EFFICACY OF ESSENTIAL OILS AGAINST BLACK BEAN APHID(*Aphis fabae*Scopoli) UNDER LABORATORY CONDITIONS

Abstract

The black bean aphid (*Aphis fabae*), poses a significant threat to cultivated crops, leading to food insecurity and hunger concerns. Essential oils from plants offer promising low-risk alternatives to synthetic chemicals for aphid control whose widespread use has raised serious environmental and health issues. To assess the efficacy of plant essential oils, an experiment was carried out at the Entomology Laboratory of Lamjung Campus following a completely randomized design with three replications using eight treatments including a control (distilled water and ethanol). The essential oils used were Neem (*Azadirachtaindica),* Eucalyptus (*Eucalyptus globulus),* Palma rosa (*Cymbopogon martini*), Citronella (*Cymbopogonwinterianus*), lemongrass (*Cymbopogoncitratus*), Juniperberry (*Juniperusrecurva*), Mint (*Menthaarvensis*) and control (distilled water and ethanol) at the concentration of 1% and 2% with the exposure time of 12, 24 and 48 hours for contact mortality and 2 µL and 4 µL with the exposure time of 12 and 24 hours for fumigation mortality. The result revealed that individual mortality rate increased with increasing oil concentration and exposure time. Lemongrass with 2% concentration resulted in the high mortality percentage (66.66%) whereas, Neem with 1% concentration demonstrated the lowest (23.3%) in contact assay. Similarly, in fumigation assay, the highest mortality percentage was exhibited by 4 µL Lemongrass (100%) when compared to 2 µL Neem and Juniper berry have lowest mortality percentage (73.33%) after the control.Therefore, Lemongrass with 2% concentration for contact assay and 4 µL Lemongrass for fumigation assay was considerably more effective than other used essential oils. However, more research

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is necessary with locally available essential oils to assure the long-term effectiveness in field and lab conditions.

Keywords*: Black bean aphid, Essential oils, Faba bean, Mortality*.

INTRODUCTION

Aphids being the most hostile pests for almost all cultivated crops, seriously diminish the productivity of crops and cause spoilage by sucking the sap from the leaves as well as delicate stems (Chalise & Dawadi, 2019). The annual average yield losses brought on by aphids range from 30 to 50% (Alghamdi, 2018).Aphid's saliva includes non-enzymic, reducing compounds, which, in the presence of oxidases, can mix with and inactivate protective phytochemicals, including those generated in response to damage and transmitted in the phloem sieve tube sap on which Aphid feed (Miles, 1999). The black bean aphid (*Aphis fabae*) is a major pest of field beans, which are sown in the season of spring and the data of field studies have revealed that yield losses by the black bean aphid infestations can exceed 50% of the yield (Hansen et al., 2008). Black bean aphids directly damage the plants by feeding on the phloem that results in severe reductions of plant development and productivity (Pruter & Zebitz, 1991). In addition to direct plant injury, black bean aphid infestation harms faba bean due to honeydew excretion on the leaves, which interferes with physiological processes in the host plant (Hurej & Werf, 1993). These aphids can indirectly damage by acting as vectors for plant viruses (Hogenhout et al., 2008).They transfer the bean leaf rolling virus and the faba bean necrotic yellows virus (Casper, 1993).It has been long since botanical insecticides have been regarded as acceptable alternatives for killing the harmful insects because of their low retention in the environment, minimal toxicity to mammals, better selectivity and the popularity(Ebrahimiet al., 2013).Numerous plant species' essential oils have a variety of insecticidal, antifeedant, repellent, oviposition-deterrent,

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growth-regulating, and antivectorial effects on nuisance insects(Vinelina, Dima and Georgi, 2014). Essential oils are complicated, organic, volatile compounds with a distinct smell that are produced by aromatic plants as secondary metabolites. They are often produced via steam or hydro-distillation, which Arabs invented in the Middle Ages (Bakkali et al., 2008). The majority of research concluded that essential oils have significant potential for pest management, particularly in greenhouses and fields(Isman, 2000). Essential oils are very bioactive and can be very effective insecticides. As a result, there should be a lot more research done on them to help manage aphids (Tomova et al., 2005).

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MATERIALS AND METHODS

The experiment was carried out from March to April of 2023 in the entomology laboratory of the Institute of Agriculture and Animal Science, Lamjung campus, which is in Sundarbazar, the Lamjung district of Gandaki province. The site was located at an elevation of 610m above sea level with latitude: 28.2847° N and longitude: 84.3637°Eunder humid sub-tropical climate.The highest and lowest temperatures recordedwere~~, respectively~~, 28–30°C and 20–22°C respectively. Apterous (wingless) black bean aphid was collected from the field of faba bean located nearby Lamjung campus. The required essential oils were obtained from Herbs Production and Processing Company Limited, Kathmandu. Two factorial Completely Randomized Experimental Design was selected as the design of the research. Seven treatments of essential oils namely: Neem, Eucalyptus, Palma rosa, Citronella, Lemongrass, Juniper berry, Mint along with one control were used. Three replication per treatments were done. The aphid mortality was assayed through two parameters during the experiment.

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a. Contact mortality assay (Leaf dip bioassay):Using ethanol as a non-polar solvent, each treatment oil was dissolved before being utilized to investigate the direct contact effect of essential oils on aphid species. There were two concentration levels 1% and 2% -prepared for each treatment. In three replications, each individual faba bean leaf was immersed in

the oil solution of every treatment for about five minutes. The volatile solvent was then allowed to evaporate by letting them dry for a while. Following treatment, the leaves were placed in sterilePetri plates with damp filter paper within. In each petri dish, ten aphids were released and given time to settle on the leaves that had been treated. Then the petri plate was covered by muslin cloth so that aphids present inside the petri plate could not escaped away. After 12 hours and 24 hours, the number of dead aphids was counted. Using a little brush to gently strike the aphid and keeping an eye out for any movement of its legs or antennae, one may identify dead aphids.

b. Fumigation mortality assay: Saturated filter paper was stored in three layers within sterile 9 cm petri dishes. At the bottom of the filter sheets was a tiny, rectangular (5×2 cm) filter paper. Each essential oil was directly added to the rectangular piece of filter paper with a micropipette, at concentrations of 2 µL and 4 µL. To avoid direct contact between the oils and the experimental pest, ten aphids were then introduced onto the upper layer of the petri dish. To keep the treated oils from leaking, parafilm was then used to enclose the entire apparatus. Similar methods were described in Chalise & Dawadi, 2019.

Mortality of aphids was counted after 12hrs, 24hrs and 48hrs.Mortality of treated aphid was then calculated by dividing the number of dead aphids in petri plate by total number of aphids in petri plate and expressing it in terms of percentage. The collected data of aphid mortality was processed with MS Excel 365 and analysis of variance was done using R- Stat software (version 4.1.0). Mean comparison was done using Duncan´s Multiple Range Test at 5% level of significance.

RESULTS

1. Effect of treatments on the contact mortality of aphid

Table 1: Effect of Essential oils on aphid mortality on contact assay

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Factor A (Essential oils)	**Contact mortality after treatment application**		
	12hrs	**24hrs**	**48hrs**
Neem	10.00[c]	15.00[d]	31.66[cd]
Eucalyptus	15.00[bc]	18.33[cd]	30.00[d]
Palmarosa	25.00[a]	35.00[b]	55.00[a]
Citronella	13.33[bc]	23.33[c]	43.33[b]
Lemongrass	26.66[a]	43.33[a]	61.66[a]
Juniper berry	16.66[b]	18.33[cd]	38.33[bc]
Mint	23.33[a]	33.33[b]	45.00[b]
Control	1.66[d]	6.66[e]	8.33[e]
CV%	17.73	13.13	15.19
F-test	***	***	***
LSD	5.36	6.57	6.99
SEM	2.97	4.28	5.82
Factor B (Concentration)	**12hrs**	**24hrs**	**48hrs**
1%	12.08[b]	18.33[b]	32.91[b]
2%	20.83[a]	30.00[a]	45.41[a]
CV%	17.73	13.13	15.19
F-test	***	***	***
LSD	2.68	3.28	3.49
SEM	4.375	5.835	6.25
Grand mean	16.45	24.16	39.167
P value	.	**	**

*, **and *** at P=0.05, P=0.01 and P=0.001 level of significant respectively.

The effect of treatments on mortality of aphid was found significant at $p<0.001$ at 12, 24 and 48hrs.At 12hrs, the highest mortality percentage was found in Lemongrass (26.66%) which was statistically par with Palmarosa and Mint and the lowest mortality rate was in control .The lowest aphid mortality after control was in Neem (10%) which was statistically par with Citronella and Eucalyptus. Similarly, at 24hrs, highest aphid mortality was seen in Lemongrass (43.33%) and lowest mortality was in Neem (15%) but Eucalyptus and Juniper berry were also significantly at par. In the 48hrs, similar result was observed where Lemongrass had the highest aphid mortality rate (61.66%), which was statistically similar with Palmarosa and Eucalyptus. The lowest mortality percentage was shown by Eucalyptus (30%) which was statistically par with Neem.

Table2: Interaction of essential oils and concentration on aphid mortality in contact assay

Essential oils	12hrs		24hrs		48hrs	
	1%	2%	1%	2%	1%	2%
Neem	6.66^{ghi}	13.33^{efg}	13.33^{gh}	16.66^{fg}	23.33^{g}	40.00^{de}
Eucalyptus	10.00^{fgh}	20.00^{cde}	10.00^{gh}	26.66^{de}	26.66^{fg}	33.33^{ef}
Palmarosa	23.33^{bcd}	26.66^{abc}	33.33^{cd}	36.66^{bc}	43.33^{cd}	66.66^{a}
Citronella	10.00^{fgh}	16.66^{def}	13.33^{gh}	33.33^{cd}	30.00^{fg}	56.66^{b}
Lemongrass	23.33^{bcd}	30.00^{ab}	33.33^{cd}	53.33^{a}	56.66^{b}	66.66^{a}
Juniper berry	10.00^{fgh}	23.33^{bcd}	13.33^{gh}	23.33^{ef}	33.33^{ef}	43.33^{cd}
Mint	13.33^{efg}	33.33^{a}	23.33^{ef}	43.33^{b}	40.00^{de}	50.00^{bc}
Control	0.00^{i}	3.33^{hi}	6.66^{h}	6.66^{h}	10.00^{h}	6.66^{h}

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LSD	7.59	3.28	9.89
Grand mean	16.45	24.16	39.16
CV%	17.73	24.23	15.19

*, ** and *** at P=0.05, P=0.01 and P=0.001 level of significant respectively.

The mortality rate had increased with exposure time and higher the concentration of Essential oils from 1% to 2%, more was the mortality rate. From the interaction table, in 12hrs it was found that Mint at 2% concentration revealed the highest mortality percentage (33.33%) which was statistically par with Lemongrass (30%) and Palmarosa (26.66%) but Neem at 1% concentration demonstrated lowest mortality (6.66%). In 24hrs, Lemongrass with 2% concentration exhibited the highest mortality rate (53.33%) whereas lowest mortality was shown by Neem, juniper berry and citronella at 1% concentration with 13.33% .Similarly, in 48hrs, Lemongrass with 2% mortality exhibited the highest mortality (66.66%) whereas Neem with 1% mortality showed the lowest (23.33%).

2. Effect of treatments on fumigation mortality of aphid

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Table 3:Effect of Essential oils on aphid mortality in fumigation assay

Factor A (Essential oils)	**Fumigation mortality after using treatments**	
	12hrs	**24hrs**
Neem	71.66^{c}	75.00^{d}
Eucalyptus	81.66^{ab}	95.00^{ab}
Palmarosa	85.00^{a}	90.00^{bc}
Citronella	83.33^{ab}	96.66^{ab}
Lemongrass	78.33^{abc}	98.33^{a}
Juniper berry	76.66^{bc}	83.33^{c}
Mint	85.00^{a}	95.00^{ab}

Control	5.00[d]	6.66[e]
CV%	8.39	7.21
F-test	***	***
LSD	6.99	6.78
SEM	**9.54**	**10.83**
FactorB (concentration)	**12hrs**	**24hrs**
2µl	66.25[b]	77.08[b]
4 µl	75.41[a]	82.91[a]
CV%	8.39	7.21
F-test	***	**
LSD	3.49	3.39
SEM	4.58	2.91
Grand mean	70.83	80.00
P value	***	.

*, ** and *** at P=0.05, P=0.01 and P=0.001 level of significant respectively.

From the table, at 12hrs, the highest mortality percentage was shown by Palmarosa and Mint with 85% but statistically, it was similar with Citronella, Eucalyptus and Lemongrass. Mortality percentage in Lemongrass was highest (98.33%) at 24hrs which were significantly par with Citronella, Eucalyptus and Mint. Neem at 12hrs (71.66%) and 24hrs (75%) showed the lowest mortality percentage after control.

Table 4: Interaction of essential oils and concentration on aphid mortality in fumigation assay

Essential oils	12hrs		24hrs	
	2µL	4 µL	2 µL	4 µL
Neem	66.6^{ef}	76.6^{cd}	73.33^{d}	76.66^{d}
Eucalyptus	73.3^{de}	90.0^{ab}	93.3^{abc}	96.6^{ab}
Palmarosa	83.33^{bc}	86.6^{ab}	86.66^{c}	93.3^{abc}
Citronella	83.33^{bc}	83.3^{bc}	96.66^{ab}	96.6^{ab}
Lemongrass	63.33^{f}	93.33^{a}	96.66^{ab}	100.0^{a}
Juniper berry	70.0^{def}	83.3^{bc}	73.33^{d}	93.3^{abc}
Mint	83.33^{bc}	86.6^{ab}	90.00^{bc}	100.0^{a}
Control	6.6^{g}	3.3^{g}	6.66^{e}	6.66^{e}
CV	8.39		7.21	
LSD	7.29		9.59	
Grand mean	70.83		7.21	

*, ** and *** at P=0.05, P=0.01 and P=0.001 level 0f significant respectively.

The mortality rate had increased with exposure time and concentration of Essential oils from 1 µl to 2 µl. From the interaction table, in 12hrs, it was observed that Lemongrass with 4µl concentration showed the highest mortality (93.33%) and in 24hrs, highest mortality was observed in Lemongrass with 4 µl concentration (100%) whereas lowest mortality was shown by 2 µl Neem and Juniper berry with 73.33%.

DISCUSSION

Tomova et al., (2005), Ebrahimi et al., (2013), and Alghamdi, (2018) also reported that the action of essential oils on the aphid is dosage dependent that the individual mortality percentage increased with increasing oil concentration. Hence, lemongrass was effective against black bean aphid in both contact and fumigation assay which was in agreement with

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Shahid Nisar et al., (2023) reported that the best result with the highest mortality of aphid was shown by lemongrass with 80% . Chalise & Dawadi, (2019) also reported that the highest contact mortality percentage had resulted in Lemongrass. Ricci et al. discovered that lemongrass oil could efficiently repel *Diuraphisnoxia* (Mordvilko), a Russian wheat aphid. Zhang et al.(, 2016)reported that with LC_{50} value of 169.6 mg/L in 24 hours after treatment, Lemongrass essential oil showed high toxicity against *Aphis citricola*. The various bioactive cyclic and acyclic terpene constituents present in the oil of Lemongrass attributed to its insecticidal property (Eden et al. 2020). The primary contributor for the insecticidal property of Lemongrass oil is citral which is a mixture of geranial and neral(Eden et al., 2020). Citral can regulate cell proliferation by interacting with intracellular oxygen radicals and oxidative stress. Furthermore, citral and other components may act on neuroreceptors, obstruct signal transduction, and induce hormonal imbalance, membrane damage, and cytotoxicity in the host (Feroz, 2020). In addition to its major constituent, minor component such as germacrene D (2.24%), caryophyllene (0.57%) and caryophyllene oxide (0.58%) in limited quantity exhibit substantial insecticidal and repellent activities (Talbi et al., 2020). Lemongrass has the ability to block the function of several neurotransmitters, including acetylcholine esterase and octopamine (Singh et al., 2017).

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CONCLUSION

Aphis fabae, the black bean aphid (Homoptera: Aphididae) is the most devastating pest of the faba bean. Synthetic pesticide shows negative impact on human health and ecosystem including pollution, pest resistance, biodiversity loss and toxicity to non-target organisms. Botanical insecticides including essential oils, with their new, highly bioactive constituents, have the potential to be highly effective pesticides as they are non-toxic to beneficial fauna, are biodegradable, environmentally friendly, human health-safe, and residue-free. The research revealed that Lemongrass with higher concentration had the highest mortality

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194 percentage while the lowest mortality percentage was shown by Neem with lower
195 concentration after control in both contact and fumigation process. Therefore, with proper
196 validation, Lemongrass can be used as an alternative to synthetic insecticides for the control
197 of black bean aphid. However, further research in field condition is highly recommended to
198 test the derived result which allows broader application at the farmer's level.

199 **REFERENCES**

200 Alghamdi, A. S. (2018). Insecticidal effect of four plant essential oils against two aphid
201 species under laboratory conditions. *Journal of Applied Biology & Biotechnolog*, *6*(2),
202 27–30. https://doi.org/10.7324/jabb.2018.60205

203 Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential
204 oils - A review. *Food and Chemical Toxicology*, *46*(2), 446–475.
205 https://doi.org/10.1016/j.fct.2007.09.106

206 Casper, R. (1993). *Characterisation and serology of virus-like particles associated with faba*
207 *bean necrotic yellows*. 629–647.

208 Chalise, P. P., & Dawadi, S. (2019). *Efficacy of plant essential oils on black bean aphid*
209 *(Aphis fabae) and cabbage aphid (Brevicoryne brassicae) under laboratory condition*
210 *Storage insect pest management View project Traditional beekeeping with Apis cerana*
211 *F. in Nepal View project. December*. http://www.entomoljournal.com

212 Ebrahimi, M., Safaralizade, M. H., Valizadegan, O., & Amin, B. H. H. (2013). Efficacy of
213 three plant essential oils, Azadirachta indica (Adr. Juss.), Eucalyptus camaldulensis
214 (Dehn.) and Laurus nobilis (L.) on mortality cotton aphids, Aphis gossypii Glover (Hem:
215 Aphididae). *Archives of Phytopathology and Plant Protection*, *46*(9), 1093–1101.
216 https://doi.org/10.1080/03235408.2012.758347

217 Eden, W. T., Alighiri, D., Supardi, K. I., & Cahyono, E. (2020). *The Mosquito Repellent*
218 *Activity of the Active Component of Air Freshener Gel from Java Citronella Oil (*

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Cymbopogon winterianus). 2020.

Feroz, A. (2020). Ef fi cacy and cytotoxic potential of deltamethrin , essential oils of Cymbopogon citratus and Cinnamonum camphora and their synergistic combinations against stored product pest , Trogoderma granarium. *Journal of Stored Products Research*, *87*, 101614. https://doi.org/10.1016/j.jspr.2020.101614

Hansen, L. M., Lorentsen, L., & Boelt, B. (2008). How to reduce the incidence of black bean aphids (Aphis fabae Scop.) attacking organic growing field beans (Vicia faba L.) by growing partially resistant bean varieties and by intercropping field beans with cereals. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, *58*(4), 359–364. https://doi.org/10.1080/09064710701788844

Hogenhout, S. A., Ammar, E. D., Whitfield, A. E., & Redinbaugh, M. G. (2008). Insect vector interactions with persistently transmitted viruses. *Annual Review of Phytopathology*, *46*, 327–359. https://doi.org/10.1146/annurev.phyto.022508.092135

Hurej, B. M., & Werf, W. V. A. N. D. E. R. (1993). *The influence of black beaq aphid , Aphis fabae Scop ., and its honeydew on the photosynthesis of sugar beet.* 189–200.

Isman, M. B. (2000). Plant essential oils for pest and disease management. *Crop Protection*, *19*(8–10), 603–608. https://doi.org/10.1016/S0261-2194(00)00079-X

Miles, P. W. (1999). Aphid saliva. *Biological Reviews*, *74*(1), 41–85. https://doi.org/10.1111/j.1469-185X.1999.tb00181.x

PRÜTER, C., & ZEBITZ, C. P. W. (1991). Effects of Aphis fabae and Uromyces viciae□favae on the growth of a susceptible and an aphid resistant cultivar of Vicia faba. *Annals of Applied Biology*, *119*(2), 215–226. https://doi.org/10.1111/j.1744-7348.1991.tb04860.x

Shahid Nisar, M., Rashid, A., Samiullah, K., Haidar, M. R., & Malik, S. (2023). Ecofriendly Approaches for Controlling Mustard Aphid (Lipaphis Erysimi Kalt.) Infestation. *Plant*

Protection, *7*(1), 1–7. https://doi.org/10.33804/pp.007.01.4455

Singh, K. D., Labala, R. K., Devi, T. B., Singh, N. I., Chanu, H. D., Sougrakpam, S., Nameirakpam, B. S., & Sahoo, D. (2017). Biochemical efficacy , molecular docking and inhibitory effect of 2 , 3-dimethylmaleic anhydride on insect acetylcholinesterase. *Scientific Reports*, *June*, 1–11. https://doi.org/10.1038/s41598-017-12932-0

Talbi, M., Hajji, L., Brouzi, A. El, & Mohammedia, T. (2020). *Chemical composition and insecticidal activity of Anacyclus pyrethrum essential oil from the Bensliman area against Culex pipiens*. *10*(1), 13–21.

Tomova, B. S., Waterhouse, J. S., & Doberski, J. (2005). The effect of fractionated Tagetes oil volatiles on aphid reproduction. *Entomologia Experimentalis et Applicata*, *115*(1), 153–159. https://doi.org/10.1111/j.1570-7458.2005.00291.x

Vinelina YANKOVA, Dima MARKOVA, Georgi VELICHKOV, N. V. (2014). Plant Oils for Control of Cotton Aphid (Aphis gossypii Glov.) in Greenhouse Cucumbers. *Türk Tarım ve Doğa Bilimleri Dergisi*, 1565–1568.

Zhang, C., Liu, R., He, J., Ma, Z., & Zhang, X. (2016). Chemical compositions of ligusticum chuanxiong oil and lemongrass oil and their joint action against aphis citricola van der goot (Hemiptera: Aphididae). *Molecules*, *21*(10). https://doi.org/10.3390/molecules21101359

Alghamdi, A. S. (2018). Insecticidal effect of four plant essential oils against two aphid species under laboratory conditions. *Journal of Applied Biology & Biotechnolog*, *6*(2), 27–30. https://doi.org/10.7324/jabb.2018.60205

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils - A review. *Food and Chemical Toxicology*, *46*(2), 446–475. https://doi.org/10.1016/j.fct.2007.09.106

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Casper, R. (1993). *Characterisation and serology of virus-like particles associated with faba bean necrotic yellows*. 629–647.

Chalise, P. P., & Dawadi, S. (2019). *Efficacy of plant essential oils on black bean aphid (Aphis fabae) and cabbage aphid (Brevicoryne brassicae) under laboratory condition Storage insect pest management View project Traditional beekeeping with Apis cerana F. in Nepal View project*. *December*. http://www.entomoljournal.com

Ebrahimi, M., Safaralizade, M. H., Valizadegan, O., & Amin, B. H. H. (2013). Efficacy of three plant essential oils, Azadirachta indica (Adr. Juss.), Eucalyptus camaldulensis (Dehn.) and Laurus nobilis (L.) on mortality cotton aphids, Aphis gossypii Glover (Hem: Aphididae). *Archives of Phytopathology and Plant Protection*, *46*(9), 1093–1101. https://doi.org/10.1080/03235408.2012.758347

Eden, W. T., Alighiri, D., Supardi, K. I., & Cahyono, E. (2020). *The Mosquito Repellent Activity of the Active Component of Air Freshener Gel from Java Citronella Oil (Cymbopogon winterianus). 2020*.

Feroz, A. (2020). Ef fi cacy and cytotoxic potential of deltamethrin , essential oils of Cymbopogon citratus and Cinnamonum camphora and their synergistic combinations against stored product pest , Trogoderma granarium. *Journal of Stored Products Research*, *87*, 101614. https://doi.org/10.1016/j.jspr.2020.101614

Hansen, L. M., Lorentsen, L., & Boelt, B. (2008). How to reduce the incidence of black bean aphids (Aphis fabae Scop.) attacking organic growing field beans (Vicia faba L.) by growing partially resistant bean varieties and by intercropping field beans with cereals. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, *58*(4), 359–364. https://doi.org/10.1080/09064710701788844

Hogenhout, S. A., Ammar, E. D., Whitfield, A. E., & Redinbaugh, M. G. (2008). Insect vector interactions with persistently transmitted viruses. *Annual Review of Phytopathology*, *46*,

327–359. https://doi.org/10.1146/annurev.phyto.022508.092135

Hurej, B. M., & Werf, W. V. A. N. D. E. R. (1993). *The influence of black beaq aphid , Aphis fabae Scop ., and its honeydew on the photosynthesis of sugar beet.* 189–200.

Isman, M. B. (2000). Plant essential oils for pest and disease management. *Crop Protection*, *19*(8–10), 603–608. https://doi.org/10.1016/S0261-2194(00)00079-X

Miles, P. W. (1999). Aphid saliva. *Biological Reviews*, *74*(1), 41–85. https://doi.org/10.1111/j.1469-185X.1999.tb00181.x

PRÜTER, C., & ZEBITZ, C. P. W. (1991). Effects of Aphis fabae and Uromyces viciae□favae on the growth of a susceptible and an aphid resistant cultivar of Vicia faba. *Annals of Applied Biology*, *119*(2), 215–226. https://doi.org/10.1111/j.1744-7348.1991.tb04860.x

Shahid Nisar, M., Rashid, A., Samiullah, K., Haidar, M. R., & Malik, S. (2023). Ecofriendly Approaches for Controlling Mustard Aphid (Lipaphis Erysimi Kalt.) Infestation. *Plant Protection*, *7*(1), 1–7. https://doi.org/10.33804/pp.007.01.4455

Singh, K. D., Labala, R. K., Devi, T. B., Singh, N. I., Chanu, H. D., Sougrakpam, S., Nameirakpam, B. S., & Sahoo, D. (2017). Biochemical efficacy , molecular docking and inhibitory effect of 2 , 3-dimethylmaleic anhydride on insect acetylcholinesterase. *Scientific Reports*, *June*, 1–11. https://doi.org/10.1038/s41598-017-12932-0

Talbi, M., Hajji, L., Brouzi, A. El, & Mohammedia, T. (2020). *Chemical composition and insecticidal activity of Anacyclus pyrethrum essential oil from the Bensliman area against Culex pipiens*. *10*(1), 13–21.

Tomova, B. S., Waterhouse, J. S., & Doberski, J. (2005). The effect of fractionated Tagetes oil volatiles on aphid reproduction. *Entomologia Experimentalis et Applicata*, *115*(1), 153–159. https://doi.org/10.1111/j.1570-7458.2005.00291.x

Vinelina YANKOVA, Dima MARKOVA, Georgi VELICHKOV, N. V. (2014). Plant Oils for

Control of Cotton Aphid (Aphis gossypii Glov.) in Greenhouse Cucumbers. *Türk Tarım ve Doğa Bilimleri Dergisi*, 1565–1568.

Zhang, C., Liu, R., He, J., Ma, Z., & Zhang, X. (2016). Chemical compositions of ligusticum chuanxiong oil and lemongrass oil and their joint action against aphis citricola van der goot (Hemiptera: Aphididae). *Molecules*, *21*(10). https://doi.org/10.3390/molecules21101359