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# POTENCY OF THREE BOTANICAL OILS AGAINST THE *Aphis craccivora* KOCH (HOMOPTERA: APHIDIDAE) NYMPHS UNDER LABORATORY CONDITIONS

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## ABSTRACT

Botanicals are promising and attractive alternatives for pest management. In the present study, three botanical oils namely neem (*Azadirachta indica*), karanja (*Pongamia pinnata*) and mehogony (*Swietenia mahagoni*) were tested against the nymphs of *Aphis craccivora* Koch to evaluate the toxic and repellent effects under laboratory conditions (25 ± 5$^{o}$C, 65-75% RH). Four concentrations (0.5, 1.0, 1.5, and 2.0%) along with control were maintained with distilled water and tween-20 was used as emulsifier. Leaf dipped method were used for insect bioassay. Insect mortality was recorded at 24, 48 and 72 hours after intervals while repellency was carried out at 2 hours after intervals upto 10$^{th}$ hours and the collected data were analyzed through MSTAT-C program. Results indicated that all the tested oils had toxic and repellent effects against the *A. craccivora* nymphs. Among the tested botanical oils, no significant difference was observed in terms of mortality over treatment time. But significant difference was noticed over level of concentrations exerted by the botanical oils. The average highest mortality (28.62%) was recorded by the application of mehogony oil whereas neem oil showed the lowest mortality (27.21%) against the *A. craccivora* and the mortality was directly proportional to the level of concentrations and hour after treatment (HAT). Probit analysis showed the lowest $LD_{50}$ values of mehogony oil which revealed the highest toxic effect against the nymph of bean aphid. The highest repellent effect (77.33%) was found in mehogony oil (repellent class IV) among all the botanical oils applied. On the contrary, neem (57.33%) and karanja (55.00%) oils belonged to the same repellent class that is repellent class II. Although all the tested botanical oils evaluated showed toxic and repellent effects but mehogony oil performed as the best potent oil against the nymphs. We therefore suggested using the mehogony oil for the management of bean aphid.

**Keywords:** Botanical oils, *Aphis craccivora*, Mortality, Repellent effect

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## INTRODUCTION

Country bean (*Lablab purpureus* L.) is a highly proteineous legume and a major winter vegetable crop in Bangladesh (Salim et al., 2013). About 21 to 38% of leaf protein and 20 to 28% crude protein was reported in leaves and seeds of country bean, respectively (Cook et al., 2005). Besides, seeds are rich micronutrients and minerals also (Kala et al., 2010; Shaahu et al., 2015). It is one of the atmospheric N-fixing legume and a valuable green manure forming crop (Cook et al., 2005). However, crops are threatened by many insect pests resulting huge economic losses (Oliveira et al., 2014).

Among the insect pests of legumes crops, bean aphid, *Aphis craccivora* Koch (Homoptera: Aphididae) is the most destructive and cosmopolitan pest. About 4700 species of aphids have been found worldwide and cause enormous loss of different types of crops (Blackman and Eastop, 2007; Alikhani et al., 2010). Due to severe infestation of *A. craccivora* resulting from 20 to 40% yield loss of bean, *Lablab purpureus* L. (Islam, 2008) while mustard aphid cause from 87.16 to 98.16% yield loss of mustard crop (Anonymous, 1995) in Bangladesh. Both the nymphs and adults of bean aphid suck cell sap from the leaves, twigs, inflorescences, pods, and may cause upto 100% yield loss (Akhtar et al., 2010; Razaq et al., 2011). Besides, *A. craccivora* transmit bean common mosaic virus (Kaiser and Mossahebi, 1974) groundnut rosette virus (Storey and Ryland, 2008), pumpkin mosaic virus (Singh, 1981) etc. Moreover, aphid also serve as vector of 20 non-persistent plant viruses including broad bean mosaic, die back virus, Iranian strain viruses, etc., in many places of the world and transmit more than 50 viral diseases (Heneberry and Jech, 2001). They also secrete honeydew causing the growth of sooty mould fungus, which inhibits photosynthetic activity of plant (Singh et al., 2014; Trivedi and Singh, 2014).

Aphid is a prolific breeder and randomly corrosive insecticides are used to control them for quick knockdown (Pavela et al., 2009). But chemical protection measures suffer so many serious drawbacks (Lee et al., 2001; Ambethar, 2009). Their extensive and indiscriminate use causes ecological imbalance, resistance of pesticides to pest, pest resurgence and outbreak of secondary pests, creates phytotoxicity, insecticidal residues in foods, feed and leads to health and environmental risks (Mahmud et al., 2002; Ashamo, 2004; Nas, 2004; Mweke et al., 2020). As a result, researchers and scientists all over the world are now trying to adopt alternatives to insecticides to protect crop from insect pest infestation as eco-friendly manner.

Use of natural products is an excellent source and stands top most position to protect insect pests in the field among different alternatives (Franck et al., 2009). Various botanical products derived from different plants emerged as promising tools to control pests by offering several advantages over insecticides, such as host specific, non-toxic to mammals and beneficial organisms, less prone to insect resistance, readily biodegradable and less expensive as well (Saxena, 1992). Among the botanicals, many plant derivatives essential oils have been reported effective against *A. craccivora* and other related insect pests (Tewary et al., 2006; Khater, 2012; Jahan et al., 2013). Various products of plants have been tried by several researchers with a good degree of success as crop protectants against aphids in Bangladesh (Khan et al., 2019). For example, plant oils and extracts including neem, karanja and mehogony were reported to be effective in managing *A. craccivora* (Das et al., 2008; Yasmin et al., 2017). Further, numerous other studies by using oils from botanicals have also been implied (Aziz et al., 2015; Aziz et al., 2018). The present study was therefore, planned and, design in order to evaluate the mortality and repellent effects of three botanical oils of *Azadirachta indica* (neem), *Pongamia pinnata* L. (karanja) and *Swietenia mahagoni* L. (mehogony) on nymphs of bean aphid.

## MATERIALS AND METHODS

### Experimental site

The experiment was carried out in the laboratory conditions (25 ± 5$^{o}$C, 70 ± 5% RH) of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh during September 2016 to January 2017.

### Host plant

Host plants were used as country bean (BARI sheem-4). Seeds were collected from the local market of Dinajpur town and raised seedling in pots in the entomology research lab corridor of HSTU, Dinajpur. Plants were fertilized as needed and watering was done as necessary but free from pesticide.

### Collection and rearing of test insects

The *A. craccivora* were collected from the infested bean plants of Entomology field lab, HSTU and maintained in the laboratory (25 ± 5$^{o}$C, 70 ± 5% RH). Aphids were gently removed from the bean twigs with the help of soft camel hair brush and released on the fresh bean twigs kept in cylindrical jars (14H × 10.5 D cm) in the laboratory. The jars were covered with a piece of cloth fastened with rubber bands to prevent insect get away. For the mass culture, newly emerged crawlers were placed on to the fresh bean leaves. These processes were continued upto the experimental requirements. Only 3$^{rd}$ - 4$^{th}$ instar nymphs were used for the study.

**Identification of *A. craccivora***

Aphid species has been identified based on their morphological characteristics (Emden and Harrington, 2007). Late instar nymphs ($3^{rd}$ and $4^{th}$ instar) were used in the experiment as stated by Blackman and Eastop (2000) and Trivedi and Singh (2014).

**Tested botanical oils**

Tested three crude plant oils of neem (*Azadirachta indica*), mehogony (*Swietenia mahagoni*) and karanja (*Pongamia pinnata*) were collected from the local market of Dinajpur town. Four concentrations of each oil viz. 2.0, 1.5, 1.0 and 0.5% were prepared separately (v/v). For the preparation of concentrations, 2.0, 1.5, 1.0 and 0.5 ml of neem, karanja and mehogony oils were taken in conical flask (100 ml) separately and added 98.0, 98.5, 99.0 and 99.5 ml of distilled water for each oil and concentrations, respectively. A single drop of tween-20 was added as an emulsifier for each concentration separately and mixed properly.

**Direct toxicity test**

Toxicity effects were performed in the laboratory conditions ($25 \pm 5^{o}C$, $70 \pm 5\%$ RH) against the *A. craccivora*. Fresh young bean leaves were collected and dipped in respective oil concentrations of each treatment separately for 5-10 seconds and then the leaves were air-dried for 15 minutes. Each leaf was placed separately in a Petri dish (90 mm). Ten (10) $3^{rd}$ to $4^{th}$ instar nymphs were released by the help of a camel hair brush. Three replications were done for each concentration. The mortality was recorded at 24, 48 and 72 hours after treatments. Mortality was corrected by Abbott’s (1925) formula:

$$P = \frac{p' - C}{100 - C} \times 100$$

Where,

$P$ = Percentage of corrected mortality

$P'$ = Observed mortality (%)

C = Mortality (%) at control

**Repellency test**

The repellency test was conducted according to described by Talukder and Howse (1995). Briefly, Petri dishes (120 mm) with filter papers (Whatman No. 40) were cut in two half and 1.0 ml of each prepared oil was applied to a half of filter paper uniformly with a pipette. The treated half were then air-dried and attached with the untreated half with a cello-tape such a way those could not interfere to the free movement of insect from one half to another. Distance between the treated and untreated filter paper remained sufficient to prevent seepage of test samples from one half of circle to another. Each filter paper was then placed in a Petri dish and 10 nymphs were released. Number of nymphs on each treated and untreated portion was counted at two-hour intervals up to the $10^{th}$ hour. The data were expressed as percentage repulsion (PR) by the following formula: [PR (%) = (Nc-50) × 2]. Where, Nc = the percentage of insects present in the control half. Positive (+) values expressed repellency while negative value represent (-) attractancy. The average values were then categorized according to the standard scale as described by McDonald et al. (1970).

**Statistical Analyses**

The data were analyzed using completely randomized design (CRD) through MSTAT-C program. All graphs were done using MS-Excel software. The treatment mean values were compared by Duncan's New Multiple Range Test (DMRT). The median lethal values ($LD_{50}$) were determined by probit analysis (Finney, 1947).

## RESULTS AND DISCUSSION

**Direct toxic effects of oils against *A. craccivora***

The toxicity effects of three botanical oils, doses and interactions against the *A. craccivora* nymphs are reflected in the Tables 1-3. The highest (28.62%) mortality was recorded in mehogony oil but the lowest in neem oil (27.21%) which are statistically non-significant (Table 1). On the basis of average nymphal mortality percentage, the order of the toxic effect of three botanical oils was found as mehogony > neem > karanja. Again, the nymphal mortality was dose dependent in where the highest mortality (48.78%) was found at 2.0% concentration. Conversely, the lowest mortality (20.32%) was recorded at the 0.5% concentration. Average mortality increased with the concentration levels. Very little mortality (2.20%) was recorded in untreated control. The interaction effects of oils, doses and times significantly the highest mortality (52.60%) was calculated in mehogony oil at 2.0% concentration while the lowest (2.20%) in the control (Table 3).

Results from the present study indicate that all the tested botanical oils had promising toxic effects against the nymph of *A. craccivora* in laboratory conditions. The mehogony oil offered promising toxicity by applying the highest dose of 2.0% against the nymph (Table 2). Our present findings are also similar with those of Yasmin et al. (2017). They cited that mehogony oil proved the highest (29.83%) mortality whereas the lowest (22.96%) in karanja oil against the adult *A. craccivira* Koch under laboratory conditions. Present findings are also in close proximity with those of Bahar et al. (2007) and Pinto et al. (2013). They found that the eucalyptus, mehogony oils and neem-based product (neemseto) reduced aphid population but different among the field, net-house and laboratory conditions. Again, present results are also in line with Lin et al. (2009) who reported that sugar apple (*Annona squamosa*) seed oil, an edible tropical fruit was also promising in controlling the cotton aphid, *A. gossypii* Glover on melon plant. Patil and Chavan (2009) cited that *Acacia concianna* extract was the most toxic against sugarcane woolly aphid, *Ceratovacuna lanigera* Zehnter. Some plant oils have broad spectrum insecticidal activity against many destructive pests, affecting insect nervous and defense systems (Isman, 2000; Ketoh, 2004). Moreover, physiology of the destructive insects is arrested due to biological activity of oils might resulting quickened to death (Schoonhoven, 1978).

Mortality of the tested extracts were concentrations and exposure time dependent under laboratory conditions. Significant level of success of potential suppression of aphid population as reported by various researchers with different botanicals including neem and karanja leaf extracts (Prabal et al., 2000; Katsvangwa and Chigwaza, 2004; Rawleigh and Boyd, 2008; Biswas, 2013). The result of this study indicates that all levels of tested oil except 0.5% and 1.0% concentrations had shown sufficient aphicidal effects. However, though all plant oils showed potential but mehogony oil exerted promising toxicity by applying the highest concentration (2.0%) against the nymph of bean aphid. The main phytoconstituents of mehogony oils are alkaloids, terpinoids, steroids, glycosides as cyclomahogenol, tannins, alkaloids, saponins and terpenoids (Sahgal et al., 2009; Hajra et al., 2011) might be attributed toxic to aphid.

Table 1. Direct toxic effect of different botanical oils against the nymphs of *A. craccivora* at different HATs (Interaction of botanical oils and times)

| Botanical oils | Nymph mortality (%) at different HATs | | | Average mortality (%) |
|---|---|---|---|---|
| | 24 | 48 | 72 | |
| Neem | 17.33[a] | 28.00[a] | 36.30[a] | 27.21[a] |
| Karanja | 18.00[a] | 26.67[a] | 37.78[a] | 27.48[a] |
| Mehogony | 17.33[a] | 29.33[a] | 39.19[a] | 28.62[a] |
| LSD | 2.723 | 2.941 | 3.278 | 2.178 |
| CV % | 20.80 | 14.09 | 11.64 | 10.52 |
| Level of significant | NS | NS | NS | NS |

HAT= Hour after treatment. Within column values followed by same letter is insignificant by DMRT at 5% level of probability. NS= Not significant.

Table 2. Direct toxic effect of different botanical oils at different doses against the nymph of *A. craccivora* at different HATs (Interaction of doses and times)

| Doses (%) | Nymphs mortality (%) at indicated HATs | | | Average mortality (%) |
|---|---|---|---|---|
| | 24 | 48 | 72 | |
| 2.0 | 33.33 $^{a}$ | 51.11 $^{a}$ | 61.85 $^{a}$ | 48.78 $^{a}$ |
| 1.5 | 25.56 $^{b}$ | 40.00 $^{b}$ | 51.24 $^{b}$ | 38.93 $^{b}$ |
| 1.0 | 18.89 $^{c}$ | 28.89 $^{c}$ | 38.02 $^{c}$ | 28.61 $^{c}$ |
| 0.5 | 10.00 $^{d}$ | 20.00 $^{d}$ | 30.99 $^{d}$ | 20.32 $^{d}$ |
| Control | 0.00 $^{e}$ | 0.00 $^{e}$ | 6.67 $^{e}$ | 2.20 $^{e}$ |
| LSD | 3.515 | 3.797 | 4.231 | 2.811 |
| CV % | 20.80 | 14.09 | 11.64 | 10.52 |

HAT= Hours after treatment. Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 3. Toxicity effect of different doses of botanical oils against the nymph of *A. craccivora* at different HATs (Interaction of botanical oils, doses and times)

| Botanical oils | Doses (%) | Nymphs mortality (%) at different HATs | | | Average mortality (%) |
|---|---|---|---|---|---|
| | | 24 | 48 | 72 | |
| Neem | 2.0 | 30.00 $^{bc}$ | 50.00 $^{b}$ | 60.74 $^{ab}$ | 46.93 $^{b}$ |
| | 1.5 | 26.67 $^{cd}$ | 36.67 $^{d}$ | 46.29 $^{cd}$ | 36.53 $^{c}$ |
| | 1.0 | 20.00 $^{ef}$ | 30.00 $^{e}$ | 35.55 $^{ef}$ | 28.53 $^{d}$ |
| | 0.5 | 10.00 $^{g}$ | 23.33 $^{efg}$ | 32.22 $^{f}$ | 21.83 $^{ef}$ |
| Karanja | 2.0 | 36.67 $^{a}$ | 46.67 $^{bc}$ | 57.03 $^{b}$ | 46.80 $^{b}$ |
| | 1.5 | 26.67 $^{cd}$ | 40.00 $^{cd}$ | 53.71 $^{bc}$ | 40.13 $^{c}$ |
| | 1.0 | 16.67 $^{f}$ | 26.67 $^{ef}$ | 35.55 $^{ef}$ | 26.30 $^{de}$ |
| | 0.5 | 10.00 $^{g}$ | 20.00 $^{fg}$ | 35.92 $^{ef}$ | 21.97 $^{ef}$ |
| Mehogony | 2.0 | 33.33 $^{ab}$ | 56.67 $^{a}$ | 67.78 $^{a}$ | 52.60 $^{a}$ |
| | 1.5 | 23.33 $^{de}$ | 43.33 $^{bcd}$ | 53.71 $^{bc}$ | 40.13 $^{c}$ |
| | 1.0 | 20.00 $^{ef}$ | 30.00 $^{e}$ | 42.96 $^{de}$ | 31.00 $^{d}$ |
| | 0.5 | 10.00 $^{g}$ | 16.67 $^{g}$ | 24.81 $^{g}$ | 17.17 $^{f}$ |
| Control | 0.0 | 0.00 $^{h}$ | 0.00 $^{h}$ | 6.67 $^{h}$ | 2.20 $^{g}$ |
| LSD | | 6.089 | 6.577 | 7.329 | 4.870 |
| CV % | | 20.80 | 14.09 | 11.64 | 10.52 |

HAT= Hours after treatment. Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

**Probit analysis of oils against *A. craccivora***

The $LC_{50}$ values of the tested oils are presented in Table 4. It was found that karanja oil (3.52%) attained the lowest $LC_{50}$ values at 24 HAT while mehogony oil (1.76%, 1.21%) at 48 and 72 HATs (Table 4). On the contrary, neem (5.0 and 1.55%, respectively 24 and 72 HATs) and karanja oils (48 HAT) possessed the highest toxicity. The chi-square ($\chi^2$) values were insignificant at 5% level of probability of three botanical oils at different HATs and mortality data did not show any heterogeneity. The relationship between probit mortality of insect and log doses of the tested botanical oils are presented in the probit regressions lines (Figure 1). The probit regression equations for the regression line of neem, karanja and mehogony oils were Y=1.291x+2.839, Y=1.553x+2.586, Y=1.307x+2.81 for 24 HAT, Y=1.145x+3.406, Y=1.284x+3.214, Y=1.821x+2.730 for 48 HAT and Y=1.155x+3.631, Y=0.973x+3.873, Y=1.821x+3.028 for 72 HAT. The insect mortality rate showed positive correlation with the doses in all treatments. The probit regression lines of three botanical oils showed a clear linear relationship between probit mortality and their log doses and the regression lines become sleeper as doses increased, because the nymphs were treated with more toxins for the same period at higher doses.

Novel innovative research illustrated that diverse plant products have been tried by several researchers with a good degree of success against several species of aphids (Dimetry and EL-Hawary, 1995; Mareggiani et al., 2008; Mehetre et al., 2008). Different plant products were tested by many scholars and found promising against aphids, such as orange peel (*Citrus sinensis*), bitter gourd (*Momordica dioica*), garlic (*Allium vineale*), marigold, hot pepper (*Capsicum frutescens*) and tobacco (*Nicotiana tabacum*) to wheat aphid (Iqbal, 2011); garlic bulbs (*Allium sativum*), endod (*Phytolacca dodecandra*) and neem seeds (*Azadirachta indica*) to pea aphids, *Acyrthosiphon pisum* (Harris) (Megersa, 2016). Mexican marigold, garlic, sodom apples and ginger were also effective against the aphids *Brevicoryne brassicaea* (Peris and Kiptoo, 2017); neem and moringa (*Moringa olifera*) to wheat aphid species, *Schizaphis graminum* (R.), *Rhopalosiphum padi* (L.) and *Sitobion avenae* (F.) (Shah et al., 2017).

Table 4. Relative toxicity (probit analysis) of different botanical oils treated against the nymphs of *A. craccivora* after 24, 48 and 72 HATs

| Botanical oils | Nymph used | $LD_{50}$ (%) values | 95% fiducially limits | | $\chi^2$ values at 2 df |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| 24 HAT | | | | | |
| Neem | 30 | 5.00 | 1.14 | 21.93 | 0.10 |
| Karanja | 30 | 3.52 | 1.42 | 8.72 | 0.18 |
| Mehogony | 30 | 4.81 | 1.21 | 19.22 | 0.16 |
| 48 HAT | | | | | |
| Neem | 30 | 2.38 | 1.09 | 5.20 | 0.60 |
| Karanja | 30 | 2.39 | 1.16 | 4.93 | 0.30 |
| Mehogony | 30 | 1.76 | 1.21 | 2.55 | 0.25 |
| 72 HAT | | | | | |
| Neem | 30 | 1.55 | 0.90 | 2.69 | 1.10 |
| Karanja | 30 | 1.44 | 0.80 | 2.60 | 0.91 |
| Mehogony | 30 | 1.21 | 0.90 | 1.64 | 0.17 |

HAT = Hour after treatment. Values were based on five concentrations, three replications of 10 insects each. $\chi^2$ = Goodness of fit. The tabulated value of $\chi^2$ is 5.99 (d.f = 2 at 5% level)

**Repellent effects of oils against *A. craccivora***

The repellent effects of three botanical oils, doses and interactions against the *A. craccivora* nymphs are presented in the Tables 5-7. Among three tested oils, mehogony showed the highest (77.33%) repellency while the lowest (55.0%) from karanja (Table 5). Repellency value decreased with the progress of time and increased with increasing doses of all oils (Table 5). The repellency class of tested oils at different concentrations level varied between classes III to IV. Among the doses, 2% provided highest (66.67%) repellency at 10 HAT while the lowest at 0.5% but statistically non-significant (Table 6). Repellency percent was increased with the doses. In the interaction effects of three botanical oils and doses the highest (84.0%) repellency was recorded on 2.0% of mehogony oil, whereas the lowest (38.67%) on 0.5% of neem oil (Table 7).

*A. craccivora* nymph repelled significantly while treated with the tested botanical oils of mehogony, neem and karanja. This indicated that the pest repellency properties of tested botanical oils were dispersed inconsistently. Also, the repellency rate decreased with increasing of exposure times (Tables 5-7). Significant level of success due to repellency of plant oils on aphid suppression were accounted by several researchers (Hossain et al., 2014; Manzoor et al., 2015). The potency of the tested oils can be attributed to its alkaloids contents (Alice et al., 2007; Jastad et al., 2009).

These might associate with deterrent, repellent and anti-feedant actions against *A. craccivora* (Katsvangwa and Chigwaza, 2004; Yasmin et al., 2017).

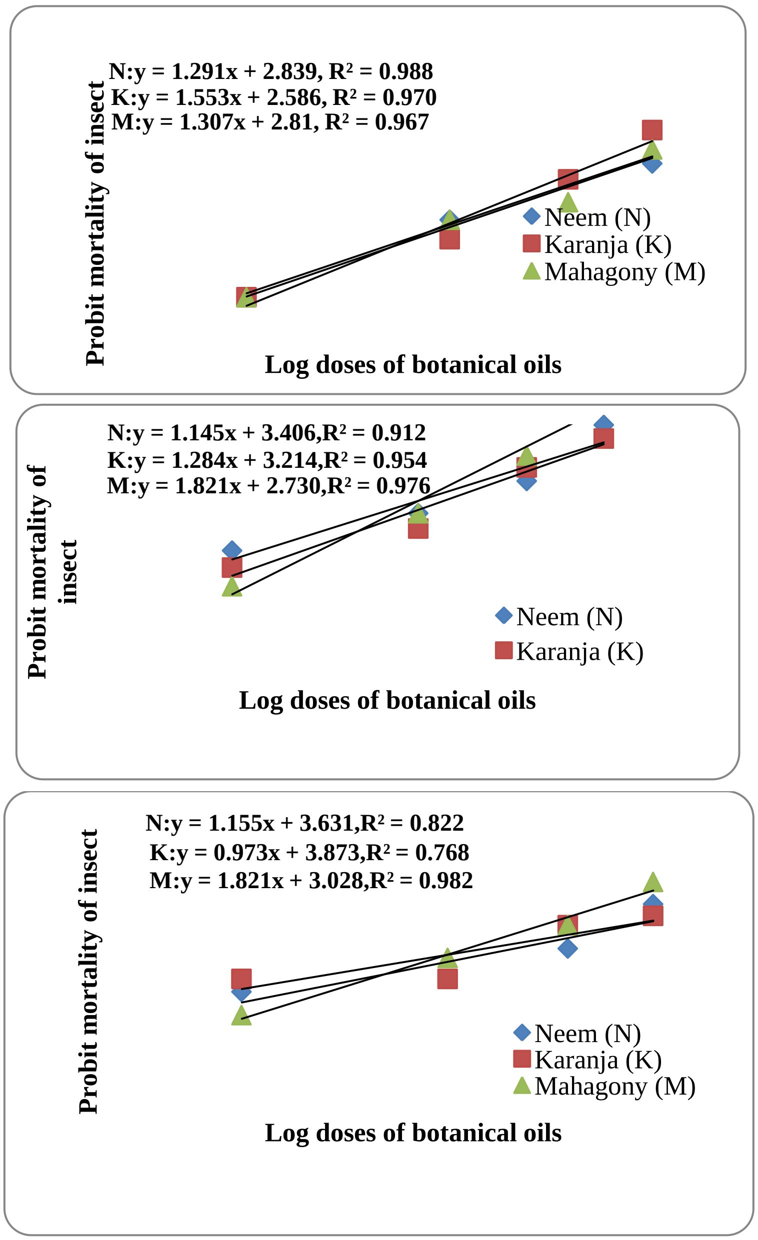


Fig. 1. Relationship between probit mortality and log doses of different botanical oils on the nymphs of *A. craccivora* at 24 HAT (top), 48 HAT (middle) and 72 HAT (bottom)

Table 5. Repellent effect of different botanical oils against the nymph of *A. craccivora* at different HATs (Interaction of botanical oils and times)

| Botanical oils | Repellency (%) at different HATs | | | | | Average repellency (%) | Repellent class |
|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | | |
| Neem | 71.67 a | 63.33 ab | 50.00 b | 50.00 b | 51.67 b | 57.33 b | III |
| Karanja | 71.67 a | 48.33 b | 53.33 b | 51.67 b | 50.00b | 55.00 b | III |
| Mehogony | 80.00 a | 81.67 a | 71.67 a | 73.33 a | 80.00a | 77.33 a | IV |
| LSD | 16.13 | 19.86 | 14.32 | 13.17 | 12.56 | 10.45 | |
| CV % | 25.72 | 36.57 | 29.14 | 26.80 | 24.62 | 19.61 | |

HAT= Hours after treatment. Mean followed by different letter(s) are significantly different by DMRT at 5% level of probability. NS= Not significant.

Table 6. Repellent effect of different botanical oils at different doses against the nymph of *A. craccivora* at different HATs (Interaction of doses and times)

| Doses (%) | Repellency (%) at different HATs | | | | | Average repellency (%) | Repellent class |
|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | | |
| 2.0 | 68.89 a | 64.44 a | 68.89 a | 66.67 a | 64.44a | 66.67 a | IV |
| 1.5 | 84.44 a | 66.67 a | 57.78ab | 57.78 ab | 57.78 a | 64.89a | IV |
| 1.0 | 77.78 a | 66.67 a | 57.78 ab | 60.00 ab | 64.44 a | 65.33 a | IV |
| 0.5 | 66.67 a | 60.00 a | 48.89 b | 48.89 b | 55.56 a | 56.00 a | III |
| LSD | 18.63 | 22.93 | 16.54 | 15.21 | 14.50 | 12.07 | |
| CV % | 25.72 | 36.57 | 29.14 | 26.80 | 24.62 | 19.61 | |

HAT= Hours after treatment. Mean followed by the same letter(s) did not differ significantly at 5% level by DMRT.

Table 7. Repellent effect of different botanical oils and doses against the nymph of *A. craccivora* at different HATs (Interaction of oils, doses and times)

| Botanical oils | Dose (%) | Repellency (%) at different HATs | | | | | Average repellency (%) | Repellent class |
|---|---|---|---|---|---|---|---|---|
| | | 2 HAT | 4 HAT | 6 HAT | 8 HAT | 10 HAT | | |
| Neem | 2.0 | 60.00 a | 66.67 ab | 73.33 a | 73.33 a | 73.33 ab | 69.33 abc | IV |
| | 1.5 | 93.33 a | 66.67 ab | 53.33ab | 66.67 ab | 66.67 abc | 69.33 abc | IV |
| | 1.0 | 73.33 a | 60.00 ab | 46.67 ab | 40.00 bcd | 40.00 cd | 52.00 bcd | IV |
| | 0.5 | 60.00 a | 60.00 ab | 26.67 b | 20.00 d | 26.67 d | 38.67 d | II |
| Karanja | 2.0 | 60.00 a | 53.33 ab | 60.00 a | 60.00 abc | 46.67 bcd | 56.00 bcd | III |

| Botanical oils | Dose (%) | Repellency (%) at different HATs | | | | | Average repellency (%) | Repellent class |
|---|---|---|---|---|---|---|---|---|
| | | 2 HAT | 4 HAT | 6 HAT | 8 HAT | 10 HAT | | |
| | 1.5 | $86.67^{a}$ | $46.67^{ab}$ | $46.67^{ab}$ | $33.33^{cd}$ | $33.33^{d}$ | $49.33^{cd}$ | III |
| | 1.0 | $66.67^{a}$ | $53.33^{ab}$ | $53.33^{ab}$ | $60.00^{abc}$ | $66.67^{abc}$ | $60.00^{bcd}$ | IV |
| | 0.5 | $73.33^{a}$ | $40.00^{b}$ | $53.33^{ab}$ | $53.33^{abc}$ | $53.33^{bcd}$ | $54.6^{bcd}$ | III |
| Mehogony | 2.0 | $93.33^{a}$ | $86.67^{a}$ | $73.33^{a}$ | $80.00^{a}$ | $86.67^{a}$ | $84.00^{a}$ | V |
| | 1.5 | $73.33^{a}$ | $86.67^{a}$ | $73.33^{a}$ | $73.33^{a}$ | $73.33^{ab}$ | $76.00^{ab}$ | IV |
| | 1.0 | $86.67^{a}$ | $73.33^{ab}$ | $73.33^{a}$ | $66.67^{ab}$ | $73.33^{ab}$ | $74.67^{ab}$ | IV |
| | 0.5 | $66.67^{a}$ | $80.00^{ab}$ | $66.67^{a}$ | $73.33^{a}$ | $86.67^{a}$ | $74.67^{ab}$ | IV |
| LSD | | 32.27 | 39.72 | 28.64 | 26.35 | 25.12 | 20.90 | |
| CV % | | 25.72 | 36.57 | 29.14 | 26.80 | 24.62 | 19.61 | |

HAT = Hours after treatment Mean followed by different letter(s) are significantly different by DMRT at 5% level of probability.

## CONCLUSION

It is concluded that the botanical oils tested in the present study had direct toxic effect on the nymphs of *A. craccivora* but mehogony showed the highest toxic and repellent effects. However, further studies need to be conducted in future to isolate, evaluate and characterization of active compound with its mode of action of the tested oils.

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