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Original article

# Larvicidal, pupalicidal and adulticidal effects of *Artemisia absinthium* L. against dengue vector *Aedes aegypti* (Diptera: Culicidae) in Jazan region, K. S.A.

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ABSTRACT

In the current study, the biological effects of various solvents concentrations of *Artemisia absinthium* were assayed on different stages (larva, pupa and adult) of *Aedes aegypti* under controlled laboratory conditions. The life initiation and mortality for each insect stage were evaluated. Different lethal concentrations were measured. *Aedes aegypti* L. was susceptible to all plant extract solvents in different conc. ANOVA test, correlation analysis and simple linear regression were used to evaluate the significance. The results correlated with other comparative studies with different *Artemisia* sp. to put the studied species in the proper way in Asteraceae family. The study gave *A. absinthium* L. its bright position as a perfect natural insecticide especially as larvicidal due to the low $Lc_{50}$ degree. Scientists welcome to use natural insecticide at initial stages of insect not in later ones.

## 1. Introduction

Arthropods are regarded as the most important vectors for different number of parasites and pathogens which are pandemics or epidemics in all populations in all countries from humans even though animals and birds. Mosquito (Diptera: Culicidae) threats majority of all higher living organisms in the world because they are the vectors of such dangerous diseases like dengue fever malaria, West Nile virus fever, yellow fever, filariasis, Ziks virus and Japanese encephalitis (Mehlhorn 2015; Benelli and Mehlhorn 2016; Benelli et al. 2016a) (Mehlhorn et al. 2012; Benelli, 2015; Benelli et al. 2016b, Benelli and Mehlhorn, 2016). The main vector of dengue, chikungunya, yellow fever and Zika viruses around the world is the *Aedes aegypti*. Although this species was first recorded in 1956 at southwestern Saudi Arabia, the initial outbreak for dengue fever disease occurred in 1994. The number of cases has exceeded in the current years (Marimuthu and Giovanni 2016).

According to the latest estimates, mosquito mortality rate reach at least 198 million cases in last decades mostly in African region. The most important mosquito-borne virus increased in the last 60 years. Most of the incidences are related to children infection from malaria disease (Jensen and Mehlhorn 2009; WHO 2014; WHO 2012a).

Recently, different utilizations of mosquito insecticides face several serious problems such as negative impact on non-target organisms especially human rather than the environment. Recently, the number of resistant-insecticide mosquito populations is developed and increased that extremely threat on crop protection, vector control and human health worldwide (Hodgson and Levi 1996; WHO 2012b; Hemingway and Ranson 2000; Naqqash et al. 2016; McCaffery and Nauen 2006; Nauen 2007) and more specifically Saud Arabia (Mashlawi et al. 2022; Al Nazawi et al. 2017).

These problems focus on the importance of new natural alternatives pest control which are more suitable for the human health and environment (Benelli 2016a, 2016b; Pavela and Benelli 2016). These existing alternative solutions aim at reducing the pest populations based on the use of plant extracts as pest control which is considered as the most effective promising method (Amer and Mehlhorn 2006a, 2006b, 2006c, 2006d; Govindarajan et al. 2016a, 2016b). Bio-ingredients like essential oils and other related main phyto-compounds are environmentally

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interesting friendly as they are able to biodegrade and have the less side effects on any non-target living organisms besides the environment (Govindarajan 2010; Govindarajan et al. 2012, 2013).

*Artemisia* is considered as the largest widely distributed genus of Asteraceae family which comprises over 400 species spreading all over temperate zones of South Africa, Asia, Europe and North America (He et al. 2009). Most of *Artemisia* sp. are traditional medicinal plants and used popularly as the treatments for different parasitic diseases such as hepatitis, malaria, bruising, diuresis, inflammation, allergy, hypertension, cancer, jaundice and other infectious diseases caused by fungi, viruses and bacteria (Rustaiyan and Masoudi 2011). *Artemisia* species possess insecticidal, medicinal, antifeedent or repellent properties (Negahban et al. 2006a, 2006b). *Artemisia abrotanum* and *Artemisia dracunculus* are medicinal plants (Evans 2001). *Artemisia herba-alba* is inhibitor agent against the asexual reproduction of *Pencillium italicum*, *Zygorrhychus* sp. and *Aspergillus niger* (Tantaoui et al. 1993). *Artemisia vulgaris* has been extensively stated as toxic, antiplasmodial and repellent to *Tribolium castaneum* (Wang et al. 2006; Tu 2011). *A. scoparia* can be used as anti-inflammatory, choleretic, and diuretic agents against hepatitis treatment (Hikino 1985).

In Saudi Arabia, there are about 17 *Artemisia* species where *Artemisia absinthium* is the only plant species recorded in flora of Jazan region where situated in the south western as a part of Saudi Arabia at 16°20′N, 42°45′E. Jazan region is stretched from area is called Al-Tuwal located in the south to another area; Wadi Lejib located in the north where contains different many wadis which are formed from deposits of silt soil carrying from the floods in various banks of wadis. Each Jazan wadi has a nearly mean annual rain from 7.0-7.4 $m^3$/sec. The Jazan vegetation is placed near the foot of different hills where most of time is dry due to high deposition of sand and silt. *Artemisia absinthium* is used traditionally in Jazan region for ornamentation in wedding parties due to its odor. There is no available information on insecticidal activity against *Aedes aegypti* in different stages. (Ahmed et al. 2005; Masrahi 2012).

The aim of this work is to illustrate the insecticidal activity of *Artemisia absinthium* L. versus *Aedes aegypti* in different stages through using variety of solvents for each leaves and stems parts separately.

## 2. Materials and methods

### 2.1. Plant collection and identification

*A. absinthium* L., the plant material was collected in March 2020 from the foot of Faifa mountains, Jazan Province, Saudi Arabia, (17°15′55.3″ latitude, 43°06′47.1″ longitude, 382 m elevation). The identification of the studied species was done at the JAZUH herbarium of Faculty of Science at Jazan University (Voucher No. JAZUH 2064).

### 2.2. Plant morphology and anatomy

The studied plant species was described all its characters morphologically and anatomically by determining the qualitative (main item) and quantitative (measured value) ones. Each Morphological character may be major parameter like plant height and color or minor one as Cypselas and florets. For description of anatomical characters; the node no. 4 of the stem was chosen to be sectioned using a very sharp razor blade, after that the obtained thin slices were put in dist. water then mounted onto a glass slide with adding some drops of ethyl alcohol 100 % for tissue hardening and stained with some drops of light green: safranin (1v:1v) solutions. Removing excess stain was done by washing off with running water finally adding a drop of glycerine to be permanent. Coverslips were added onto slides and then adjusted to release the air bubbles and prevent dehydration. Slides can be seen by using binocular compound light complementary with a digital camera unit to take photographs with bar measurements (Goodman, 2005; El-Shabasy and El-Gifri 2019). The photographs were be able to illustrate different the locations of dermal, ground and mechanical supportive tissues.

### 2.3. Plant extraction

A total of 5 kg whole plant species were cleaned, sterilized with ethanol 70 %, air dried and separated its parts into leaves and stems. Leaves and stems were dried using an oven at 55 °C for 48 h. Each part was ground into a fine homogenous powder. Each organic solvent; acetone, methanol and chloroform was added separately to the powder for plant extraction (10 ml/g of the dry weight of the material). The mixture was homogenized for 30 min over a magnetic stirrer and incubated over night at room temperature. To evaporate the filtrate completely, a vacuum rotary evaporator was used. The extract was concentrated by heating in a water bath at 65 °C till constant weight. The extruded form of yield extract was obtained then stored at 5 °C until used. Different dilutions of the extracts were made (125, 250, 500, 750 and 1000 ppm) with triple repetition for each plant part sample through serial dilution according to the following formula: ppm = Conc. X Weight (or Volume) $X10^6$. The dilutions were autoclaved under sterile dist. water mixed with Triton X-100 (10 µL/L of water). The negative control is distilled water (Perazzo et al. 2008; Azizi et al. 2016; Jazem et al. 2014; Gauray et al. 2014).

### 2.4. Collection, culturing and rearing of mosquitoes

First the eggs of *Aedes aegypti* were identified then collected from colonies reared at the vector control laboratory, Biology Department, Faculty of Science, Jazan University, KSA. Eggs were placed in trays 20 × 15 × 5 cm filled with 500 ml tap water (70–75 % relative humidity; 29 ± 1 °C; photoperiod 14: 10 h (light: dark). First instar larvae were hatched next day and feeded on the cultural medium; yeast powder and dog biscuit (ratio 1:2 w/w). On the third day, the larvae molted into second instar. The third instar larvae were hatched in the fifth day and obtained for the larvicidal experiments in the present study.

The life conditions were changed to be at 75–80 % relative humidity, 27 ± 3 °C,; photoperiod of 12: 12 h (light: dark). Larvae were fed on chicken liver continued till the larvae transformed into pupae. Pupae were collected to be used in pupal experimental part. Pupae were transferred to glass cups (12 cm × 9.8 cm diameter) containing 500 ml clean water and covering with a net for inhibiting adult emergence.

The adults were moved into the cage (20 x20x20 cm) and fed on 10 % sucrose solution soaked in cotton (male adults) and blood fitted unit covering with parafilm membrane (female adults) under the same previous conditions. Females were deprived and kept inside a separated netted cages of mosquitoes for adulticidal experiments (Govindarajan and Sivakumar 2014; Jurnal 2019; Panneerselvam et al. 2012).

### 2.5. Bioassay procedure

Bioassays were carried out according to the W.H.O. protocol of larval, pupal and adult susceptibility test methods (WHO 2005). The early third instar larvae, pupae and female adult mosquitoes (2–5 days old fed) of *A. aegypti* were treated with various concentrations of the studied plant part species (Leaves and stems) in groups of waxed paper cups containing 300 ml of sterilized mineral water. Three replicates were carried out, for a total of 10 tested staged insects for each plant part extract concentration besides control trials. Temephos is known as a common chemical positive control insecticidal solvent used following the method of WHO (2005). It was prepared by using 1.5 ml of the solvent in 250 ml of water. Cumulative mortalities, pupation and adult emergence were recorded per staged insect at 24 h after exposure (Sarma et al. 2019).

### 2.6. The lethal concentration LC determinations

$LC_{50}$ (median lethal concentration) is the concentration of a plant extraction at which half the members of a staged insect population are killed after a specified duration of exposure.

The ppm concentrations (x-value) are entered as mass of substance per volume of plant extract. The responses (Y-value) are typically entered as percentage of population killed (ranged from 0 to 100). The Hill coefficient is a measure of the extent to which the binding behavior between two molecules; one from plant extract and the other from binding insect surface deviates. It can be obtained by the following the slope-intercept formula:

$$\text{Hill coefficient} = m\,x + b$$

where $m$ is the slope of the mortality line, $b$ is the value of $y$ where the extended straight line crosses the $y$-axis.

From previous equation $LC_{50}$ is calculated according to the following equation:

$$Y = \text{Min} + \frac{\text{Max} - \text{Min}}{1 + \left(\frac{x}{LC50}\right)^{\text{Hill coefficient}}}$$

From $LC_{50}$ values, other lethal concentrations ($LC_{80}$, $LC_{85}$, $LC_{90}$ and $LC_{95}$) can be obtained from the next equation:

$$Lc_F = \left(\frac{F}{100 - F}\right)^{1/\text{Hill coefficent},Lc_{50}}$$

where F is percent response (80, 85, 90 or 95) (Gomez 1976)

## 3. Statistical analysis

Correlation between metamorphosis variables versus mortality ones are performed according to (Shaban, 2005; Tamhane, 2009). *P* values for significance test for the degrees of freedom were done following to Dutilleul (1993) approaches. They were directed to statistical analysis to determine ANOVA. *F*-test was used to evaluate the difference among them on basis standard error which was calculated following Welham et al. (2015). The representation of correlated data was obtained from the linear regression approach which extracted the extent condition for metamorphosis and mortality variables respectively (Maindonald 1992; Miller and Franklin 2002).

## 4. Results

### 4.1. Plant characterizations

*A. absinthium* L. (Family: Asteraceae) is perennial erect herb with 70–120 cm tall. The stem is hairy. Leaf is ovate or ovate to elliptic 10.5 ± 1.01 × 8 ± 0.09 cm. Tri-pinnatisect in segments which are pinnately lobed. Lobules are linear or lanceolate-elliptic 11 ± 1.23 × 3.5 ± 2.02 mm with obtuse apex. Leaf blade is elliptic-ovate or ovate. Leafy bracts are 3-lobed and entire Leafy bracts are entire and 3-lobed. Cypselas are oblong with minute upper crown. The leaves are silver-gray from below and grayish-green from above. The inflorescence are small and yellow in color. The outer tubular florets are pistillate and inner funnel florets are bisexual.

The epidermis is unicellular layer covering with high dense branched uniseriate trichomes. The cortex is differentiated into two zones. The upper and lower zones are characterized with 3–4 lamellar collenchymatous layers, 6–7 angular collenchymatous layers respectively. The latter zone is intersected with upper one in limited regions where localized sclerenchymatous tissues are distributed in it. Other 3–4 sclerenchymatous layers surround the vascular bundles. The pith is centered in a narrow area with low intracellular spaces. The cells are large and stored parenchymatous tissues **(Photos 1 & 2)**.

### 4.2. Bioassay analysis

The bioassay was undergone by using different plant extract solvents with different concentrations. Each whole plant extract was prepared by standard methods of El-Amier et al. (2019). 20 g of each plant material was placed in 250 ml of studied solvent then stirred using a water bath at 45 °C for 10 h. After that, the plant residue was separated by filtration through a Whatman No. 1 filter paper and the solvent was evaporated under vacuum on a rotary evaporator at 40 °C (Rotavapor R-200, Büchi Labortechnik, Flavil, Switzerland) except for aqueous solvent. The resulting residue was dissolved in 50 ml dimethyl sulfoxide (DMSO) and stored at −20 °C for further use. Plant extract yields (%) using different organic solvents were determined in (Table 1). Different insect stages were treated with different plant parts (leaves & stems). The insecticidal treatments were applied on metamorphosis and mortality. The metamorphosis included larval duration, pupation and adult emergence **(Photos 3 & 4)**. As a general, the metamorphic processes decreased according to increment of plant extract concentrations. They were ranged from 100 % at control to 10 % at 100 ppm). The readings were decreased gradually in all metamorphosis with the different replica per ppm (±standard deviation) except pupation in acetone leaves, adult emergence in acetone (leaves & stems) besides chloroform stems, larval duration in methanol stems and pupation in methanol leaves (Table 1).

The mortality was larvicidal, pupalicidal and adulticidal that increased gradually reaching 100 % at 1000 ppm. Only larvicidal mortality in all plant extract part concentrations that has different replica per ppm (±standard deviation). All ppm had mortality effect except methanol leaves 125 ppm on adults.

Lc is the degree of plant extract toxicity. The bioassay analysis involved different Lc values *i.e.* $Lc_{50}$, $Lc_{80}$, $Lc_{85}$, $Lc_{90}$ and $Lc_{95}$ for each plant part extracts of different staged insect. It was cleared that Lc values increased for upgrading metamorphic stage. In acetone extracts; all Lc values had readings from 898 to 995.18 ppm except larvicidal effects of both plant parts in $Lc_{50}$, $Lc_{80}$ and $Lc_{85}$ besides pupalicidal effects of both plant parts in $Lc_{50}$. On the other hand, chloroform extracts had different attitude. All Lc had readings from 930.04 to 998 ppm except larvicidal effects of both plant parts (leaves & stems) in $Lc_{50}$, $Lc_{80}$ and $Lc_{85}$ besides $Lc_{50}$ and $Lc_{80}$ respectively. Furthermore, pupalicidal effects had 858.09 and 874.13 ppm while adulticidal effects had 891.90 and 891.40 ppm in leaves and stems respectively. Similarly, methanol extract followed the chloroform attitude. All Lc had readings from 921.22 −997 ppm except except larvicidal effects of both plant parts (leaves & stems) in $Lc_{50}$, $Lc_{80}$ and $Lc_{85}$ besides $Lc_{50}$ and $Lc_{80}$ respectively. Furthermore, pupalicidal effects had 747.18 and 858.21 ppm while adulticidal effects had 898.31 and 894.53 ppm in leaves and stems (Table 2) (Figs. 1, 2 & 3).

The analysis of variance to bioassay criteria by ANOVA tests showed highly significant difference for metamorphosis versus mortality parameters. According to *F*-test, adult emergence versus adult mortality for acetone stems revealed the greatest value 21.51 while adult emergence versus adult mortality for acetone leaves revealed the lowest value 1.03. Correlation analysis of chloroform stems showed that larval duration had a highly positive significant correlation with larval mortality at 0.89 while chloroform leaves showed a weak positive significant correlation between pupation and pupal mortality at 0.08. However, acetone stems showed both highly and weak negative significant correlations for larval duration versus mortality at −0.48 and adult emergence versus mortality at −0.03 respectively. Simple Linear Regression (SLR) curves indicated that all co-variables were positively correlated despite adult and pupa variables of acetone stems and chloroform leaves respectively were moderate correlated. Finally, adult variables of chloroform leaves and stems besides larva acetone stems were negative correlated (Table 3**:13)** (Fig. 4, Fig. 5**, &** **Fig. 6)** (See Table 4Table 5).

Comparative studies on larvacidial analysis were occurred among *A. absinthium* leaves against other *Artemisia* sp. leaves which are treated against *Aedes aegypti* L. *A. absinthium* was correlated against *A. annua, A. herba alba* and *A. vulgaris. A. absinthium* versus *A. annua* was the greatest correlated value while *A. absinthium* versus *A. herba alba* was the lowest one. (SLR) curves showed positively correlated among *A.* sp. **(Fig. 7)**.

**Table 1**
Insecticidal effects of different plant part extract solvents of *Artemisia absinthium* L.

| Plant extract | plant part (Conc. %) | Conc. (ppm) | Larval mortality (%) | Larval duration (%) | Pupation (%) | Pupal mortality (%) | Adult emergence (%) | Adult mortality (%) |
|---|---|---|---|---|---|---|---|---|
| **Acetone** | **Leaves** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(15 %)** | **125** | 20 | 80 | 80 | 20 | 40 | 10 |
| | | **250** | 40 | 70 | 60 | 20 | 30 | 10 |
| | | **500** | 56.67 ± 0.09 | 63.33 ± 0.18 | 40 | 20 | 20 | 10 |
| | | **750** | 63.33 ± 1.23 | 60 | 40 | 30 | 20 | 10 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |
| | **Stem** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(10 %)** | **125** | 20 | 86.67 ± 2.30 | 80 | 30 | 50 | 10 |
| | | **250** | 30 | 66.67 ± 2.10 | 70 | 30 | 40 | 10 |
| | | **500** | 60 | 56.67 ± 1.01 | 40 | 30 | 20 | 20 |
| | | **750** | 63.33 ± 1.25 | 50 | 23.33 ± 1.00 | 36.67 ± 2.03 | 10 | 20 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |
| **Chloroform** | **Leaves** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(15 %)** | **125** | 30 | 80 | 63.33 ± 2.03 | 20 | 50 | 10 |
| | | **250** | 40 | 73.33 ± 3.00 | 46.67 ± 3.01 | 20 | 23.33 ± 2.11 | 10 |
| | | **500** | 56.67 ± 1.24 | 50 | 36.67 ± 4.33 | 20 | 20 | 13.33 ± 2.00 |
| | | **750** | 66.67 ± 2.05 | 40 | 30 | 20 | 20 | 20 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |
| | **stem** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(10 %)** | **125** | 20 | 83.33 ± 2.36 | 80 | 30 | 50 | 10 |
| | | **250** | 26.67 ± 2.33 | 66.67 ± 1.32 | 73.33 ± 2.66 | 30 | 40 | 10 |
| | | **500** | 36.67 ± 1.32 | 60 | 63.33 ± 3.52 | 30 | 40 | 20 |
| | | **750** | 50 | 50 | 46.67 ± 2.99 | 30 | 30 | 20 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |
| **Methanol** | **Leaves** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(15 %)** | **125** | 30 | 90 | 40 | 20 | 26.67 ± 3.21 | 0 |
| | | **250** | 36.67 ± 2.33 | 80 | 40 | 20 | 13.33 ± 1.02 | 10 |
| | | **500** | 56.67 ± 3.55 | 76.67 ± 2.11 | 40 | 20 | 10 | 10 |
| | | **750** | 70 | 70 | 40 | 30 | 10 | 13.33 ± 1.04 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |
| | **Stem** | **control** | 0 | 100 | 100 | 0 | 100 | 0 |
| | **(10 %)** | **125** | 23.33 ± 3.66 | 70 | 76.67 ± 0.09 | 16.67 ± 3.03 | 60 | 10 |
| | | **250** | 40 | 60 | 60 | 20 | 50 | 13.33 ± 3.66 |
| | | **500** | 43.33 ± 4.30 | 50 | 56.67 ± 4.00 | 20 | 36.67 ± 2.35 | 20 |
| | | **750** | 60 | 40 | 43.33 ± 1.99 | 23.33 ± 4.20 | 30 | 20 |
| | | **1000** | 100 | 10 | 10 | 100 | 10 | 100 |

**Table 2**
Lethal concentrations of different plant part extract solvents against *Aedes aegypti* L.

| Plant extract | plant part | plant toxicity | $LC_{50}$ | $LC_{80}$ | $LC_{85}$ | $LC_{90}$ | $LC_{95}$ | Hill coefficient |
|---|---|---|---|---|---|---|---|---|
| **Acetone** | **Leaves** | **Larvicidal effect** | 355.90 | 798.66 | 889.09 | 984.51 | 997.50 | −0.65 |
| | | **Pupalicidal effect** | 783.36 | 931.14 | 950.60 | 969.10 | 989.54 | −3.66 |
| | | **Adulticidal effect** | 936.66 | 979.25 | 984.84 | 990.14 | 995.18 | −12.85 |
| | **Stem** | **Larvicidal effect** | 430.02 | 773.27 | 835.03 | 898.04 | 962.31 | −0.85 |
| | | **Pupalicidal effect** | 874.13 | 961.85 | 972.37 | 982.19 | 991.40 | −7.72 |
| | | **Adulticidal effect** | 921.69 | 974.42 | 981.32 | 987.85 | 994.07 | −10.22 |
| **Chloroform** | **Leaves** | **Larvicidal effect** | 380.86 | 801.34 | 883.02 | 967.99 | 998.00 | −0.65 |
| | | **Pupalicidal effect** | 858.09 | 955.66 | 967.84 | 979.31 | 990.14 | −6.30 |
| | | **Adulticidal effect** | 891.90 | 964.94 | 974.45 | 983.45 | 992.01 | −5.51 |
| | **stem** | **Larvicidal effect** | 612.08 | 887.20 | 930.04 | 972.24 | 996.00 | −1.42 |
| | | **Pupalicidal effect** | 874.13 | 961.85 | 972.37 | 982.18 | 991.40 | −7.72 |
| | | **Adulticidal effect** | 891.40 | 964.46 | 974.05 | 983.16 | 991.82 | −7.03 |
| **Methanol** | **Leaves** | **Larvicidal effect** | 389.78 | 787.32 | 862.74 | 940.72 | 996.50 | −0.74 |
| | | **Pupalicidal effect** | 747.18 | 924.10 | 947.30 | 969.34 | 987.17 | −3.21 |
| | | **Adulticidal effect** | 898.31 | 966.34 | 975.39 | 984.01 | 992.22 | −7.18 |
| | **Stem** | **Larvicidal effect** | 502.97 | 860.56 | 921.22 | 982.18 | 997.00 | −0.99 |
| | | **Pupalicidal effect** | 858.21 | 953.75 | 966.38 | 978.38 | 989.81 | −5.26 |
| | | **Adulticidal effect** | 894.53 | 965.85 | 975.10 | 983.86 | 992.18 | −7.59 |

## 5. Discussion

Asteraceae family possesses many medicinal herbs owing immense larvicidal activity. The plant architecture is compatible with its metabolic activity. Distribution of mechanical layers like collenchyma and sclerenchyma tissues reflect the adapted behavior of any plant especially medicinal one (Chi et al., 2023).

*A. absinthium* has a biocidal effect on mosquito which can be used as a natural insecticide instead of any synthetic ones. To represent the efficiency of any plant extract, one should undergo different plant extractions with different solvents to evaluate the potential of plant substances. Nonetheless, the quality of the study can be raised by detecting the induced part of plant. All of these instructions, the present study follow to give the detail picture of plant activity. $Lc_{50}$ of acetone

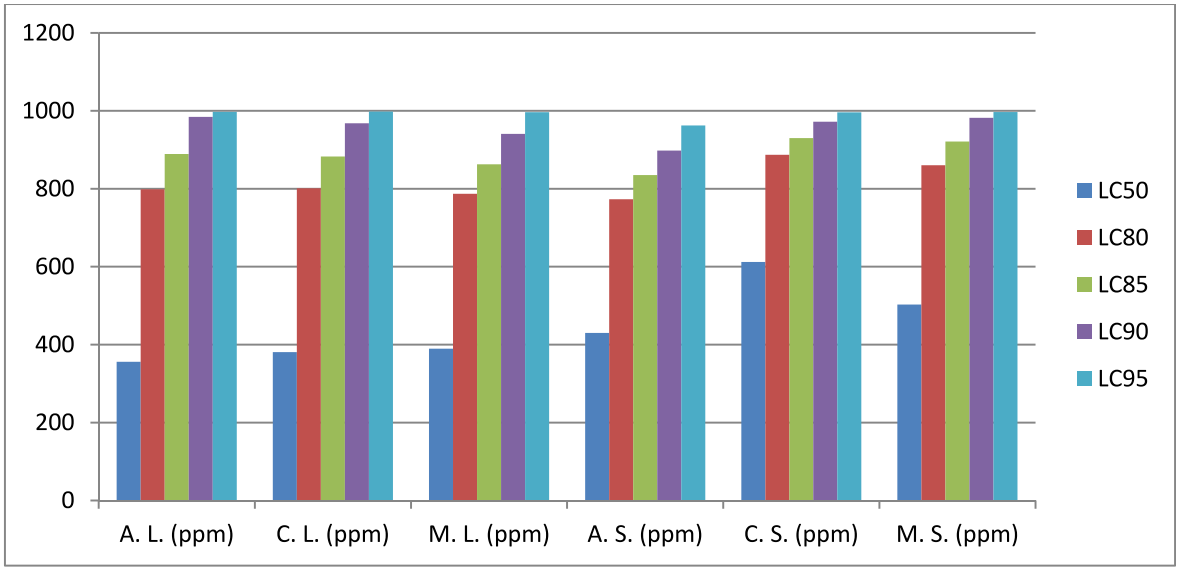


**Fig. 1.** Lethal concentrations of different plant part extract solvents on larvae of *Aedes aegypti* (A. L.: Acetone Leaves; C. L.: Chloroform Leaves; M. L.: Methanol Leaves; A. S.: Acetone Stem; C. S.: Chloroform Stem; M. S.: Methanol Stem).

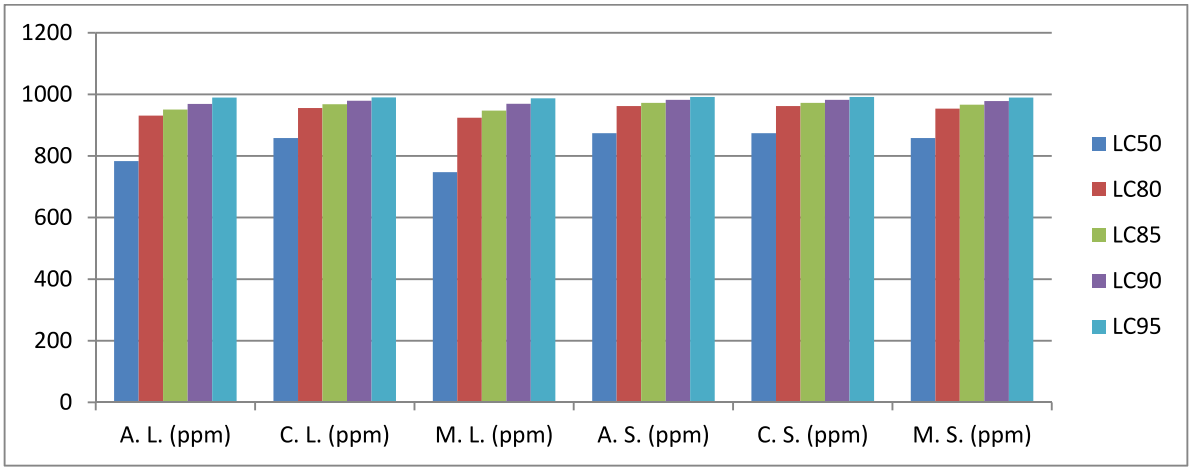


**Fig. 2.** Lethal concentrations of different plant part extract solvents on pupae of *Aedes aegypti* (A. L.: Acetone Leaves; C. L.: Chloroform Leaves; M. L.: Methanol Leaves; A. S.: Acetone Stem; C. S.: Chloroform Stem; M. S.: Methanol Stem).

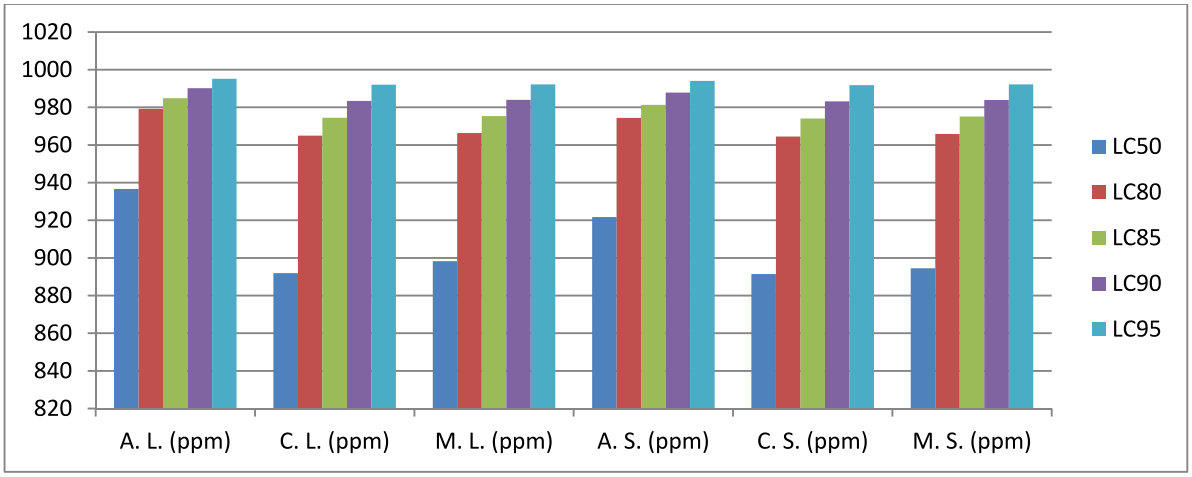


**Fig. 3.** Lethal concentrations of different plant part extract solvents on adults of *Aedes aegypti* L. (A. L.: Acetone Leaves; C. L.: Chloroform Leaves; M. L.: Methanol Leaves; A. S.: Acetone Stem; C. S.: Chloroform Stem; M. S.: Methanol Stem).

**Table 3**
Insecticidal correlation of acetone leaves extracts.

| | Larval mortality | Larval duration | Pupal mortality | Pupation | Adult mortality | Adult emergence |
|---|---|---|---|---|---|---|
| **Larval mortality** | – | 0.76 | | | | |
| **Larval duration** | 0.76 | – | | | | |
| **Pupal mortality** | | | – | 0.40 | | |
| **Pupation** | | | 0.40 | – | | |
| **Adult mortality** | | | | | – | 0.57 |
| **Adult emergence** | | | | | 0.57 | – |

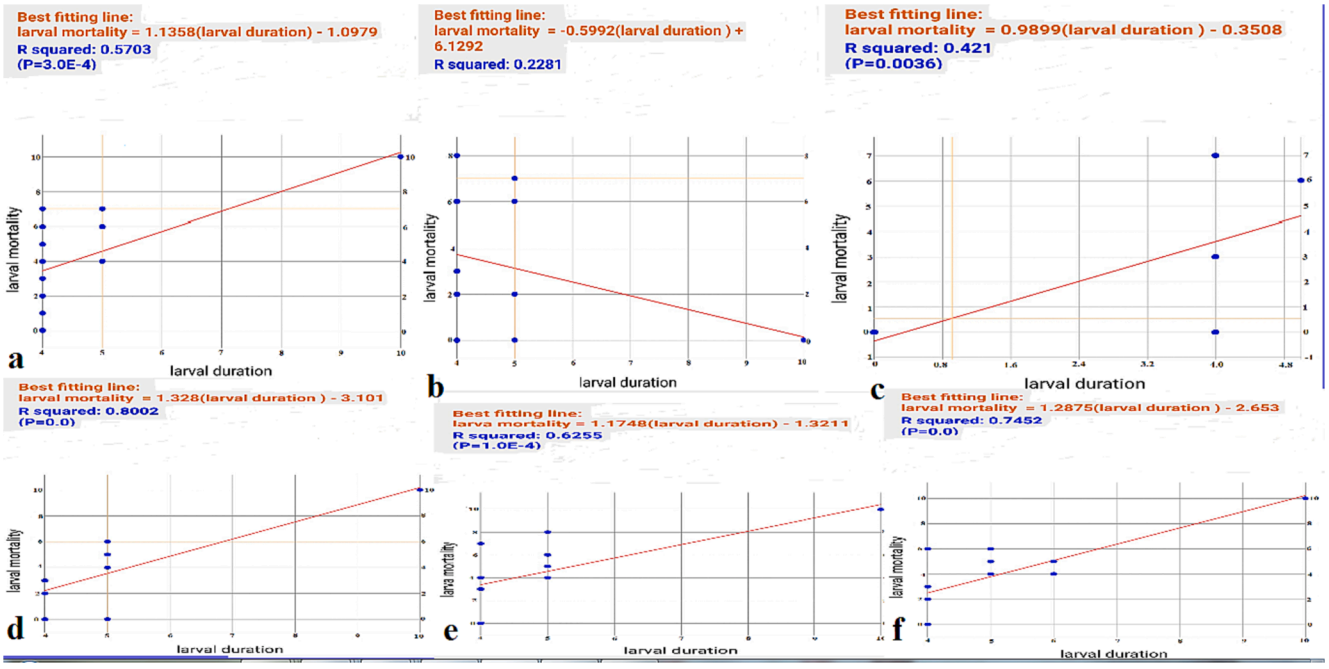


**Fig. 4.** Simple Linear Regression of the larvicidal significant relationships between mortality and duration by using different solvent of plant part extracts; a. acetone leaves, b. acetone stems, c. chloroform leaves, d. chloroform stems, e. methanol leaves, f. methanol stems.

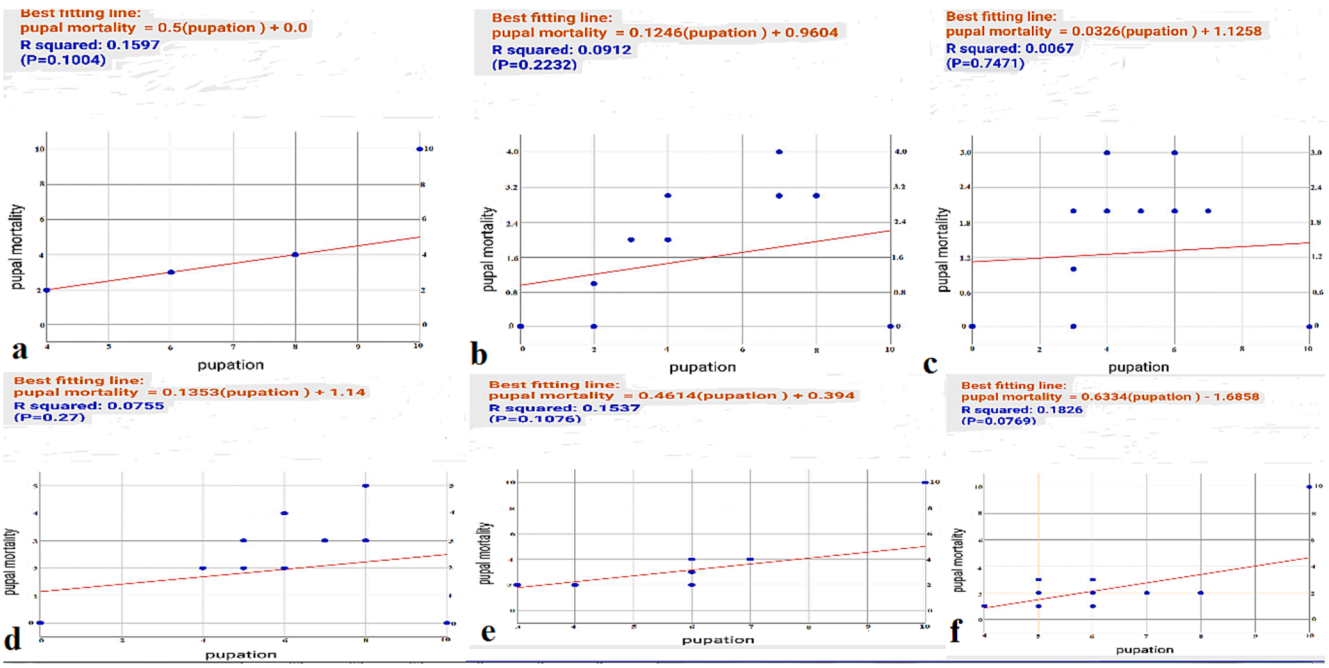


**Fig. 5.** Simple Linear Regression of the pupacidal significant relationships between mortality and duration by using different solvent of plant part extracts; a. acetone leaves, b. acetone stems, c. chloroform leaves, d. chloroform stems, e. methanol leaves, f. methanol stems.

**Table 4**
Insecticidal correlation of acetone stems extracts.

| | Larval mortality | Larval duration | Pupal mortality | Pupation | Adult mortality | Adult emergence |
|---|---|---|---|---|---|---|
| **Larval mortality** | – | −0.48 | | | | |
| **Larval duration** | −0.48 | – | | | | |
| **Pupal mortality** | | | – | 0.30 | | |
| **Pupation** | | | 0.30 | – | | |
| **Adult mortality** | | | | | – | −0.03 |
| **Adult emergence** | | | | | −0.03 | – |

**Table 5**
Insecticidal correlation of chloroform leaves extracts.

| | Larval mortality | Larval duration | Pupal mortality | Pupation | Adult mortality | Adult emergence |
|---|---|---|---|---|---|---|
| **Larval mortality** | – | 0.65 | | | | |
| **Larval duration** | 0.65 | – | | | | |
| **Pupal mortality** | | | – | 0.08 | | |
| **Pupation** | | | 0.08 | – | | |
| **Adult mortality** | | | | | – | −0.13 |
| **Adult emergence** | | | | | −0.13 | – |

leaves on larva assay records the less value of all Lc values. Therefore, it is the best extract that can be used as larvicidal. This value points to the right way to overcome mosquito in initial stages *i.e.* it is consumed the little plant extract concentration. The late stages need more concentrations to reach to the lethal dose in all solvents. Thus, the synthetic insecticide is regarded the best solution for this condition. The negative regression of chloroform extract in larva reflects the converse relationship between extract effectiveness and solvent polarity. *P* value/*F* tests were homogeneity among larva and pupa stages of *Ae. aegypti*. population showing the high degree of adult resistant.

**Vika *et al.* (2020)** used *Artemisia vulgaris* as alternate insecticide against *Ae. aegypti*. The bio efficacy of *A. vulgaris* extracts as larvicidal and adulticidal was clear. It was correlated with *A. absinsium* as a moderate value. Gaurav et al. (2014) stated that *Artemisia annua* leaf extract has a strong larvicidal potential against *Aedes aegypti* L. by using chloroform solvent. It has a high correlated value with the present study. Finally, *Artemisia herba alba* showed the less correlated value with *A. absintheum* due to the low larval mortality whose acetone solvent of *A. herba alba* leaves proceeded (Jazem et al., 2014). The significant integration among Artemisia sp. correlations raises the insecticidal value of this genus.

## 6. Conclusion

The acetone extract of *Artemisia absinthium* leaves is regarded the best natural insecticide against the initial stages of *Aedes aegypti* L. The study confirms generally on using different solvents to test each plant part extract as insecticidal in different stages not only one.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sjbs.2023.103853.

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