceh Province in Indonesia experienced the most severe earthquake and tsunami disaster in 2004. After the tsunami infrastructure development occurred rapidly in Banda Aceh City. Banda Aceh City became the administrative center of Aceh Province and was the most tsunami-affected area. Residential settlement development continues to increase yearly in Banda Aceh City (Gadeng *et al*., 2019). The return of the community to new settlements with all the activities of daily life has created a habitat for *Aedes* and an explosion of cases of dengue hemorrhagic fever (DHF). Reports from the Ministry of the Health Republic of Indonesia revealed that cases of dengue fever in Aceh continued to increase after the tsunami (Ministry of Health Indonesia, 2007). Cases of dengue fever in Banda Aceh City after the tsunami from 2005 to 2007 experienced a significant increase. The explosion of very high dengue cases occurred in 2010, with 759 cases after the return of the community to new housing in 2009 (Agustina *et al*., 2021).

This condition is related to the high population of *Aedes* and other supporting factors that caused the presence of *Aedes* in the tsunami's neighborhood area of Banda Aceh City. *Aedes* is an invasive species that can adapt to and interact with the surrounding environment. The invasive species interactions vary in space and time and depend on local conditions (Cunze *et al*., 2018).

Mosquitoes exist around humans because of the availability of breeding places, eating, and resting habitats. Therefore, it is necessary to have control efforts oriented to the habitat conditions and the necessities of life for it. The life of *Aedes* depends on plants. Plants are resting places and sources of food for male and female *Aedes aegypti* L. and *Aedes albopictus* Skuse (Agustina *et al*., 2019). Plants can serve as attractors or repels, and each type has a different attraction. Mosquitoes come to plants because smells or colors attract them to get food (Barredo and DeGennaro, 2020).

*Corresponding Author
Elita Agustina, Department of Biology Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia.
E-mail: elita.agustina @ ar-raniry.ac.id

The selection of plant species by various mosquitoes is related to the volatile compounds produced by each plant. The olfactory systems of *A. aegypti*, *Aedes mcintoshi* Huang, and *Anopheles gambiae* l. can detect different volatile compounds in plants (Nyasembe *et al*., 2018) because they have an affinity for certain plant species (host plants). Their olfactory system influences the selection of host plants. Plants that attract mosquitoes or are called attractants are very limited in the study, even though these attractant plants also have the potential to control mosquitoes (Nyasembe *et al*., 2015). Other studies also revealed that eliminating the mesquite plant [*Prosopis juliflora* (Sw.) DC.], which is the food source of *Anopheles*, can reduce the population of malaria vector mosquitoes by 69% (Muller *et al*., 2017). Plant attractant compounds can serve as an effective biological control strategy. The content of secondary metabolites in plants that attract mosquitoes can as act bait in mosquito surveillance and control programs (Dormon *et al*., 2021). Parts of the plants have attractions such as flowers, sharp aromas, and high nectar content that can attract mosquitoes.

A repellent is an insecticide that is repelling and nonkilling. Every plant has a composition of chemical compounds called secondary metabolites. Essential oils, flavonoids, alkaloids, and aromatic compounds are metabolites in plants that have the potential to be mosquito repellents (Boate and Abalis, 2020). Essential oils, also called volatile oils, are secondary metabolites of volatile plants. This oil exists in fruits, seeds, leaves, flowers, stems, bark, roots, and rhizomes (Sengül Demirak and Canpolat, 2022). Therefore, plants as a place for mosquito feeding and resting activities also have a favorable opportunity to become one of the mosquito control strategies by utilizing secondary metabolite compounds. Plants around us have the potential insecticides, but it is necessary to identify which bioactive molecules in repellent plants have a higher effect on disease-transmitting mosquitoes (Athuman *et al*., 2016).

House yard plants not only support the life of mosquitoes but also have the potential to control the mosquito population. Based on the content of plant compounds, these plants can act as repellents or attractants for *Aedes.* This information is necessary to know an effective and targeted control strategy. This study was to determine the potential of house yard plants as an alternative to dengue vector control in the tsunami area settlements of Banda Aceh City.

MATERIALS AND METHODS

Study area

The study is in Banda Aceh City, as it was severely affected by the earthquake and tsunami disasters in 2004 (Fig. 1). Banda Aceh City is between 5°30′ – 05°35′ north latitude and 95°30′ – 99°16′ east longitude, with an average elevation of 0.80 meters above sea level, with an area of 61.36 km^2 (BPS, 2019). The city of Banda Aceh consists of nine subdistricts, and the research sites are the Meuraxa Subdistrict and Syiah Kuala Subdistrict. The Meuraxa and Syiah Kuala Subdistricts were chosen as the research sites because of the endemic areas for dengue cases. In addition, these two areas were also the worst affected by the tsunami.

Data collection

This research begins with a preliminary survey using an explorative method to determine the condition of the houses in the Meuraxa Subdistrict and Syiah Kuala Subdistrict, Banda Aceh City. Purposive sampling was used to sample 200 sample houses. The selection was houses suspected of having an *Aedes* breeding place and plants in the yard. The collection of house yard plants involved the larva monitoring community in each village. To determine secondary metabolites that attract or repel *Aedes* using a literature study, all plants found in the house yards were collected and documented. The data were then summarized, and the results of the studies arranged in the tabular form of the list of secondary metabolites in plants that can function as repellents or attractants.

Data analysis

The data from this research are presented and analyzed using descriptive statistics.

Statistical analysis

Statistical analysis for calculation of graph and table data was carried out with Microsoft Excel.

RESULTS AND DISCUSSION

The results of 200 houses in the tsunami area settlement of Banda Aceh City found 150 species and 63 families of house yard plants (Fig. 2). The category of plant habitus found in the study area comprised herbs (44%), shrubs (32%), and trees (24%) (Fig. 3). The tsunami disaster caused the coast to be badly damaged, and almost all the vegetation was destroyed and lost. After the tsunami, much vegetation of the damaged coastal area naturally changed (succession), namely, the emergence of pioneer plant species such as herbs, shrubs, and trees (Suryawan, 2007).

The family's highest number of species are from the group Araceae (14 species), Euphorbiaceae (8 species), Asparagaceae (7 species), Lamiaceae (6 species), Apocynaceae (5 species), Arecaceae (5 species), Fabaceae (4 species), Myrtaceae (4 species), Portulacaceae (4 species), Solanaceae (4 species), and Zingiberaceae (4 species) (Fig 2). Many species in this family found at the research sites are related to the COVID-19 pandemic. Restrictions on activities outside the home during the COVID-19 pandemic have provided much free time at home and made many people take up new hobbies such as caring for ornamental plants and business opportunities for buying and selling plants. Plants in pots are obtained easily by ordering through online media or direct purchase. Residents in the tsunami area of Banda Aceh City planted the Araceae family such as *Aglaonema* and other species because they follow trends and other aspects such as the benefits that they can filter air pollution at home and are easy to maintain (Zahara and Win, 2020).

The families Apocynaceae, Arecaceae, Asparagaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Myrtaceae, Portulacaceae, Solanaceae, and Zingiberaceae are species commonly grown by communities in tsunami areas for various needs or uses such as food crops, medicine, ornamental plants, and traditional ceremonies. Home gardens have contributed to increasing food security, social, cultural, health, and economic community (Du Toit *et al*., 2022 ; Galhena *et al*., 2013). Table 1 and Figure 4 shows that 63 families

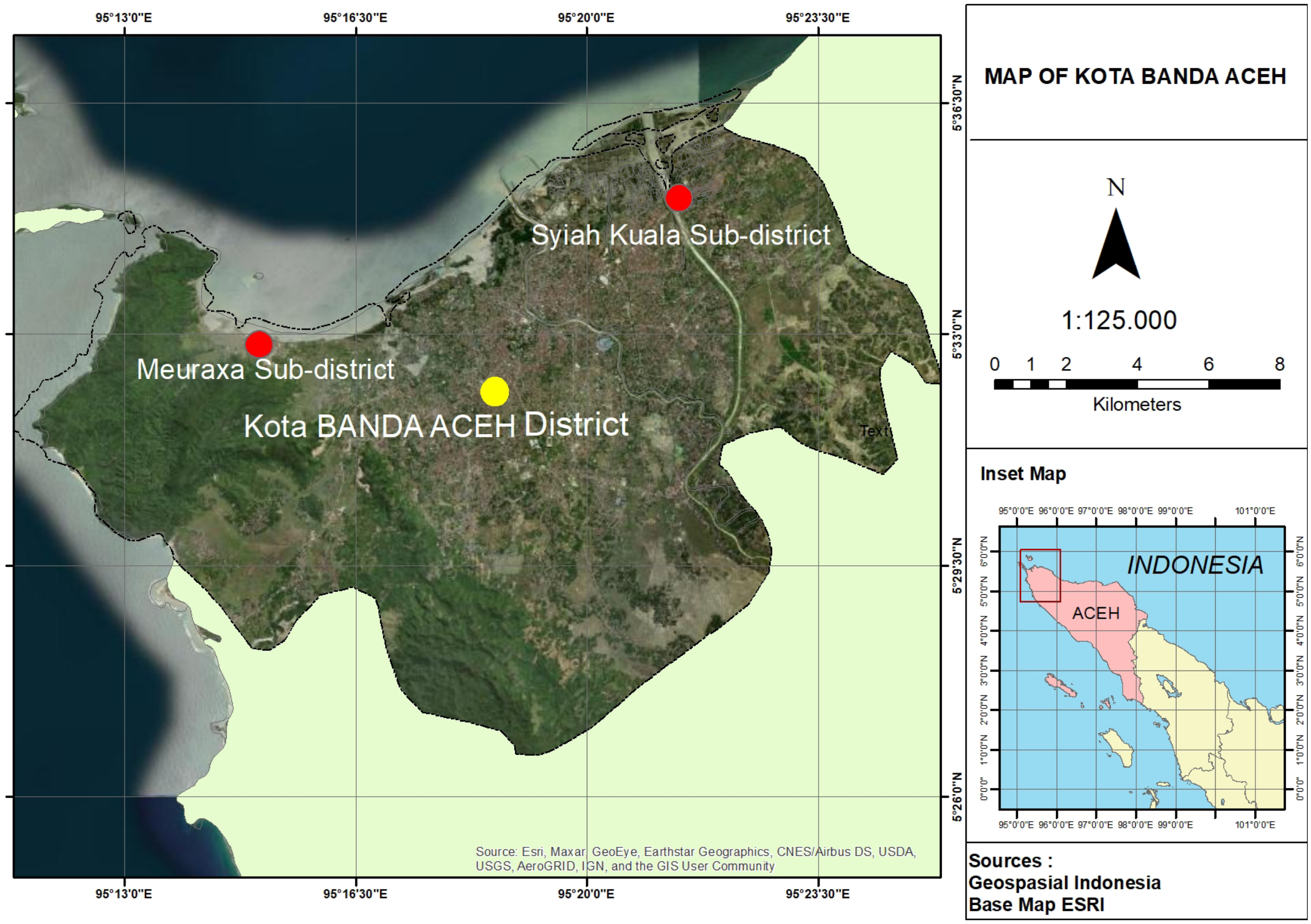

Figure 1. Location of study area.

have potential as *Aedes* mosquito repellent plants. 16 families have potential as *Aedes* attractants. Analysis of the determination of the plant acting as a repellent or attractant based on the content of secondary metabolites obtained information from the literature study sought.

Potential of house yard plants as repellent of *Aedes* spp.

The repellants used by the public to prevent mosquito bites are synthetic repellants, one of which contains diethyltoluamide (DEET). These compounds can protect longer than other synthetic and botanical repellents. This synthetic active ingredient has health effects such as contact urticaria, skin eruptions, and encephalopathy. Plants around us have potential as insecticides, but it is necessary to identify bioactive molecules that have the effect of repelling or killing disease-transmitting vectors (Athuman *et al*., 2016).

Plant parts studied for their repellant content were the roots, stems, leaves, and flowers. Research on protecting from the bites of *A. aegypti*, *Anopheles minimus* Theobald, and *Culex quinquefasciatus* Say using essential oils showed different responses from mosquito species. The group of plant essential oils used was *Zingiber cassumunar* Roxb. (Zingiberaceae), *Ocimum basilicum* L. (Lamiaceae), and *Cymbopogon nardus* L. (Poaceae). These three essential oils are effective as repellents and food inhibitors against *A. minimus, C. quinquefasciatus*, and *A. aegypti*. However, the period of protection against *A. Aegypti* is lower than other mosquito species (Phasomkusolsil and Soonwera, 2010). The *Z. cassumunar* essential oil consists of sabinene, b-pinene, caryophyllene oxide, and caryophyllene (Bhuiyan *et al*., 2008). In the basil leaf extract of *O. basilicum*, the active compounds are flavonoids, saponins, tannins, and essential oils, which are considered toxic to mosquitoes (Ramayanti *et al*., 2017). The stems and leaves of citronella contain a toxin, and that substance can act as a repellant (Arcani *et al*., 2017). Essential oil *Z. cassumunar* was tested at several concentrations showing that the higher the concentration, the higher the activity to repel mosquitoes (Yulianis *et al*., 2018).

Volatile oils from four plant species *Curcuma longa* L. (Zingiberaceae), *Citrus hystrix* DC. (Rutaceae), *Cymbopogon winterianus* Jowitt, and *Ocimum americanum* added with 5% the vanillin showed a repellent effect against *A. aegypti*, *Anopheles dirus* Peyton & Harrison, and *C. quinquefasciatus*. The volatile oils of turmeric, lemongrass, and basils were able to repel the three mosquito types for 8 hours, while the kaffir lime oil was effective

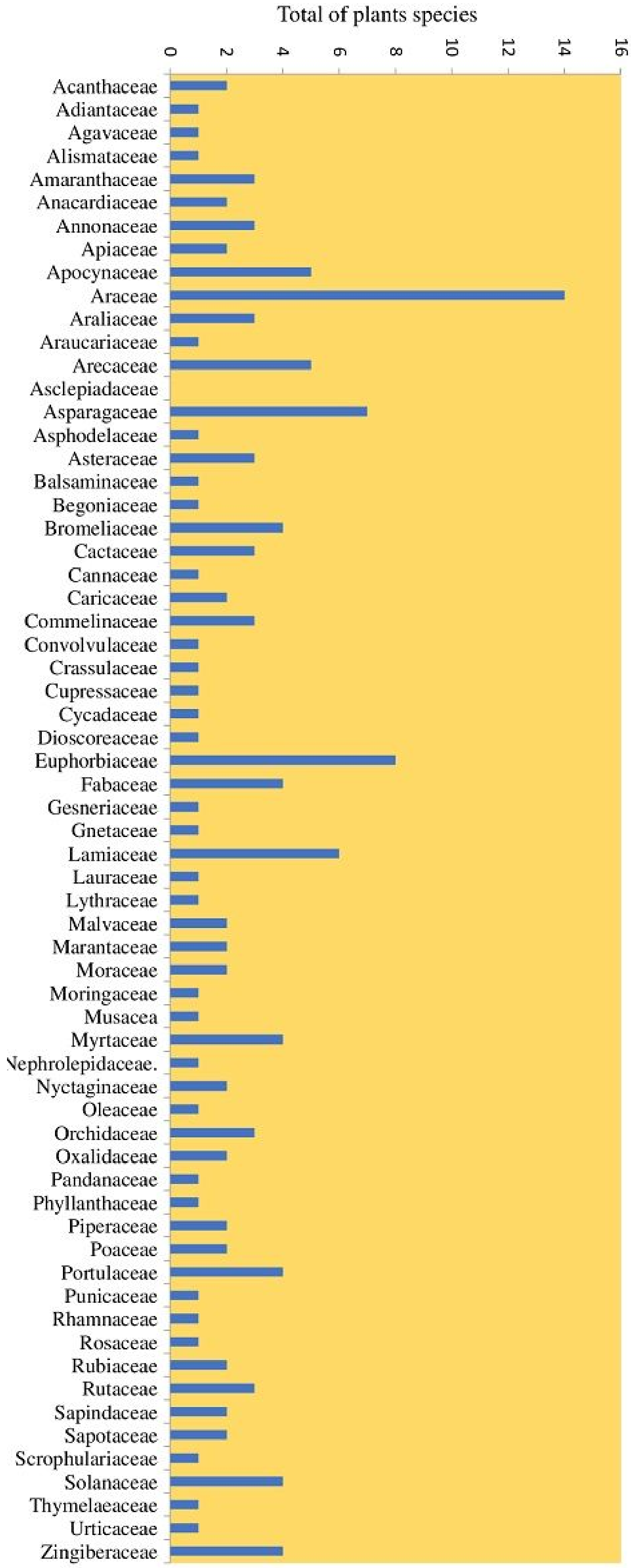

Figure 2. Plant families found in study area

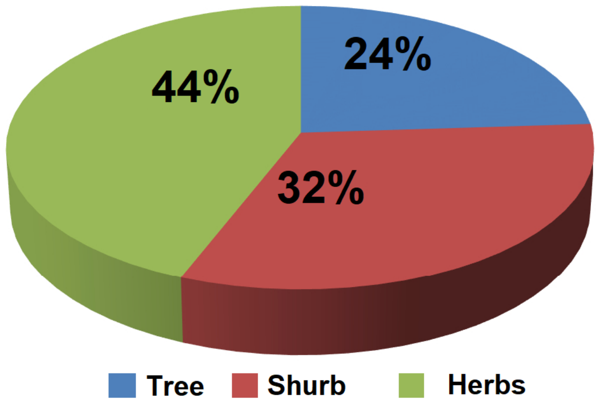

Figure 3. Category of habitus plants in study are.

in repelling mosquitoes for up to 3 hours (Tawatsin *et al*., 2001). One of the plants that contain biologically active ingredients and can be used as an alternative controller is turmeric. The essential oils of turmeric can be used as natural insecticides to replace chemicals to kill mosquito larvae. In addition, the essential oil is also effective as a mosquito repellent for *Aedes* (Aseptianova, 2019). The essential oil content in kaffir lime leaves is citronellal, citronellol, linalool, and geraniol compounds (Munawaroh and Astuti, 2010). The largest components produced in citronella oil are citronellal, citronellol, and geraniol (Eden *et al*., 2018). The components of basil oil (*O. americanum*) are linalool, neral, citral, β-caryophyllene, α-humulene, and germacrene-d (Hapsari and Feroniasanti, 2019). The compounds contained in all the plants above have the potential and act as mosquito repellents and larvicides.

Table 1. Families of plants that have the potential dengue vector control in the tsunami area settlement of Banda Aceh City.

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
Acanthaceae	*Graptophyllum pictum* L. *Ruellia simplex* L.	Leaf Leaf	Anthocyanin, chlorophyll, carotenoids, alkaloids, terpenoids, phenols, fiber,saponins, flavonoids, nitrogen, organic carbon, lignans, coumarins, triterpenes, sterols, phenolic glycosides, phenylethanoids, megastigmane glycosides, benzoxazinoid glucosides	√		(Lestari *et al*., 2015) (Samy *et al*., 2015)
Adiantaceae	*Adiantum capillus-veneris* L.	Leaf Rhizome/ roots	Flavonoids, triterpenoids, aoleananes, , alicyclics phenylpropanoids, carbohydrates, carotenoids Triterpenoids, hydroxy adiantone, triterpenoid epoxide (adiantoxide), isoadiantol isoadiantone,isoglaucanone, doxyhopane hydroxyadiantone	√		(Al-snafi, 2015) (Taha and Ali, 2020)
Agavaceae	*Cordyline terminalis* (L.) Kunth	Leaf	Steroidal saponins, apogenins	√		(Simmons-boyce and Tinto, 2007)
Alismataceae	*Echinodorus palaefolius* Nees & Mart. JF Macbr.	Leaf	Tannin, flavonoid, terpenoids, phenolic	√		(Behera *et al*., 2021)
Amaranthaceae	*Celosia cristata* L. *Gomphrena globosa* L. *Amaranthus hyochondriacus* L.	Leaf	Diterpenoid, triterpenoid, trinotriterpenoid D-laktosa, enneanoorpenoid heksanortrititerpenoid, oktanortiterpenoid	√		(Iwuagwu *et al*., 2019)
Anacardiaceae	*Mangifera indica* L.	Flower Fruit	Terpenoids, benzenoids, fruktosa, humulene, myrcene (E)-caryophyllene, terpinolena		√	(Gouagna *et al*., 2010) (Meza *et al*., 2020)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
			α-pinene, limonene			
	Spondias dulcis G.Forst	Leaf	α-phellandrene, p-cymene, heptane, β-pinene, ledene, α-gurjunene, βmyrcene, γ-terpinene,carene, trans (β)-caryophyllene, monoterpenes	√		(Asadollahi *et al*., 2019) (Alwala *et al*., 2010)
Annonaceae	*Cananga odorata* L. *Annona muricata* L. *Annona squamosa* L.	Seeds	Flavonoids, triterpenes, sterols, leucoanthocyanes, polyphenols, polysaccharides	√		(Ravaomanarivo *et al*., 2014)
		Leaf	Isoeugenol, ropenylguaiacol, phenylpropanoid, sesquiterpene		√	(Polya, 2003)
Apiaceae	*Centella asiatica* (L.) Urban *Apium graveolens* L.	Rhizome/ roots	Linoleic acid, 3-N-butylphthalide, butylidenephthalide	√		(Champakaew *et al*., 2016)
Apocynaceae	*Adenium obesum* (Forssk.) Roem & Schult. *Chatarantus roseus* L. *Allamanda cathartica* L. *Calotropis gigantea* (L.)W.T Aiton. *Ceropegia woodii* Schltr.	Flower	Terpenoids, benzenoids, fruktosa	√		(Dhivya and Manimegalai, 2013)
		Flower	Phenylacetaldehyde, benzaldehyde and (E)-2-nonenal		√	(Otienoburu *et al*., 2012)
Araceae	*Anthurium crystallinum* Liden & Andre. *Anthurium plowmanii* Croat. *Philodendron selloum* K. Koch. *Zamioculcas zamiifolia* (Lodd.) Engl. *Caladium bicolor* (W.Ait.) Vent. *Monstera adansonii* Schott. *Epipremnum aureum* Lind & Andre. *Aglaonema* sp. *Dieffenbachia* sp. *Alocasia cucculata* (Lour.) Schott. *Alocasia* sp. *Homalomena rubescens* (Roxb) Kunth. *Syngonium podophyllum* Schott. *Alocasia sanderiana* W. Bull.	Tuber Leaf Stem	Terpenoid, alkaloid ,lipofilik flavonoid, steroid, tanin, saponin, carbohydrates	√		(Suparman *et al*., 2017) (Gomathi *et al*., 2014)
		Flower	Pyrroline, methyl damasceninate, nigelline, ethylpyrazine, indole, benzopyrrole		√	(Polya, 2003)
Araliaceae	*Nothopanax scutellarium* Merr. *Polyscias scutellaria* (Burm.f.) Fosberg. *Schefflera arboricola* (Hayata) Merr.	Leaf	Alkoloid, saponin, tannin, flavonoid	√		(Ahdiyah and Purwani, 2015)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
Araucariaceae	*Araucaria heterophylla* (Salisb.) Franco.	Leaf	Beyerene, caryophyllene oxide, α-pinene, germacrene, kaurene, 13-epi-dolabradiene,(E)-caryophyllene, caryophyllene oxide, (E)-β-farnesene, rimuene, dolabradiene, copaene, gurjunene, α-cadinene, sandaracopimara,15-diene	√		(Verma *et al*., 2014)
Arecaceae	*Cyrtostachys lakka* Becc. *Chrysalidocarpus lutescens* H. Wendl. *Rhapis excels* (Thunb.) A. Henry *Areca catechu* L. *Cocos nucifera* L.	Flower	Limonene, cineole, trans-β-ocimene, cis-β-ocimene, linalool oxide, linalool.	√		(Stashenko and Martinez, 2018)
Asparagaceae	*Sansevieria trifasciata* Hort. *Chlorophytum comosum* (Thunb.) Jacques *Chlorophytum amaniense* Engl. *Asparagus setaceus* (Kunth) Jessop. *Agave gigantea* (Vent.) D. Dietr *Dracaena marginata* Lam. *Dracaena reflexa* Lam.	Flower	Limonene, 1,8-cineole, carvone, α-terpineol, sesquiterpenoids (cis, cis-farnesol, cis-limonene oxide, trans-limonene oxide, linalool, nerolidol)	√		(Stashenko and Martinez, 2018)
Asphodelaceae	*Aloe vera* L.	Leaf	Glycosides, saponins, tannins, flavonoids	√		(Lubis *et al*., 2018)
		Leaf	Antrakuinon, saponin, lignin, sterol, laktin, polisakarida, alkilbenzena, Salisilat acid		√	(Choudhri *et al*., 2018)
Asteraceae	*Helianthus annus* L. *Tegetes erecta* L. *Chromolaena odorata* (L.) R.M. King & H. Rob.	Leaf	Alkaloid, flavonoid, saponin, tannin	√		(Marini *et al*., 2018)
		Leaf Flower	Hexanal, limonene, β-pinene, (E)-β-Ocimene, (E)- linalool oxide, (E)- β-farnesene, glucose, galaktoce, rhamnose, fruktoce, maltoce, sukroce		√	(Nyasembe *et al*., 2012)
Balsaminaceae	*Impatiens balsamina* L.	Leaf	Polyphenols, flavonoids, saponins, tannins, quinones, steroids, terpenoids	√		(Hariyanto *et al*., 2018)
Begoniaceae	*Begonia* sp.	Laeaf	Glucopyranoside, flavanoids, carbohydrates, proteins, steroids, resins, tannins , thiols alkaloids, phenols, saponins, tannins, luteolin, quercetin, β-sitosterol, epi-friedelinol, -sitosterol, luteolin, quercetin	√		(Murugesan *et al*., 2016)
Bromeliaceae	*Ananas comosus* L. *Cryptanthus* sp. *Neoregelia* sp. *Aechmea* sp.	Flower	Anthracene, coumarins anthraquinones, flavonoids, tannins, lignans, mono and diterpenes	√		(Oliveira-Júnior *et al*., 2017)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
Cactaceae	*Opuntia cochenillifera* (L.) Mill. *Echinocactus grusonii* Hildm. *Euphorbia trigona* Mill.	Stem	Flavonoid, steroid, phenolic, anthocyanins	√		(Alves *et al*., 2017)
Cannaceae	*Canna indica* L.	Leaf	Carbohydrates, proteins, amino acids, steroids, alkaloids, phenolics, flavonoids, tannins, terpenoids	√		(Kanase and Vishwakarma, 2018)
Caricaceae	*Carica papaya* L. *Cnidoscolus aconitifolius* Mill.	Leaf	Flavonoid, alkaloid, tannin, saponin, steroid	√		(Marini and Sitorus, 2019)
Commelinaceae	*Rhoeo discolor* L'Her. *Tradescantia pallida* (Rose) D.R. Hunt. *Callisia fragrans* (Lindl) Woodson.	Leaf	Alkaloid, carbohydrate, glycosides, tannins, steroid, flavonoids, saponins	√		(Nikam *et al*., 2013)
Convolvulaceae	*Ipomoea aquatic* Forssk.	Leaf	Flavonoids, amino acids, alkaloids, lipids, steroids, saponin, phenols, reducing sugar, tannins, β-carotene, glycosides	√		(Malakar and Choudhury, 2015)
Crassulaceae	*Kalanchoe pinnata* L.	Leaf	Fenol, flavonoid, tannin, saponin, alkaloid, α-amyrin acetate, friedelin, glutinol, dotriacontanol, phytol, stigmasta, β-sitosterol, Isorhamnetin, dihydroxypropyl tetradecanoate,,eriodictyol, gallic acid, quercetin, kampferol-3-O-rutinoside, isovitexin	√		(Singh *et al*., 2019) (Saleh *et al*., 2014)
Cupressaceae	*Thuja orientalis* L.	Leaf	Terpinen-4-ol	√		(Giatropoulos *et al*., 2013)
Cycadaceae	*Cycas revoluta* Thunb.	Petiole and rachis Roots	β-sitosteryl, β- glucopyranoside, palmitate, hydroxy-trans-cinnamate esters,hydroxy-cis- cinnamate esters, β-sitosterol, unsaturated triacylglycerols, methyl fatty acid esters, flavan 3-ols, flavanones, flavanone, flavone, isoflavones, biflavonoids, methyltetrahydrohinokiflavone	√		(Santos *et al*., 2015) (Afifi *et al*., 2021)
Dioscoreaceae	*Dioscorea japonica* Thunb.	Rhizome	Steroids, clerodane diterpenes, quinones, cyanidins, phenolics, diarylheptanoids	√		(Salehi *et al*., 2019)
Euphorbiaceae	*Acalypha hispida* Burm.f. *Codiaeum variegatum* (L.) A. Juss. *Jatropha curcas* L. *Manihot esculenta* Crantz. *Pedilanthus tithymaloides* (L.) Poit. *Pedilanthus pringlei* Robins *Euphorbia milii* Des. Moul. *Excoecaria cochinchinensis* Lour.	Leaf Flower	Hexanal ,limonene, β-pinene, (E)-β-Ocimene, (E)- linalool oxide, (E)- β-farnesene, glucose, galaktoce, rhamnose, fruktoce, maltoce, sukroce		√	(Nyasembe *et al*., 2012)
		Stem bark	Alkaloids, tannins, flavonoid, saponins, glycosides, terpenoids, sterol	√		(Idris et al., 2014)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
Fabaceae	*Caesalpinia pulcherrima* (L.) Swartz. *Tamarindus indica* L. *Vigna sinensis* (L.) Savi ex Hausskn. *Macroptilium atropurpureum* (Moc. & Sesse ex DC.) Urb.	Leaf Flower	Linalool oxide, β-ocimene, 2-hexenol, hexanal, benzaldehyde, β-myrcene, indole		√	(Nyasembe *et al*., 2018)
		Leaf Flower	Cyanogenic glucosides (prunasin, linamarin, lotaustralin, proacacipetalin), alkaloid (indole, erythrina)	√		(Wink, 2013)
Gesneriaceae	*Episcia reptans* Mart.	Leaf	Phenols, glutathione, β-aminoisobutyric acid, β-sitostero	√		(Liu *et al*., 2019)
		Leaf	Sucrose, raffinose, galactinol, glucose, fructose , inositol		√	(Muller *et al*., 1997)
Gnetaceae	*Gnetum gnemon* L.	Leaf	Saponin, flavonoid, tannin	√		(Tanamal *et al*., 2017)
Lamiaceae	*Coleus atropurpureus* (L.) Benth. *Clerodendrum thomsoniae* Balf.f. *Orthosiphon aristatus* (Blume.) Miq. *Ocimum africanum* Lour. *Mentha piperita* L. *Plectranthus amboinicus* (Lour.) Spreng.	Leaf	Linalool, neral, sitra, mentol isokariofilen, α- humulen, menthone, isomenthone, cineole, pinene,limonene, neomenthol, eukalipto, p-cimene, γ-terpinene, α-terpinene, α-thujene, E-α bergamoteme, methyl eugenol, E-β ocimene	√		(Phasomkusolsil and Soonwera, 2010) (Ramayanti *et al*., 2017)
		Leaf Flower	Linalool oxide, β-ocimene, indole 2-hexenol, hexanal, benzaldehyde, β-myrcene		√	(Nyasembe *et al*., 2018)
Lauraceae	*Cinnamomum burmannii* (Nees. & T. Nees) Blume.	Leaf Bark	Trans-cinnamaldehyde cinnamyl acetate, cinnamyl alcohol. trans-cinnamic acid α-Linoleic acid, α-Copaene Benzopyrene, alkaloid, flavonoid , saponin, tannin, Quinone, triterpenoid, Glycoside, Coumarin	√		(Fajar *et al*., 2019) (Ervina *et al*., 2019)
Lythraceae	*Lawsonia inermis* L.	Leaf Fruit	Carbohydrates, glycosides, quinones, steroids,flavonoids naphthoquinone derivatives, Aliphatic, triterpenes, sterols, Phenolic, coumarins, xanthones	√		(Sharma and Goel, 2018) (Biswas *et al*., 2016)
Malvaceae	*Hibiscus rosa-sinensis* L. *Waltheria indica* L.	Leaf Flower Root	Flavonoid, alkaloid, triterpenes, phenolic	√		(Ferreira *et al*., 2019)
		Leaf	Linoleic acid , octadecenoic acid		√	(Polya, 2003)
Marantaceae	*Calathea* sp. *Maranta leuconeura* E. Morren.		Saponin, tannin, fenolic	√		(Hidayatullah *et al*., 2015)
Moraceae	*Ficus benjamina* L. *Ficus carica* L.	Leaf	Flavonoid, alkaloid, saponin, steroid, tannin, terpenoid	√		(Hikma and Ardiansyah, 2018)
Moringaceae	*Moringa oleifera* L.	Leaf	Alkaloids, flavonoids, saponins, steroids, tannins, phenolics, terpenoids	√		(Aliyu *et al*., 2016)
Musacea	*Musa paradisiaca* L.	Stem	Alkaloids, saponins, flavonoids, polyphenols, reducing sugars	√		(Onyenekwe *et al*., 2013)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
Myrtaceae	*Syzygium aqueum* (Burm.f.) Alston. *Syzygium oleina* Wight. *Syzygium cumini* L. *Psidium guajava* L.	Leaf	Fenolat, flavonoid, tannin saponin, alkaloid, flavonoid	√		(Rahayu *et al*., 2021)
Nephrolepidaceae	*Nephrolepis* sp.	Leaf	Alkaloid, flavonoid, tannin, terpenoid, fenol, saponin	√		(Renjana *et al*., 2021)
Nyctaginaceae	*Bougainvillea glabra* Choisy. *Mirabilis jalapa* L.	Leaf Stem Flower Bark Root	Phytosterols, terpenes, carbohydrates, linalool	√		(Abarca-Vargas and Petricevich, 2018) (Saleem et al., 2018)
Oleaceae	*Jasminum sambac* (L.) Aiton.	Leaf	Monoterpene (methyl jasmonate)	√		(Xu *et al*., 2014)
Orchidaceae	*Cymbidium chloranthum* Lind. *Dendrobium aggregatum* Roxb. *Cymbodium* sp.	Leaf Flower	Alkaloids, bibenzyls, phenanthrenes, stilbenoids, phenols, flavonoids, anthocyanins, polysaccharides glycosides, tannins, coumarin, quinine, steroids, terpinoids, saponin, anthroquinone	√		(Teoh, 2016) (Akter *et al*., 2018)
Oxalidaceae	*Averrhoa bilimbi* L. *Averrhoa carambola* L.	Leaf Fruit	Saponin, tannin, steroid, flavonoid, alkaloids, carbohydrates, phenols	√		(Hasim *et al*., 2019) (Suluvoy and Grace, 2017)
Pandanaceae	*Pandanus amaryllifolius* Roxb.	Leaf	Alkaloida, saponin, flavonoida, tannin, polifenol	√		(Cahyadi *et al*., 2016)
Phyllanthaceae	*Sauropus androgynus* L.	Leaf	Alkaloids, flavonoids, phenols, terpenoids, glycosides	√		(Fikri and Purnama, 2020)
Piperaceae	*Piper batle* L. *Piper crocatum* Ruiz & Pav.	Leaf	Phenolic, 4-allyl phenylacetate, isoeugenol, eugenol	√		(Alighiri *et al*.,2018)
Poaceae	*Cymbopogon nardus* (L.) Rendle. *Eleusineindica* sp.	Leaf Stem	Geraniol, citronella, citronellal	√		(Phasomkusolsil and Soonwera, 2010) (Arcani et al, 2017)
		Flower Leaf	α-pinene, limonene, *p*-Cymene, nonanal, benzaldehyde, α- and ß-pinene, 3-carene, caryophyllene, limonene, nonanal		√	(Wondwosen *et al*., 2017) (Asmare *et al*., 2017)
Portulaceae	*Portulaca oleracea* L. *Portulaca grandiflora* Hook. *Portulacaria afra* (L.) Jacq. *Iresine herbstii* Hook.	Leaf Flower	Phenolic alcohols, aldehydes, hydroxycinnamic acids, alcohols, acylquinic acids, cinnamic acid amides, coumarins, flavonoids, lignans, naphtho-quinones, amino acids, tetrahydroisoquinoline, terpenoids, alkaloids, phenolic acids, coumarins, β-carrot acid polysaccharides, ω-fatty acid	√		(Balabanova *et al*., 2020) (Wang *et al*., 2020)
Punicaceae	*Punica granatum* L.	Leaf Fruit Stem	Terpenoid, fenolik acid, lignin, stilben, tannin, flavonoid, kuinon, kumarin, alkaloid, amina,betalain	√		(Jayaprakash, 2017)
Rhamnaceae	*Ziziphus mauritiana* Lam.	Leaf	Glicoside, phenol, lignin, saponin, tannins	√		(Priyanka *et al*., 2012)
Rosaceae	*Rosa* sp.	Flower	Linalool, geraniol, citronellol	√		(Rosnaeni and Hendranata, 2010)

Continued

Family	Botanical name	Part of the plant is used	Secondary metabolic compounds	Potensial dengue vector control		Reference
				Repellent	Atractant	
		Flower	sesquiterpene (γ-elemene, α-farnesene, β-farnesene, trans-trans-farnesol)		√	(Polya, 2003)
Rubiaceae	*Morinda citrifolia* L. *Gardenia augusta* Merr.	Seed	Alkaloid, saponin, tannin, glycoside	√		(Setya and Harningsih, 2019)
		Seed	Trimethylxanthine, coffeine, guaranine, thein, theine, purine, methylxanthine, indole, pyrazine		√	(Polya, 2003)
Rutaceae	*Citrus hystrix* DC. *Citrus aurantifolia* (Christm.) Swingle. *Murraya koenigii* (L.) Spreng.	Leaf	Sitronelal, sitronelol, linalool, geraniol	√		(Tawatsin *et al*., 2001) (Munawaroh and Astuti, 2010) (Adrianto *et al*., 2014)
		Flower	Pyrroline, methyl damasceninate, nigelline, ethylpyrazine, indole, benzopyrrole		√	(Polya, 2003)
Sapindaceae	*Dimocarpus longan* Lour. *Erioglossium rubigirosum* (Robx.) Blume.	Leaf	R-pinene, limonene,γ- terpinene, R-terpinene	√		(Govindarajan and Sivakumar, 2012)
Sapotaceae	*Manilkara kauki* (L.) Dubard *Mimosops elengi* L.	Leaf Bark Root	Alkaloids, glycoside, saponin, tannin, carboxylic acids, flavanoids, flavonols, terpenoids	√		(Pratiwi *et al*., 2021) (Singh *et al*., 2015)
Scrophulariaceae	*Russelia equisetiformis* Schltdl. & Cham.	Leaf	Alkaloids, flavonoids, saponins, tannins, steroids,terpenoids	√		(Riaz *et al*., 2012)
Solanaceae	*Capsicum annum* L. *Solanum melongena* L. *Solanum lycopersicum* (L.) Karst. *Solanum torvum* Sw.	Flower	α-thujene, α-pinene, sabinene, β-pinene, β-myrcene, α-terpinene, limonene, cineole, cis-β-ocimene, trans-β-ocimene, p-cymene, α-terpinolene, allo-ocimene, citronellal, p-cymenene, cis-sabinene hydrate, linalool, terpinen-4-ol, citronellol, neral, geraniol, geranial	√		(Stashenko and Martinez, 2018)
		Leaf	sesquiterpene (γ-elemene, α-farnesene, β-farnesene, trans-trans-farnesol)		√	(Polya, 2003)
Thymelaeaceae	*Phaleria macrocarpa* (Scheff.) Boerl.	Fruit	Terpen (isoprenoid), alkaloid, benzofenon, quercetin, mahkoside, benzophenone, mangiferin	√	√	(Alara *et al*., 2016) (Handayani *et al*., 2021)
Urticaceae	*Pellonia annamica* Gagnep.	Leaf	Terpenoids, flavonoids, lignans, sterols, polyphenols, Phytol, pentadecanone, α-phellandren, isoelemicin, linalool, menta-diene, ethyl hexanoate, Benz aldehyde	√		(Ibrahim *et al*., 2018) (Saeb *et al*., 2011)
Zingiberaceae	*Alpinia galanga* L. *Zingiber officinale* Rosc. *Curcuma longa* L. *Kaempferia galanga* L.	Leaf	d-α-peladren, d-sabien, cineol borneol, zingiberen, tirmeron seskuiterpen alkohol, α-atlanton, γ-atlanton, sabinene , b-pinene, caryophyllene oxide, caryophyllene	√		(Aseptianova, 2019) (Phasomkusolsil and Soonwera, 2010) (Bhuiyan *et al*., 2008)

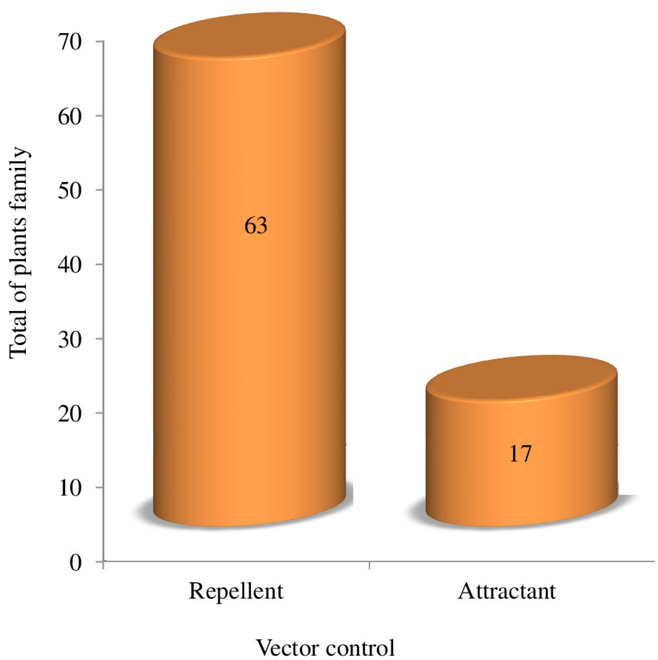

Figure 4. Families of plants that have the potential dengue vector control in study area.

The community has traditionally used *Tagetes minuta* L. (Asteraceae) to repel mosquitoes. The essential oil from *T. minuta* showed the presence of limonene, camphene, and verbenone as the main constituents. The essential oil of *T. minuta* is effective in repelling mosquitoes (Athuman *et al*., 2016). *Mentha piperita* L. (Lamiaceae) oil has potential as a larvicidal and repellant of *A. aegypti* (Manh and Tuyet, 2020). The *M. piperita* oil contains pulegone, menthone, menthol, carvone, 1,8-cineole, limonene, and β-caryophyllene (Singh and Pandey, 2018). The study of the potential of *O. Americanum* and *Blumea alata* (D.Don) DC. (Asteraceae) extracts as a source of mosquito repellent showed that *O. Americanum* gave 100% repellency for 1.5 hours, *B. alata* for 2 hours, and a mixture of *O. Americanum* and *Blumea alata* for 2.5 hours. The *O. Americanum* extract contains linalool, neral, citral, isocaryophyllene, and humulent, while *B. alata* contains terpinene-4-ol, germacrene-D, sabinene, and terpinene. The compound components contained in both types of plants potentially have mosquito protection power (Kazembe *et al*., 2012). The addition of the concentration of *Evodia suaveolens* Scheff (Rutaceae) essential oil increases the protection power as a repellant. The addition of 1.5 ml of *E. suaveolens* essential oil has 81% protection against *A. aegypti*. The ingredients in *Evodia* leaves are linalool, and pinene can repel mosquitoes such as *A. aegypti*, which causes DHF (Simaremare *et al*., 2017).

The infusion of the leaves of the fragrant *Pandanus amaryllifolius* Roxb. (Pandanaceae) has the power to repel the laying of the eggs of the *Aedes* spp. The optimum concentration effective for repelling mosquito eggs is in the range of 4.5 to 5 ml/l. *Pandanus* leaves have a fragrant aroma that affects preventing oviposition against *Aedes* spp. The contents of compounds in *Pandanus* are alkaloids, saponins, flavonoids, tannins, and polyphenols (Cahyadi *et al*., 2016). *Illicium verum* Hook.f. (Illiciaceae) contains an essential oil that can be used as a repellent of *A. aegypti*. The results showed that the clove flower essential oil at concentrations of 10%, 20%, 30%, 40%, and 50% was able to protect against the bites of *A. aegypti* for 1–2 hours. The contents of the essential oil of the clove flower are cineole, linalool, and limonene. The clove flower extract contains the linalool compound that has mosquito repellent properties from the distinctive aroma it produces. The linalool compound is a kind of stable alkali. The clover flower oil often is used as a fragrance for soaps and perfumes. Mosquitoes do not like the aroma of the clove flower essential oil and linalool compounds because they cause irritation to the mosquito's body parts and damage the mosquito's nervous system (Lestari *et al*., 2019). The *Pogostemon cablin* Benth (Lamiaceae) oil has major (patchouli alcohol) and minor (patchoulen, guaien, sychellen, and caryophyllene) components. These minor components can potentially act as repellants or as attractants to insects. The activity of *Culex* sp. using patchouli oil showed that the repellency activity had better protection than synthetic DEET (Nidianti *et al*., 2014).

Insect bioassay results showed that the essential oil and extract of *Nepeta parnassica* Heldr & Sart (Lamiaceae) were highly active against *Aedes cretinus* Edwards and *Culex pipiens* L. The protective power of *N. parnassica* extracts against *A. cretinus* was for 3 hours, while for *C. pipiens* the protective power was up to 2 hours after application. Analysis essential oil *N. parnassica*, dominated by oxygenated monoterpenes, 4aα,7α,7aβ-nepetalactone, 1,8-cineole, dichloromethane-methanol, and 4aα,7β,7aβ-nepetalactone as the main constituents. The content of dichloromethane-methanol and 4aα,7α,7aβ-nepetalactone isolated from *N. parnassica* showed very high mosquito repellency for at least 2 hours against both types of mosquitoes. This study demonstrated the potential use of essential oil extracts, especially dichloromethane-methanol and 4aα,7α,7aβ-nepetalactone *N. parnassica*, as control agents for *A. cretinus* and *C. pipiens* (Gkinis *et al*., 2014).

The *Angelica sinensis* Oliv. (Apiaceae) extract has potential as a repellent against female *A. aegypti*. The results of the GC-MS analysis revealed that the *A. sinensis* extract contains at least 21 phytochemical compounds, and the main constituent is 3-N-butylphthalide. The protective power of the *A. sinensis* extract provides an average protection time of 2.0–6.5 hours against *A. aegypti.* The combination of *A. sinensis* extracts with 5% vanillin can increase to 4.0–8.5 hours (Champakaew *et al*., 2016).

Potential of houses yard plants as attractant of *Aedes* spp.

One of the effective biological control strategies is necessary to do by finding and identifying attractant compounds produced by plants. Attractive flowers, intense aromas, and nectar content need to find metabolites that attract or repel mosquitoes (Peach and Gries, 2020). If plant-based chemicals can be identified, especially those from plants that are attractive to mosquitoes, these plants can serve as bait in mosquito control and surveillance programs (Nyasembe *et al*., 2012). Each mosquito species has a particular preference for plant sources of nutrients. Mosquitoes can detect general and plant-specific chemical cues within their ecological range. The ability of mosquitoes to detect chemical compounds in certain plants will find suitable host plants for them. The interaction of mosquitoes with plants provides information on mosquito control strategies that target plant-eating behavior like attractive toxic sugar baits and the resulting odor (Nyasembe *et al*., 2018).

The volatile compound released by the host plant is attractive to mosquitoes. This compound attracts both male and female mosquitoes. Mosquitoes prefer volatile compounds produced by plants; for example, *A. gambiae* can detect certain chemical compounds from plants (Pachuwah, 2016). The visual appearance of flowers and the volatile compounds released by them are cues for mosquitoes to distinguish and locate host plants. Some species of mosquitoes, such as *A. gambiae*, *C. Pipiens*, and *A. aegypti,* can detect and respond to certain compounds from plants and detect and respond to volatile compounds from plants. Flower volatile organic compounds are mainly composed of four chemical groups: aromatics, monoterpenes, sesquiterpenes, and fatty acid derivatives (Yu *et al*., 2015).

Female *A. aegypti* prefer ovitrap with *jenu* [*Derris elliptica* (Wall.) Benth.] leaf extract to lay their eggs compared to other ovitraps. This plant from the Fabaceae family has the potential to be an attractant to *A. aegypti* in the oviposition process. Methyl eugenol compounds such as sex pheromones are effective at attracting insects and influencing insect behavior, such as searching for a mate, searching for food, and laying eggs. Visual and olfactory integration affects oviposition search media behavior, but the olfactory signal is more influential than visuals. The olfactory organ of the mosquito is the sensilla (hair), and these spread all over its body surface. Sensilla are mostly in many mosquito antennae, and this organ is sensitive to the smell of chemical compounds (Wibowo and Astuti, 2015).

Analysis of the extract of *Silene otitis* L. (Caryophyllaceae) using gas chromatography-mass spectrometry identified 35 compounds. Most of the extract compounds are monoterpenoids, fatty acid derivatives, and benzene. Phenyl acetaldehyde was the most dominant compound found in *S. otites* flowers. The test results of a mixture of *S. otites* flower aroma extract compounds on male and female *Cx. pipiens* showed different responses. Oxide compounds linalool (furanoids) and linalool showed strong responses in male and female mosquitoes. The compound (Z)-3-hexenyl acetate had positive responses only from female mosquitoes. Male mosquitoes showed moderate responses to compound (Z)-3-hexenyl acetate. Female mosquitoes have a moderate reaction to benzaldehyde and methyl salicylate compounds. Meanwhile, the lilac aldehyde, lilac alcohol, and linalool oxide (pyranoid) compounds had moderate responses from both sexes of mosquitoes (Jhumur *et al*., 2008).

The extract *Asclepias syriaca* L. (Asclepiadaceae) showed significant orientation of male and female *Cx. pipiens*. The mixture compounds of benzaldehyde, phenylacetaldehyde, and (E)-2-nonenal most attracted mosquito responses. Therefore, we recommend further research to examine the potential use of synthetic floral scent mixtures for monitoring or controlling disease-transmitting mosquitoes (Otienoburu *et al*., 2012). The maize/*Zea mays* L. (Poaceae) crop contributes to the prevalence of malaria mosquitoes and exacerbates malaria transmission in sub-Saharan Africa. Pollen from corn serves as a food source for *Anopheles* larvae and imago. Female mosquitoes can detect breeding sites where corn pollen is abundant. The *Anopheles* mosquito uses olfactory cues to locate, distinguish, and select breeding sites by utilizing volatile compounds to guide it. The pollen is a source of energy and attractant mosquitoes. Pollen contains pinene, limonene, *p*-cymene, nonanal, and benzaldehyde compounds (Wondwosen *et al*., 2017).

The selections of the oviposition site strongly influence the reproductive success and population dynamics of *Anopheles*, a vector for malaria in female mosquitoes. Mosquitoes choose oviposition sites at different spatial scales, starting with selecting the habitat to search. *Anopheles arabiensis* Patton larvae were the most common species found in various grassy habitats. The highest larva density in habitats was found overgrown by *Echinochloa pyramidalis* (Lam.) Hitchc. & Chase (Poaceae). This condition caused the volatile compounds of *E. pyramidalis* grass to be more attractive than *Typha* (Typhaceae) and *Cyperus* (Cyperaceae). The preference is shown by *Anopheles coluzzii* Coetzee & Wilkerson and *A. arabiensis* prove volatile grass compounds in larval habitat vegetation have an effect in the selection of oviposition sites (Asmare *et al*., 2017).

CONCLUSION

This study shows that various house yard plants have secondary metabolites that have the potential to control adult *Aedes*. Plants in the tsunami settlement area of Banda Aceh City contain secondary metabolites that function as repellents and attractants of adult *Aedes*. However, further testing is necessary in the laboratory to ensure *Aedes*' preference for plants in the yard and the secondary metabolite content of each plant. This research information can be an alternative to *Aedes* control and elimination. Plants in the house yard in the tsunami settlement area of Banda Aceh City have the potential to be used as a strategy for controlling disease-transmitting vectors.

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AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

DATA AVAILABILITY

All data generated and analyzed are included within this research article.

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