Repellency of Lemongrass Extract (*Cymbopogon nardus*) in Solid and Liquid Formulation on *Diaphorina citri and Menochilus sexmaculatus*

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Abstract. Citrus Vein Phloem Degeneration (CVPD), caused by the bacterium Liberibacter asiaticus with Diaphorina citri Kuwayama as the pest vector, decreases citrus yield. This study looked at the effectiveness of Cymbopogon nardus extract in repelling D. citri populations in various formulations and concentrations. The major goal of the reaserch was to identify extract formulations and concentrations that work without having an adverse effect on the predator Menochilus sexmaculatus. Using choice and no-choice test methodologies, the study was carried out from February-March 2022 at the experimental garden of the Faculty of Agriculture, UPN "Veteran" Yogyakarta, located in Sleman, Yogyakarta. On D. citri and M. sexmaculatus, choice and non-choice tests were conducted to determine the repellency of solid and liquid formulations at concentrations of 1%, 3%, and 5%. Chi-square and analysis of variance (ANOVA) were used to analyze the data. According to the findings, a solid formulation with 5% lemongrass extract was most successful at keeping D. citri away while having no effect on M. sexmaculatus larvae or adult stages. This formulation can assist ecologically friendly agriculture. On cultivated ground, higher doses of a more durable solid formulation are advised.
Keyword: Citrus Vein Phloem Degeneration, Cymbopogon Nardus Extract, Diaphorina Citri, Menochilus Sexmaculatus, Repellency

1 Introduction

Environmentally friendly agricultural practices for sustainable agriculture is an alternative with the aim of not only relying on the use of synthetic materials which cause environmental damage and focusing only on chemicals but developing sustainable agriculture is part of how to maintain sustainability to meet the needs of future generations. Citrus is an annual plant that originated in Asia. Citrus fruit is a horticultural commodity that is very popular and is consumed in the form of fresh fruit or processed products that

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have begun to be cultivated using environmentally friendly agricultural practices [1][2]. The citrus sub-genus has 10 species and seven of them have been widely cultivated and have become commercial oranges i.e. Citrus sinensis Osbeck, Citrus reticulata Blanco, Citrus maxima Merr, Citrus limon, Citrus aurantifolia, and Citrus medica [3].

Candidatus Liberibacter americanus and L. asiaticus caused the CVPD disease are gram-negative bacteria which are classified as Pleomorphic in the form of elongated and rounded [4]. Infected plant parts will potentially spread CVPD to other plants. Infections between areas over long distances can be observed geographically through the transfer of infected seedlings and the spread of CVPD through vector pest migration D. citri. Types of association of pathogens with host plants that are persistent, circulative, and non-propagating, if the CVPD vector is the host of L. asiaticus then for the rest of its life will always contain the bacteria. Vectors can contain bacteria and can infect healthy plants after D. citri sucks the bacteria on the diseased parts for 168-360 hours. Symptoms of CVPD disease in the field are typical symptoms of CVPD, symptoms in young plants, and symptoms in mature plants. Typical symptoms are yellow stripes or spots [5] and yellow shoots [6] that do not start to develop evenly at the tips of plants or on new growth. On the leaves, characteristic symptoms appear in the form of leaves becoming stiff and wrinkled with small yellow leaves. Symptoms in young plants are characterized by the slow development of shoots with abnormal upward growth. The appearance of the color on leaves with irregular yellow stripes. The symptom of sectoral greening begins with the appearance of many water shoots, the leaves of the branches pointing up irregularly. In heavy attacks, the leaves turn yellow like a lack of element N which indicates damage to the phloem vessels. CVPD is a disease that spreads relatively quickly because the CVPD vector insects can fly and move from one plant to another. D. citri is categorized as the main pest of citrus plants (Citrus sp.) [7]. Threshold of control of D. citri containing L. asiaticusis 1 in CVPD endemic areas [5].

Diaphorina citri Kuwayama is an active pest with flying and jumping movements. Severe attacks due to psyllid activity, namely the affected plant parts become curly and over time will die. Nymphs of D. citri are yellow-green without wings. Nymphs colonize plant shoots by sucking on young cells. Wings will appear in the adult stage and show the active ability to fly and jump. The nymph stage consists of 5 instars, each successive instar for 3, 2, 3, 3, and 3 days [8]. D. citri in the adult stage has a slender body, light brown to dark brown. The eyes of D. citri are gray with brown patches. On the genitals of males, the belly is bright bluish green and in females, it is orange. The body length is between 2.7-3.3 mm with the characteristics of this insect positioning its body to form 45o. In high population conditions, it is usually marked by a transparent white discharge in a spiral shape around the shoots or leaves. D. citri will complete its life cycle more quickly in more environmental conditions hot. The population of D. citri will decrease significantly during winter (January and February) [9] and monsoon summer (June and August).

Lemongrass or serai in Javanese is a plant from tribes of grasses that are used as spices for cooking fragrances food and fragrances in the fragrance industry. Lemongrass has The Latin name Cymbopogon confertiflorus Stapt, which comes from Ceylon [10], then spread to countries in Asia, America, and Africa [11]. Lemongrass is a plant that can produce essential oil [10]. The types of citronellas that are often found are A. nardus var Ceriferus commonly known as kitchen lemongrass, A. nardus var lexuosua or also called Malabar grass, A. nardusvar marginatus reeds, and A. nardus var genuinus or citronella or citronella grass [12]. Superior varieties of citronella Maha Pengiri type have been released by Balitro, with essential oil content with geraniol content 88-89% and citronellal 39% pale yellow.
The activity of citronella oil against insects is a repellent, interesting (attractant), contact

poison, respiratory poison, reduces appetite, inhibits egg laying, inhibits growth, reduces fertility, and is an insect vector [14]. Citronellal compounds in pest control and disease act as an insecticidal agent that works as an antifeedant and repellent. The content of citronella has no effect preferred by mosquitoes and some other insects [11]. Besides citronellal insect repellent contained in the oil citronella can be in contact with insects. Work mechanism citronellal contact poison inhibits the enzyme acetylcholinesterase which results in phosphorylation of the amino acid serine in the asteratic center of the enzyme concerned [13]. Symptoms of poisoning occur in insects, namely the accumulation of acetylcholine which causes central nervous system disorders resulting in death, paralysis, breathing, and convulsions. The active ingredients include aldehydes (citronellal-C10H16O) and the alcohol compound geraniol (C10H18O) is also an anti-fungal compound belonging to the terpenoid group. The mechanism of lemongrass essential oil compounds fragrant as an antifungal that inhibits the synthesis of ergosterol or sterols which forms the fungal cell membrane [15].

Metabolic processes in plants can produce essential oils in the form of secondary bolts resulting from the reaction between chemical compounds and water. These compounds include flavonoids, terpenoids, and alkaloids [6]. These materials can be used in self-defense. Plants produce essential oils in tissues and are stored in inactive compound form. Essential oils in plant parts can be stored in roots, stems, bark, leaves, flowers, and fruit. The existence of essential oils on plant parts will give a smelly aroma, as the flower part can help pollinate, the fruit helps as a seed distribution media [14]. Insects have chemical receptors in the form of chemoreceptors that are connected to the senses of taste and smell. These parts are important because the insect's sensory center connects with various kinds of behavior, such as feeding behavior, copulation, habitat selection, and so on are often directed by chemical taste buds to insects. According to research [16], guava leaves and other parts of the fruit do not deter predatory insects like M. sexmaculatus, but they do repel mature D. citri. Guava fruit and leaves contain a variety of volatile chemicals known as "green leaf volatiles" that have an insect-repelling effect, including sesquiterpenes, aldehydes, and alcohols [17].

Insecticide formulations come in two different forms: liquid and solid. While solid formulations typically contain active chemicals, carriers, wetting, and level, liquid formulations often contain active compounds, solvents, and additives such emulsifiers, graders, and adhesives [18]. Gel-like solid formulations with fragrance or fragrance components are possible. Fragrance gel is a solid formulation with a specific composition, form, and application technique [19]. The development of an air freshener formulation included the addition of sodium benzoate as a preservative and propylene glycol as a solvent surfactant, along with carrageenan, xanthan gum, gelatin, and essential oils for air freshener solid gel [20]. Thus making this gel-shaped fragrance is more practical than fragrances in a liquid room that must be used by spraying.

Guava leaf extract and non-seed own nature repellent or repellent mature D. citri [16]. Fruit and leaf guava seeds produce compound volatile, such as sesquiterpene, aldehyde, and alcohol [17]. Substances repellent also found in lemongrass fragrant (C. Nardus), that is citronellal, geraniol, and methyl heptanone [22]. In various studies, it is stated that essential oils by traditional have long been used as repellent insect pest seeds- grains and nuts in storage warehouses [23]. Explained that lemongrass essential oil fragrance shows the highest repellency percentage compared to oil essential others. Oil lemongrass fragrant contains citronellal, geraniol, and citronellol which are capable dispel pests. Extracting lemongrass fragrant gives an effect against Helopeltis cocoa pod-sucking pests H. antonii (Hemiptera; Miridae). Citronella oil with a fraction of citronella on a dose low of 0,1

mL/tube produces a compound volatile which shows nature as a repellent insect and murderer insect test H. antonii [15]. The active ingredient of citronella which is the main insecticide is citronellal [24]. The results of the study explain that extract ethanol leaf lemongrass fragrant could use as a drug insect however still shape extract and has no in-shape formulation preparation. According to data [25], using oil is essential to control pests' weaknesses main which are ingredients extracted as botanical pesticides easily evaporate and are not stable. The moment this formulation pesticide botanical which was developed with system emulsion oil in water is wrong one alternative for upgrade solubility and stability component bioactive. Oil essential lemongrass own ability as antiphytoviral suppressor Potyvirus reason disease mosaic. Development formulation nanoparticles could control the disease transmitted by a vector so that becomes an alternative that is better if compared to pesticides other [26].

Based on the description reference study previously, the researcher is interested in doing a study to repellency extract lemongrass to Asian Citrus Psyllid (D. citri) vector CVPD disease citrus plant (Citrus sp.) and M. sexmaculatus as predator on larvae and adult stages with gift treatment formulation that is congested and liquid as well as various type concentration which consist from 1 %, 3%, and 5% as a measure to support environmentally responsible farming.

Table 1. Setting Word's margins.

Margin	**mm**
Top	24
Bottom	16
Left	20
Right	20

2 Resources and methods

2.1 Rearing of predators and d. *Citri*

Pests of the *D. citri* species were brought in from BALITJESTRO Malang, East Java, a collaborator in studies involving sterile circumstances due to the CVPD disease. *D. citri* which was bred using Kemuning plant shoots (*Murura paniculata*). Rearing was carried out on a rectangular screen. Then separate the male and female insects and so on until a large population is obtained. Besides this activity, collection and exploration of *M. sexmaculatus* (predators) are carried out by taking from plantation areas and rice fields targeting the long bean commodities. *M. sexmaculatus* is a predator of *Aphids* which are plant-sucking pests [33]. Capturing predators at the larvae and adult stages, then breeding them in the laboratory by housing them in rectangular screen cages with sizes 54 cm x 58 cm x 100 cm containing the koro bean plant (*Canavalia ensiformis*) [16]. Feed *Aphids* periodically to keep predators alive before testing. The criteria for the predator-rearing room were avoiding rain, getting enough sunlight, and the room temperature during the day not more than 30 ºC and at night not more than 10 ºC.

2.2 The formulation of lemongrass extract

The liquid formulation of lemongrass extract was made with lemongrass extract (*Cymbopogon nardus*) using distilled water as a solvent following the concentration of 1%, 3%, and 5%. Take the concentrated extract using a measuring pipette according to the volume (1 mL, 3 mL, and 5 mL), then add 70% alcohol each 5 mL, Nonylphenol 10 each 1 mL, 3 mL, and 5 mL into the flask and measure 100 mL. Followed by adjusting the solution using distilled water to a total volume of 100 mL (exactly according to the tera limit) and homogenizing the solution.

The solid formulation was made using lemongrass extract (*C. nardus*), 10 g jelly powder, 5 g pectin, 5 g gelatin, 5 mL 70% alcohol, nonylphenol 10 (3 mL, 9 mL, and 15 mL), and distilled water (269 mL, 257 mL, and 245 mL). Mixed Lansida trademark lemongrass extract, respectively 3 mL, 9 mL, and 15 mL with 5 mL 70% alcohol. Then heated at a temperature of 40 ºC with a tightly closed condition using a water bath heater until the mixed lemongrass extract is produced. The solid formulation was made without heating by mixing 10 g of jelly powder with distilled water (263 mL, 259 mL, and 255 mL). The mixture was made by mixing 5 g of gelatin and 5 g of pectin with 10 mL of distilled water at 80 ºC. Heating the jelly powder mixture that has been homogeneous at a temperature of 40 ºC. Add a mixture of gelatin and pectin. Then stir until homogeneous. Heat the mixture by increasing the heating temperature slowly until the mixture boils. Lowering the heating temperature to 70 ºC. Adding lemongrass extract (previously the polarity has been lowered) into a mixture of jelly powder, pectin, and gelatin. Then add nonylphenol 10 (NP10) 3 mL, 9 mL, and 15 mL to each formulation. Then store at room temperature until solid.

2.3 D. Citri and predator responses

2.3.1 Choice and no-choice test of D. citri

Table 2. Combination of Choice Test Treatments of *D. citri*

Arm A		Arm B
BKF1	vs	J
BKF2	vs	J
F1K1 + J	vs	F1K2 + J
F1K1 + J	vs	F1K3 + J
F1K2 + J	vs	F1K3 + J
F2K1 + J	vs	F2K2 + J
F2K1 + J	vs	F2K3 + J
F2K2 + J	vs	F2K3 + J
X + J	vs	Y + J

Information :

BK : Control blank
F1 : Solid formulation
F2 : Liquid formulation
K1 : Lemongrass extract concentration of 1%
K2 : Lemongrass extract concentration of 3%
K3 : Lemongrass extract concentration of 5%

J : Solid formulation of citrus leaf extract with 3% concentration
X : The best concentration of solid formulation
Y : The best concentration of liquid formulation

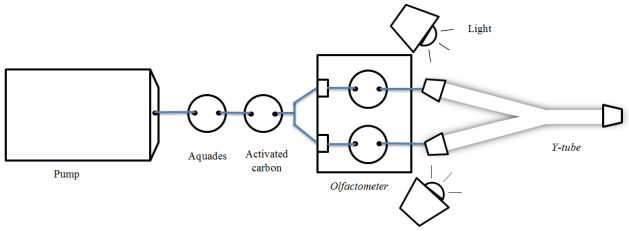

Fig. 1. Picture of *D. citri* choice test

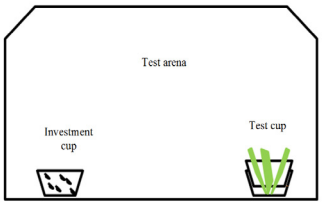

Fig. 2. Picture of *D. citri* no-choice test

2.3.2 Choice test of m. Sexmaculatus

The choice test method used Y-tube with 5 larvaes and imagoes of *M. sexmaculatus* predators in each experiment with a duration of 60 minutes. The test used the best formulation and concentration results (from the choice test of *D. citri* with the highest repellency properties) measuring 1 cm x 1 cm (mass of 1 gram). The experiment was repeated 16 times. In order to determine whether the highest levels of repellency had no impact on predators' ability to find pests, the best formulation and composition (with the highest repellency) from the D. citri choice test were combined [27]. Tests were conducted with *M. sexmaculatus* predator in larvae and imago stage. This experiment requires *M. sexmaculatus* as many 5 larvaes and imagoes of *M sexmaculatus*. The treatment uses 2 treatment combinations multiplied by 16 replicates using 80 larvaes and imagoes of *M. sexmaculatus*. Each experimental cage was carried out with 15 psyllids of *D. citri* placed in a pest dish. The experiment was carried out with 8 repetitions. Accordingly, the total number of *D. citri* that is needed is 120 psyllids. Observations were made on pests that landed on the test cup, pests that remained in the pest cup, and pests that were in the test arena. Observations were made with a time duration of 6 and 24 hours.

3 Statistical Analysis

To determine the impact of the treatment, analysis was conducted. The inquiry used the fundamental methodology of Completely Randomized Design (CRD). To ascertain the diversity of them, the information gathered was subjected to an analysis of variance (ANOVA) with a significance threshold of 5%. The Duncan Multiple Range Test is used to determine the treatments that differ significantly at a significance level of 5% if there is a significant difference. The Duncan's test is a measurement that takes into account a set of

comparison values whose values rise in proportion to the separation between the two treatments under study. Regardless of how many treatments are utilized, it can be used to test for differences between any two feasible treatment pairs.

4 Discussion

4.1 Choice test of d. Citri

The treatment of formulation and concentration of lemongrass extract (Citronella Oil) in the choice test of *D. citri* pests using Y-tube give a significant difference in the results of observations (Figure 1). Lemongrass extract containing chemicals such as Citronellal 37,73% and Geraniol 18,73% give a real repellant effect on *D. citri* pests. Citronellal compounds contain toxins that are hazardous to dehydration and act as a desiccant to cause death from ongoing fluid loss. Thus, insects exposed to the poison may perish from a dehydration [27].

The choice test of *D. citri* pests in the blank treatment utilizing solid and liquid formulations that were paired with citrus leaf extract with a 3% concentration revealed significantly different outcomes based on the analysis of variance (Figure 3). This indicates that the olfactometer supplied with an air of 10 mL/min with an electric pump can function properly. The use of blanks in the form of a tangerine leaf extract with a concentration of 3% was used to attract the insect pest *D. citri*. *D. citri* is interested in the protein content of bio-amino acids in the young shoots so it stimulates the female imago of *D. citri* to lay their eggs and copulate [8] [16]. At the time of observation, it was seen that there were *D. citri* pests that copulated during the test and walked on the test arm of the citrus leaf extract treatment with a citrus leaf extract with a 3% concentration.

The outcome demonstrated that citronella had a deterrent impact on *D. citri*. The analysis of variance of the *D. citri* choice test on variations in the concentration of lemongrass extract showed the lemongrass extract which was tested with concentrations of solid and liquid formulation treatments produced significant differences against *D. citri* pests (figure 1). This indicates that the use of concentrations of 1%, 3%, and 5% in solid and liquid formulations is able to affect the response and the level of repellency effectiveness of lemongrass extract against *D. citri*. The lemongrass extract used in the test was proven to be able to resist *D. citri* pests stating that the active ingredients of citronella and geraniol essential oils have insect-repellent properties [22]. The volatile compounds produced affect chemoreceptors or the sense of smell in insects so it can affect insect central sensors such as feeding behavior, copulation, and habitat selection. Several studies which have been conducted report that both of the active ingredients geraniol and citronellol can be used as antimicrobial and anti-insect aromatherapy [13].

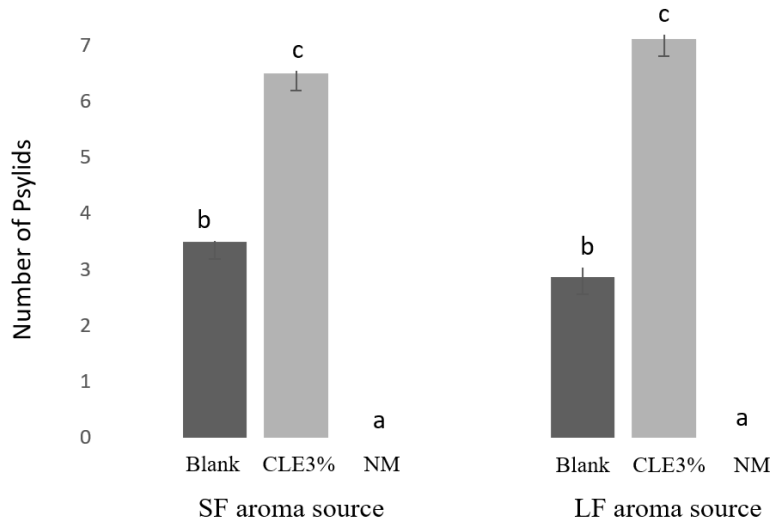

Fig. 3. Psyllids that either did not move (NM) or moved in response to volatiles entering Y-tube olfactometers on average: response to blank or Citrus leaf extract (CLE) 3 % on Liquid Formulation (LF) and Solid Formulation (SF) aroma sources (Psylids). It can be seen clearly that the observed *D. citri* moves and is attracted to Citrus leaf extract (CLE). Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 8, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

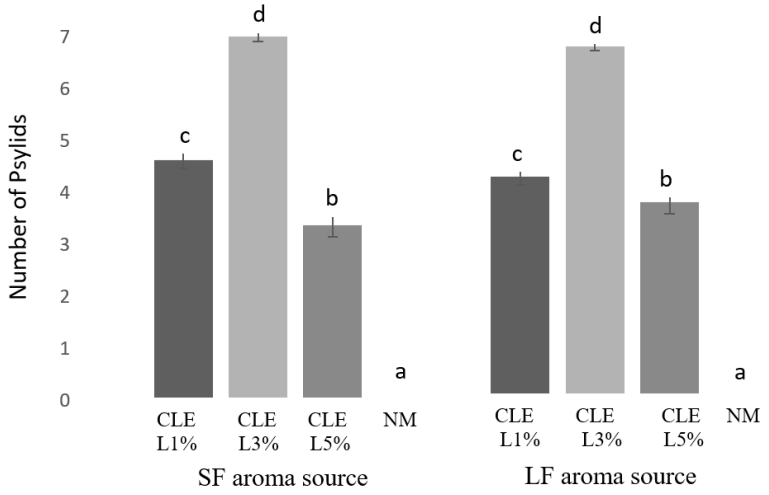

Fig. 4. Psyllids that either did not move (NM) or moved in response to volatiles entering Y-tube olfactometers on average: response to Citrus leaf extract 3% + Lemongrass 1% (CLE+L1%), Citrus leaf extract 3% + Lemongrass 3% (CLE+L3%), Citrus leaf extract 3% + Lemongrass 5% (CLE+L5%) on Liquid Formulation (LF) and Solid Formulation (SF) aroma sources (Psylids). It can be seen clearly that the observed *D. citri* was repelled and moved away from Citrus leaf extract 3% + Lemongrass 5% (CLE+L5%). Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 8, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

Based on the tests on variations in the concentration of lemongrass extract, (Figure 4) the most notable variation for *D. citri* pest repellency in each formulation was found in the 5% solid and liquid formulations. Revealed that the results of the olfactometer test on *D. citri* depend on the dose used, with very low doses it would have little effect on *D. citri* [28]. Comparison of solid and liquid formulations of lemongrass extract in the choice test of *D. citri* produce volatiles capable of repelling *D. citri*. From the analysis of variance (Figure 5), the solid formulation had a higher level of repellency effectiveness against *D. citri*. To

improve the solubility and stability of the bioactive components found in essential oils, utilize a solid formulation of lemongrass extract because it has more stable characteristics [26] essential oil as a pest control has a volatile weakness so it must be formulated in a more stable form. *D. citri* locates the host plant by using the volatile chemicals of certain species as cues and seeks for plant portions that are still uninfested by competing insects [28].

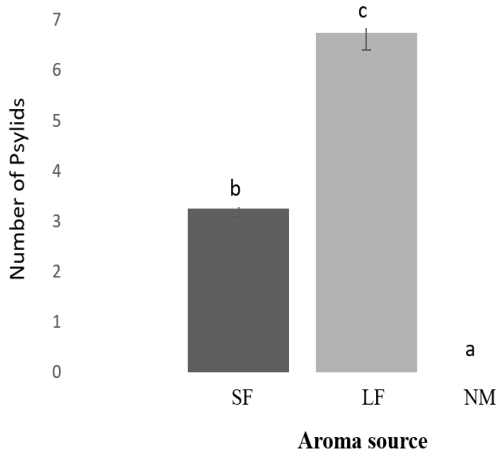

Fig. 5. Psyllids that either did not move (NM) or moved in response to volatiles entering Y-tube olfactometers on average: response to Citrus leaf extract 3% + Lemongrass 5% (CLE+L5%) on Liquid Formulation (LF) and Solid Formulation (SF) aroma sources (Psylids). It can be seen clearly that the observed *D. citri* was repelled and moved away from Citrus leaf extract 3% + Lemongrass 5% (CL +L5%) on Solid Formulation (SF). Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 8, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

The no-choice test is an advanced test of *D. citri* choice test carried out in the laboratory (figure 2). The no-choice test was carried out with the formulation and concentration of extracts that were proven to have the best repellency properties, namely the solid formulation of lemongrass extract with 5% concentration, and also tested the blank as a comparison. The test was carried out by placing the formulation of the test material in the center of the cup and also placing 5 citrus leaves arranged in a circular position in a row on the cup. Citrus plants serve as hosts for *D. citri* pests, hence in this experiment, the towing agent was citrus plant leaves. The olfactory system for volatile plant chemicals is frequently the basis for insect activity while looking for host plants. By visiting plants, insects respond to smells given forth by plants. The intensity and volume of the stimulus, as well as the insect's state at the point of the stimulus, all affect how the insect reacts to odor. In addition, one of the factors that attracts insects to their hosts is the compatibility of the chosen host. Many insects, including *D. citri*, are stimulated to locate their host plants by volatile substances emitted by the host plant.

In the citrus cultivation environment, there are volatile compounds such as the gases acetic acid and formic acid. The compound was captured by the antennae of *D. citri* as a response to determine the location and host selection [29]. Volatile substances function as semiochemicals in interactions between organisms, including those between plants and animals, insects and other insects, and plants and plants. Semiochemical substances are frequently employed in biological plant pest management. Semiochemicals are most frequently used to draw out, capture, and kill insects. [16].

The treatment of the solid formulation of lemongrass extract with 5% concentration for 6 and 24 hours of treatment differs significantly, according to the findings of the analysis of the variance no-choice test. The average of the first 6 hours of treatment in the test of the solid formulation of lemongrass extract with 5% concentration had higher repellency properties than the average 24 hours of treatment (Figure 6 on the left side). Significantly, it was seen that *D. citri* is more to move to citrus leaves after 24 hours of treatment (Figure 6 on the right side). This was because some of the volatiles in the solid formulation had evaporated from the test material so that its concentration was reduced. The concentration of these volatiles in the air has a significant impact on how repellent they are. The repellent effect at 6 hours of treatment was significantly higher than after 24 hours of treatment. Citronella oil can repel insects depending on the concentration and duration of exposure [30].

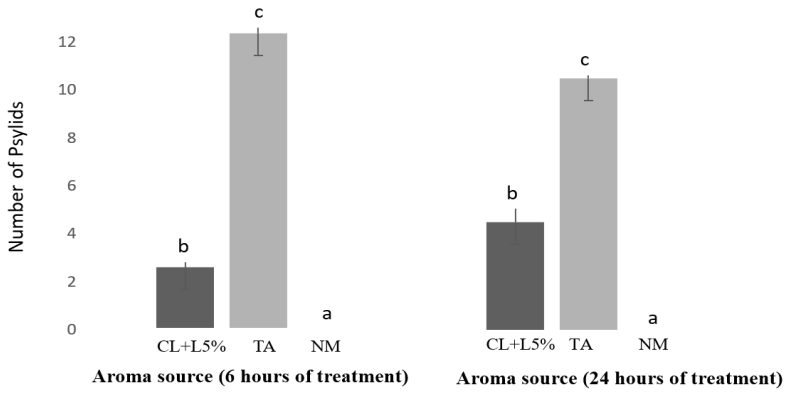

Fig. 6. Average of psylids that not moved (NM) or moved towards volatiles: response to Citrus leaf + Lemongrass 5% (CL+L5%) on liquid formulation, Test Arena (TA) for 6 and 24 hours of treatments (Psylids). It can be seen clearly that the observed *D. citri* was repelled and moved away from Citrus leaf extract 3% + Lemongrass 5% (CL+L5%) on Liquid Formulation (LF) for 6 hours and 24 hours of treatment. *D. citri* prefered to perch in the Test Arena (TA) during time of treatment. Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 8, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

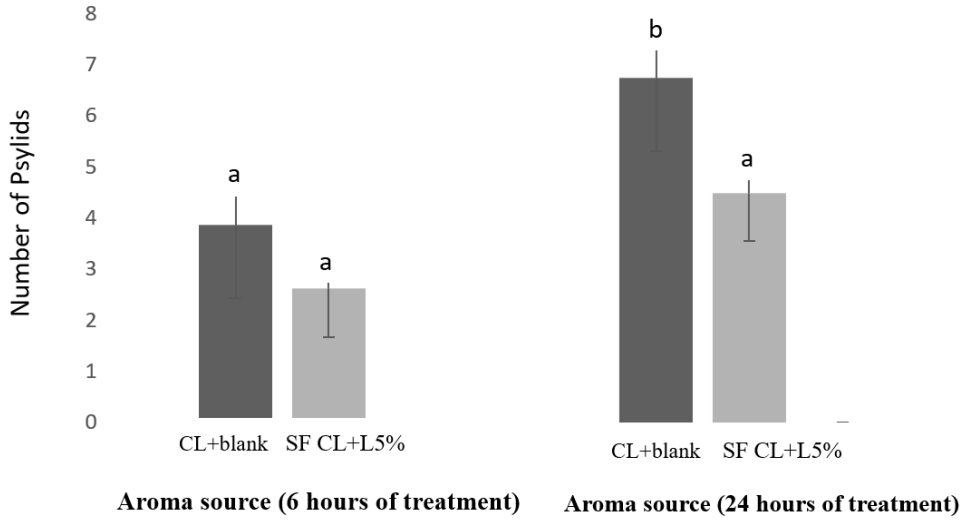

Fig. 7. Average of psylids not moving (NM) or moving in the direction of volatiles: response to Citrus leaf + sterile water blank (CL+blank), Solid Formulation of Citrus leaf + Lemongrass 5% (SF CL+ L5%) 6 and 24 hours of treatments (Psylids). It can be seen clearly that the observed *D. citri* was repelled and moved away from Citrus leaf extract 3% + Lemongrass 5% (CL+L5%) on Solid

Formulation (SF) for 6 hours and 24 hours of treatment. *D. citri* prefered to perch in Citrus leaf + sterile water blank (CL+blank) during time of treatment. Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 8, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

On observation, it was seen that some adult *D. citri* were not attracted to the host's citrus leaf containing the aroma source of the lemongrass extract. This phenomenon proves that the repellency effect of lemongrass extract prevents mature *D. citri* from choosing citrus leaves as a signal to its host plant (Figure 7). The results showed that psyllids failed to recognize the aroma of citrus leaves at the test site due to the repulsion effect of volatile ingredients from guava extract of red, seedless, and white [16]. The use of volatiles in mineral oil can suppress the releasing and disguising of host plant volatiles as an attractant and repellent *D. citri* [31]. The effect of volatile compounds on citrus psylid can cause physical disturbances in host recognition, the attractive effect of volatile compounds released by citrus leaves reacts with volatiles in the air to disrupt insect instincts in finding hosts [32]. Volatile substances have the potential to deter psyllid populations and lessen the effects of huanglongbing in citrus groves.

The research that has been done, planting guava among citrus clumps can be an option to protect against psyllids in citrus orchards. When citrus and guava plants interact allelopathically, compounds known as allelopathic agents directly repel or deter herbivorous pests, which can reduce the appeal of their hosts to psyllids [32]. Seeing the potential of the indiscriminate test that has been carried out with the results of citronella being able to reject *D. citri*. Cultivation of citronella in citrus orchards as an integrated pest control measure with the use of volatile compounds has the potential to affect the orientation and choice of *D. citri* to host plants.

4.2 Choice test of of M. sexmaciulatus

The *D. citri* insect utilizes specific types and concentrations of volatile chemicals as chemical markers to find its host plant and locate plant portions that are still free of rival insect pests. The same substance is also used by the polyphagous predator *M. sexmaculatus* to locate plants or insect habitats for its prey. To find out how lemongrass extract impacted *D. citri* predators, *M. sexmaculatus* was put through a choice test. Tests with a solid formulation of lemongrass extract with 5% concentration which has been proven to have the best repellency properties from the result of the *D. citri* choice test in the laboratory. This test is also tested on blanks as a comparison. The predator choice test of M. sexmaciulatus is used at the larvae and imago stage which can be seen in Appendix VI. Citronellal compounds in lemongrass are ingredients that cause dehydration toxins (desiccant) which can result in death due to continuous fluid loss in insects [30].

In the choice test larvae of *M. sexmaculatus*, larvae from exploration results were used which have the characteristics of a black body (Appendix VI) with transverse and parallel white lines, a brownish yellow head, with an average length of 7,0 mm which can be estimated to enter in instar IV. The larvae stage of *M. sexmaculatus* at stage instar IV has a black color with white spots that are wider and clearer [33]. The pupa turns a dark gray or milky color. The average length of the larvae was 7,8 ± 0.5 mm and the width 3,3 ± 0,1 mm with a life span of 1-2 days in the fourth instar. Based on the analysis of variance in Appendix XI part A, it shows that in the choice test of larvae stage of *M. sexmaculatus* in Y-tube. The results were not significantly different from the solid formulation of lemongrass extract with 5% concentration and the blank treatments. Based on trials, the larvae stage of *M. sexmaculatus* were neither attracted nor repelled by the lemongrass extract so it was safe

for predatory larvae (Figure 8 on the left side). The reason is that apart from not having a real difference that did the application of citronella oil with a concentration of 1000-2000 ppm using the hanging cotton that save for the larvae stage of *M. sexmaculatus* and does not make in mortality larvae of *M. sexmaculatus*. For D. citri, the presence of secondary metabolic chemicals is repulsive, while it had no effect on the imago stage of M. sexmaculatus.

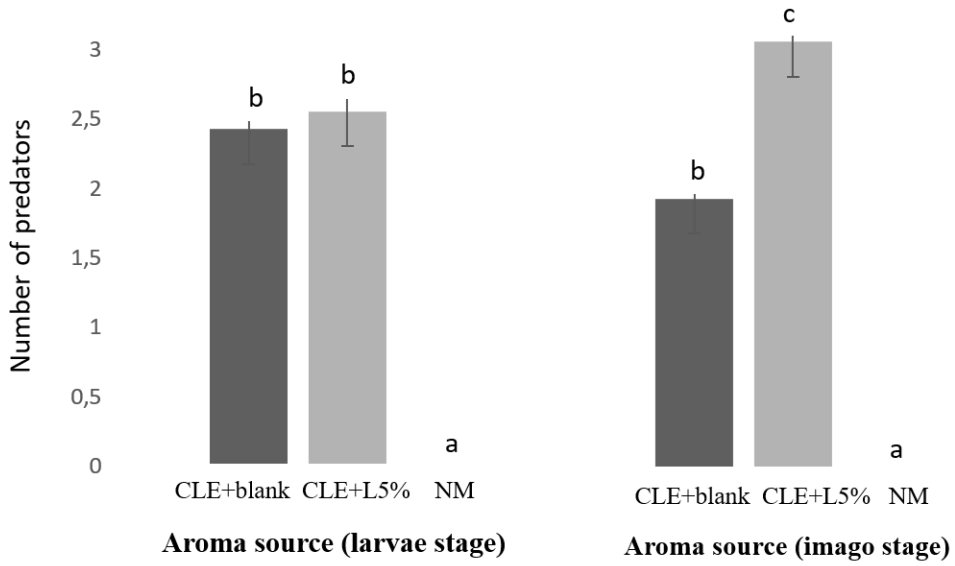

Fig. 8. Average of M. sexmaculatus predators that did not move (NM) or moved in the direction of volatiles: response to Citrus leaf extract + sterile water blank (CLE+blank), Citrus leaf extract 3% + Lemongrass 5% (CLE+L5%) (imago or larvae of *M. sexmaculatus*). It can be seen clearly that the observed *M. sexmaculatus* was not repelled from Citrus leaf extract 3% + Lemongrass 5% (CLE+L5%) on larva stage during treatment. Using the Duncan's Multiple Range Test with a significance level of 5% and a sample size of 16, the mean is followed by various letters in one graphic to indicate that there is a statistically significant difference.

Based on the analysis, it was shown that in the choice test imago stage of *M. sexmaculatus* in the Y-tube, the results were significantly different from the solid formulation of lemongrass extract with a concentration of 5% and the blank treatments. Based on trials, the lemongrass extract affects the imago stage of *M. sexmaculatus* and influences the behavior of female *M. sexmaculatus* to lay eggs (Figure 8 on the right side). When tested, it was seen that female *M. sexmaculatus* laid yellow eggs on a Y-tube. Testing lemongrass oil containing citronellal sprayed on Foeniculum vulgare / fennel flowers can attract predators such as Cycloneda sanguinea L. (Coleoptera: Coccinellidae) at concentrations of 1% and 5% [34]. The volatile nature of volatile essential oil compounds has a repellent effect against *D. citri*, but it does not affect predators and parasitoids., The imago of *M. sexmaculatus* was not sensitive to citronella oil applied, and it showed a low mortality rate. Reported that lemongrass extract concentrations of 1,000 - 5,000 ppm were safe against predators Cycloneda sanguinea L. (Coleoptera: Coccinellidae) [13].

Based on observations, the larvae stage of *M. sexmaculatus* was more sensitive than the imago stage of *M. sexmaculatus*. The use of a solid formulation of lemongrass extract can be used as a *D. citri* insect repellent by placing or hanging the material in the cultivation area [13]. The use of citronella oil such as aroma or an insect repellent is safer compared to it is applied to plants directly. Stated that essential oil from lemongrass is an ingredient composed of mixtures of aromas and volatile compounds so that it decomposes quickly in the environment [14]. Therefore, the application can still be done by farmers a

few days before harvest because it is environmentally friendly agriculture. Based on the concept of natural control, pest populations do not have to be destroyed, but is suppressed below the control threshold so that natural enemies can develop [13]. The use of predators as natural enemies is dependent, which means that they are able to suppress, regulate, and stabilize the pest population [35]. The new generation of insecticides must-have choice properties against non-target organisms, and it is non-persistent in the environment [36].

5 Conclusion

Lemongrass (*Cymbopogon nardus*) has repellent properties against *D. citri* and has no repellent effect on predator *M. sexmaculatus* in larvae and adult stages. The solid formulation of lemongrass extract (*Cymbopogon nardus*) with a concentration of 5% has the most effective repellent properties against *D. citri* which protects and is environmentally friendly agriculture. It is recommended for further research to use higher concentrations of lemongrass extract with a more stable solid formulation to see the direct effect on *D. citri* and its predators on cultivated land.

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