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Evaluation of the insecticidal activity of the methanol extracts of *Calotropis procera* (Asclepiadaceae) and *Albizia lebbeck* (Mimosaceae) on larvae of *Culex quinquefasciatus* Say, 1823

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Abstract

Background: Vector-borne diseases are mostly transmitted by mosquitoes. Therefore, these mosquitoes constitute a socio-economic scourge. Due to the resistance of mosquitoes to synthetic chemical insecticides and the pollution they generate, this study was conducted to assess the larvicidal activity of plant crude extracts on larvae of *Culex quinquefasciatus*.

Results: Bioassays performed on larvae shown that the extract of *Calotropis procera* at 0.6 mg/mL recorded the highest mortality rate of 100% for L1, L2 and L3. However, the extract of *Albizia lebbeck* at 0.7 mg/mL recorded the highest mortality rate of 100% for all the four stages of larvae. Negative and positive controls recorded 16% and 100% mortalities, respectively, after 24 h of exposure. The extract of *Calotropis procera* recorded LC_{50} values as follows: 0.194, 0.251, 0.258 and 0.284 mg/mL for L1, L2, L3 and L4, respectively. The LC_{90} of *Calotropis procera* were: 0.340, 0.433, 0.444 and 0.502 mg/mL for L1, L2, L3 and L4, respectively. In contrast, the extract of *Albizia lebbeck* recorded the following LC_{50}: 0.238, 0.264, 0.290 and 0.316 mg/mL for L1, L2, L3 and L4, respectively. Also, its LC_{90} were: 0.456, 0.498, 0.531 and 0.580 mg/mL, respectively, to L1, L2, L3 and L4.

Conclusion: The larvicidal bioassays performed revealed that these plant extracts have significant larvicidal properties. In the framework of fighting against vector-borne diseases, these two plants constitute alternative products to control mosquitoes.

Keywords: *Calotropis procera*, *Albizia lebbeck*, *Culex quinquefasciatus*, Larvicidal activity

Background

Vector-borne diseases remain a gripping problem for developing countries. Most of the pathogens of these diseases are transmitted by mosquitoes (Hamon et al., 1967). Among the species that are incriminated, *Culex quinquefasciatus* (Belkin, 1977; Harbach, 2012; Sirivanakarn & White, 1978) is well adapted to urban areas, particularly in most of African cities (Hamon et al., 1967; Chauvet et al., 1968). This vector transmits many diseases to human and animals (Aubry & Gaüzère, 2020; Fadila et al., 2012; Hamon et al., 1967). It is well known that this species is the main vector of filariasis (Hammantha & Subrahmanyam, 1969; Hamon et al., 1967; Madhi et al., 1963; Sajal & Probal, 2016). According to Sajal and Probal (2016), it is the potential vector of several arboviruses such as West Nile virus and Rift Valley fever virus.

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Many other authors also demonstrated that mosquitoes of this genus are vectors of the equine encephalitis: the Saint Louis encephalitis (Hill & Connelly, 2009; Khalil et al., 2008) and the avian malaria (Albuquerque et al., 1999).

Culex pipiens quinquefasciatus is very widespread in all the states of intertropical Africa (Hamon et al., 1967). In Africa, this mosquito poses a serious public health problem (Hamon et al., 1967). According to WHO (2010), lymphatic filariasis affects around 120 million people in 81 countries. About 40 million people suffer from stigmatization and debilitating clinical manifestations associated with this disease, including 15 million individuals suffering from lymphedema (elephantiasis) and 25 million men afflicted with urogenital hydrocele. In Cameroon, the total number of people needing massive administration of drugs against lymphatic filariasis was 16.968.062 in 2015. And the notified number of people treated the same year was 11.021.942 (WHO, 2016).

In addition to diseases, this species is at the origin of various nuisances such as bites which irritated the skin and noises they produced always disturb sleep. Thus, its nuisances and diseases transmitted to human and animals make its struggle a major concern. However, the most effective means of mosquito control is the use of synthetic chemical insecticides (Brengues & Coosemans, 1977; El Joubari et al., 2015; WHO, 2008). In Cameroon, *Cx. quinquefasciatus* shows resistance to organochlorine and organophosphorus insecticides due to extension and intense multiplication of mosquitoes (Darriet, 2007; Mouchet et al., 1985; Nchoutpouen et al., 2019). Thus, a high frequency of the West African kdr allele was recorded in *Cx. quinquefasciatus* resistant (Nchoutpouen et al., 2019). Synthetic chemical insecticides have negative impact to the environment and they are inducing environmental pollution due to their toxicity and their accumulation (Lévéque, 1990). The impact of chemical insecticides on the environment and the resistance of mosquitoes to synthetic chemical insecticides now limit their use. This explains the galloping interest of researchers for alternative methods (Brengues, 1978; Lévéque, 1990). Regarding alternative methods using plant extracts for vector control, several authors obtained satisfying results. According to Aouinty et al. (2006), aqueous extract of *Ricinus communis* and *Tetraclinis articulata* leaves exhibit an insecticidal activity on larvae of four mosquito's species. Hence, these plants can be used as alternative methods to fight against mosquitoes. In addition, essential oils from *Citrus sinensis*, *Citrus aurantium* and *Pistacia lentiscus* have shown larvicidal activity against larvae of stages 3 and 4 of *Culex pipiens* (Mohamed Yassine et al., 2014). According to Akpo et al. (2017), the acetone extract of the leaves of *Tephrosia vogelii* has a biocidal action on the larvae of stages 2, 3 and 4 of *Anopheles gambiae* of reference sensitive strain and of the wild strain after 24 h and 48 h of exposure. Moreover, all larval stages of *Anopheles gambiae* are susceptible to the aqueous extract of *Persea americana* (Koua, 1994). In the same line, we conducted a study to assess the larvicidal efficacy of the plant extracts from *Calotropis procera* and *Albizia lebbeck* against *Cx. quinquefasciatus*.

Methods

Collection of plant material

Plants were chosen for their traditional use as insect repellent. *Calotropis procera* (Asclepiadaceae) and *Albizia lebbeck* (Mimosaceae) leaves were harvested on September 2016, respectively, at Comice and Zokok neighborhoods in Maroua; Cameroon. The identification was confirmed at the National Herbarium of Cameroon, Yaounde by comparison with specimens of *C. procera* and *A. lebbeck* with voucher numbers N° 7808/SRF/Cam and N° 58964/HNC, respectively.

Preparation of plant extracts

The preparation of plant extracts was carried out according to the methods adopted by Jones and Kinghorn (2005), Thiaw (2008) and Kumar et al. (2014) with some modifications. The air-dried leaves of both plants were powdered and extracted thrice with methanol at room temperature for 48, 96 and 144 h, respectively. The filtrates were evaporated on a Rota vapor to give the methanol extracts. 1960 g of *C. procera* yielded 219.55 g of extract, while 2133 g of *A. lebbeck* afforded 224.18 g of extract. To prepare the stock solution of each plant extract, 200 mg of each crude extract was dissolved in 20 mL of methanol. The resulting stock solutions of 10 mg/mL were used for the preparation of seven ranges of concentrations. These concentrations ranged from 0.1 to 0.7 mg/mL.

Mosquito rearing

Culex quinquefasciatus larvae were collected from untreated lodgings in Lopéré neighborhood in Maroua; Cameroon. Larvae were identified in the laboratory of the Agricultural Research Institute for Development (IRAD) of Maroua using the identification keys of Edwards (1941), Hopkins (1952), Mattingly (1971) and Jupp (1996). The mosquito rearing was carried out as described by Rahuman et al. (2009), Saotoing et al. (2014) and Rathy et al. (2015) with slight modifications. The larvae were reared in the insectarium of that laboratory in plastic containers ($20 \times 10 \times 10$ cm). Larval density was 100 larvae for 1 L of spring water. The food used was Tetra Baby fish food. Pupae were transferred from the trays to the

cup containing borehole water and maintained in breeding cages where adults emerged. Adults were maintained in cages made up of wood, entirely covered with a mosquito net. They were continuously fed with 10% sucrose solution in a jar with a cotton wick. After four days, adult females were fed with blood meal from rabbit. Plastic cups with 100 mL of borehole water lined with filter paper were kept inside the cages for oviposition.

Larvicidal bioassays

Larvicidal tests were carried out according to the protocol recommended by the WHO (2005) and WHO (2013). Methanol extracts of *Calotropis procera* and *Albizia lebbeck* were tested against first (L1), second (L2), third (L3) and fourth (L4) stage larvae of *Culex quinquefasciatus*. These larvae were taken from the breeding strain. These bioassays were carried out using the seven concentrations (0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 mg/mL) previously prepared from a stock solution of each plant crude extract. These concentrations were determined according to the method used by Brehima (2008). For bioassays, 25 mosquito larvae were taken in four batches and inserted into 50 mL of distilled water together with the volume of specific stock solution. Then, the volume was adjusted to 100 mL with distilled water and kept at room temperature. The negative control was consisted of 25 larvae, a volume of methanol equivalent to the volume of the stock solution sampled for each concentration and distilled water to make up the volume to 100 mL. Methyl pirimiphos was used as a positive control. According to WHO (2008), methyl pirimiphos is an organophosphorus compound used in wide range of pesticide applications. It was considered by WHO as a larvicidal treatment. The positive control was made up of 25 larvae with 99 mL of distilled water and 1 mL of a solution of 0.1 g/L (i.e. 1 mg/L) of methyl pirimiphos. The test was repeated four times. Larval mortality was evaluated after 24 h of exposure. The number of dead larvae was recorded from the average of the four replications, with calculations of the mortality rate. When the percentage mortality was between 5 and 20% in control, mortality was corrected by the Abbott's formula (Abbott, 1925).

Data analysis

The analysis of variance was performed by the ANOVA method using the STAT GRAPHICS plus 5.0 software. The Chi-square and fiducidal limits values were calculated using the Excel program. The Henry simplified table that transforms the percentages of larval mortality into probit was used to determine the lethal concentration required to kill 50% (LC_{50}) and 90% (LC_{90}) of larvae (Finney, 1971).

Results

The results obtained in this study revealed that the methanol extracts of *Calotropis procera* and *Albizia lebbeck* have a toxic effect on the *Culex quinquefasciatus* larvae through the larval mortality they induced.

Effects of methanol extract of *Calotropis procera* against *Culex quinquefasciatus* larvae

The crude extract of *Calotropis procera* showed larvicidal effects after 24 h of exposure.

The mortality rate of *Cx. quinquefasciatus* larvae increases with the concentration of the crude extract of *C. procera* (Fig. 1). However, the highest mortality rate of 100% was recorded at 0.6 mg/mL for L1, L2 and L3. But the highest mortality rate of 97.61% was recorded at 0.7 mg/mL for L4. At 0.1 mg/mL, the extract exhibited lowest mortality rate of 14%, 11%, 9% and 6%, respectively, for L1, L2, L3 and L4. Larval mortality decreases from first stage larvae to fourth stage larvae.

The lethal concentration causing 50% mortality (LC_{50}) and lethal concentration causing 90% mortality (LC_{90}) values are shown in Table 1. The extract of *Calotropis procera* recorded LC_{50} values ranged as follows: 0.194 mg/mL for L1, 0.251 mg/mL for L2, 0.258 mg/mL for L3 and 0.284 mg/mL for L4. The LC_{90} of *Calotropis procera* were: 0.340 mg/mL, 0.433 mg/mL, 0.444 mg/mL and 0.502 mg/mL for L1, L2, L3 and L4, respectively. The lowest LC_{50} and LC_{90} values were observed at the first stage larvae (L1). But, the highest LC_{50} and LC_{90} values were observed at the fourth stage larvae (L4).

Furthermore, Table 1 shows the larval mortality rates, the Chi-square values, the LC_{50} and LC_{90} with fiducidal limits at the 95% confidence interval. The highest upper fiducidal limits of LC_{50} and LC_{90} were 0.314 mg/mL and 0.652 mg/mL for L4 ($P < 0.05$). The lowest upper fiducidal limits of LC_{50} and LC_{90} were 0.215 mg/mL and 0.415 mg/mL for L1 ($P < 0.05$). The

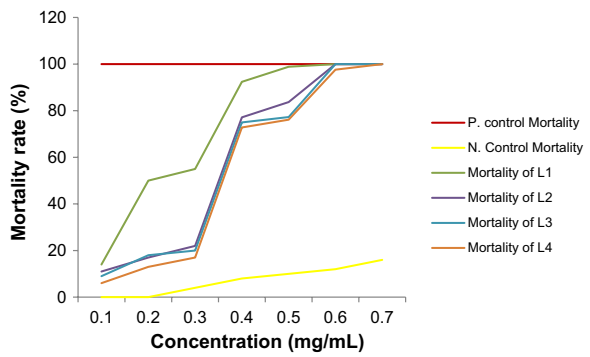

Fig. 1 Larval mortality based on concentrations of extract of *Calotropis procera* after 24 h of exposure

Table 1 Larvicidal activity of *Calotropis procera* crude extract on *Culex quinquefasciatus* at different concentrations

Larval stages	Mortality rate of *Cx. quinquefasciatus* larvae (%)							LC_{50}	LC_{90}	CI95				χ^2 (*df* = 6)	Equations of regression line
	Concentrations of crude extract of *Calotropis procera* (mg/mL)									LFL		UFL			
	0.1	0.2	0.3	0.4	0.5	0.6	0.7			LC_{50}	LC_{90}	LC_{50}	LC_{90}		
L1	14	50	55	92.39	98.86	100	100	0.194	0.340	0.174	0.278	0.215	0.415	41.24*	Y = 5.2615x + 8.75
L2	11	17	22	77.17	83.69	100	100	0.251	0.433	0.210	0.235	0.301	0.798	71.75*	Y = 5.3993x + 8.2448
L3	9	18	20	75	77.27	100	100	0.258	0.444	0.208	0.209	0.319	0.941	61.22*	Y = 5.4196x + 8.1901
L4	6	13	17	72.82	76.13	97,61	100	0.284	0.502	0.257	0.386	0.314	0.652	52.79*	Y = 5.189x + 7.8331

LFL, lower fiducidal limit; UFL, upper fiducidal limit; χ^2, *Chi*-square value; *df*, degrees of freedom; CI, confidence interval

* Significant at $P < 0.05$ level

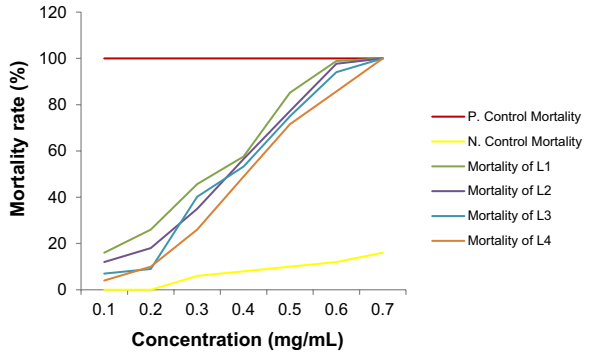

Fig. 2 Larval mortality based on concentrations of extract of *Albizia lebbeck* after 24 h of exposure

highest lower fiducidal limits of LC_{50} and LC_{90} were 0.257 mg/mL and 0.386 mg/mL for L4 ($P < 0.05$). The lowest lower fiducidal limits of LC_{50} and LC_{90} were 0.174 mg/mL and 0.278 mg/mL for L1 ($P < 0.05$). The Chi-square values were: 41.24, 71.75, 61.22 and 52.79 for L1, L2, L3 and L4, respectively.

Effects of methanol extract of *Albizia lebbeck* against *Culex quinquefasciatus* larvae

The crude extract of *Albizia lebbeck* showed larvicidal effects after 24 h of exposure. The mortality rate of *Cx. quinquefasciatus* larvae increases with the concentration of the crude extract of *A. lebbeck* (Fig. 2). However, the highest mortality rate of 100% was recorded at 0.7 mg/mL treatment concentration for all the four stages of larvae. At 0.1 mg/mL, the extract showed lowest mortality rate of 16%, 12%, 7% and 4%, respectively, for L1, L2, L3 and L4. Larval mortality decreases from first stage larvae to fourth stage larvae.

The lethal concentration causing 50% mortality (LC_{50}) and lethal concentration causing 90% mortality (LC_{90}) values are shown in Table 2. The extract of *Albizia lebbeck* recorded the following LC_{50} values: 0.238 mg/mL for L1, 0.264 mg/mL for L2, 0.290 mg/mL for L3 and 0.316 mg/mL for L4. Also, its LC_{90} were: 0.456 mg/mL, 0.498 mg/mL, 0.531 mg/mL and 0.580 mg/mL, respectively, to L1, L2, L3 and L4. The lowest LC_{50} and LC_{90} values were observed at the first stage larvae (L1). These values were increasing until the fourth stage larvae (L4).

Furthermore, Table 2 presents the larval mortality rates, the Chi-square values, the LC_{50} and LC_{90} with

Table 2 Larvicidal activity of *Albizia lebbeck* crude extract on *Culex quinquefasciatus* at different concentrations

Larval stages	Mortality rate of *Cx. quinquefasciatus* larvae (%)							LC_{50}	LC_{90}	CI95				χ^2(*df* = 6)	Equations of regression line
	Concentrations of crude extract of *Albizia lebbeck* (mg/mL)									LFL		UFL			
	0.1	0.2	0.3	0.4	0.5	0.6	0.7			LC_{50}	LC_{90}	LC_{50}	LC_{90}		
L1	16	26	45.65	57.60	85.22	98.86	100	0.238	0.456	0.196	0.208	0.288	0.983	27.20*	Y = 4.5383x + 7.8287
L2	12	18	35	56.52	77.27	97.72	100	0.264	0.498	0.221	0.264	0.315	0.939	25.26*	Y = 4.643x + 7.6836
L3	7	9	40.21	53.26	75	94.04	100	0.290	0.531	0.257	0.374	0.327	0.753	27.39*	Y = 4.8662x + 7.62
L4	4	10	26	48.91	71.59	85.71	100	0.316	0.580	0.284	0.437	0.352	0.768	17.01*	Y = 4.8692x + 7.4356

LFL, lower fiducidal limit; UFL, upper fiducidal limit; χ^2, *Chi*-square value; *df*, degrees of freedom; CI, confidence interval

*Significant at $P < 0.05$ level

fiducidal limits at the 95% confidence interval. The highest upper fiducidal limits of LC_{50} and LC_{90} were 0.352 mg/mL for L4 and 0.983 mg/mL for L1, respectively ($P<0.05$). The lowest upper fiducidal limits of LC_{50} and LC_{90} were 0.288 mg/mL for L1 and 0.753 mg/mL for L3, respectively ($P<0.05$). The highest lower fiducidal limits of LC_{50} and LC_{90} were 0.284 mg/mL and 0.437 mg/mL for L4 ($P<0.05$). The lowest lower fiducidal limits of LC_{50} and LC_{90} were 0.196 mg/mL and 0.208 mg/mL for L1 ($P<0.05$). The Chi-square values were: 27.20, 25.26, 27.39 and 17.01 for L1, L2, L3 and L4, respectively.

Discussion

It is evident from these results that the higher concentration of plant extracts induces higher mortality of *Cx. quinquefasciatus* larvae. Since the *P*-value in the ANOVA table is less than 0.01, there is a statistically significant relationship existing between mortality and concentration at 99% confidence level. So, the larval mortality rate increases with the concentration of crude plant extracts. According to Merabti et al. (2015), similar evolution was obtained between mortality rate and concentrations from the effect of the fruit extract of *C. colocynthis* (L) on Culicidae larvae. The studies carried out by Kemassi et al. (2015) showed similar results on evaluation of the larvicidal effect of *E. guyoniana* (Euphorbiaceae) aqueous extract on *Cx. pipiens*.

The crude methanol extracts of *C. procera* and *A. lebbeck* showed larvicidal activity on *Cx. quinquefasciatus* after 24 h of exposure. In fact, mortality rate decreases with the larval age. In other words, mortality is higher in L1 larvae than in L4 larvae. The sensitivity of the larvae depends on their stages of development. Thus, the immature larvae stages (L1 and L2) are more sensitive to plant extracts than old larvae stages (L3 and L4). Furthermore, larval mortality of *Cx. quinquefasciatus* fluctuates with the concentrations of crude plant extracts. These results are similar to those obtained in Morocco by El-Akhal et al. (2015) which reveal that larval mortality in larval stages 3 and 4 of *Cx. pipiens* varies with the concentrations of essential oils of *Thymus vulgaris*. In addition, Singh et al. (2005) revealed that the methanol extracts of fresh leaves of *Calotropis procera* showed larvicidal properties against larvae of *Culex quinquefasciatus* after 24 and 72 h of exposure. However, our results corroborate with those obtained by Singh et al. (2005) but they did not determine the LC_{50} values after 24 h. Some nuances observed might probably due to the fact that they used the fresh leaves while we used the dried leaves of the same plant. According to Rahuman et al. (2009), methanol leaf extracts of *Acacia arabica*, *Mangifera indica*, *Nerium indicum*, *Nicotiana tabacum* and *Solanum nigrum* showed mortality of L4 larvae of *Cx. quinquefasciatus* at 1000 ppm, after 24 h of exposure. However, these extracts recorded a mortality of 28%, 08%, 28%, 100% and 90%, respectively.

In Mali, according to Dahafolo (2009), dichloromethane, petroleum ether, ethanol and methanol extracts of *C. procera* showed a larvicidal activity on the *Anopheles gambiae* larvae after 24 h of exposure. Furthermore, larvicidal effect of these two methanol extracts showed a high mortality rate above 75% at 0.5 mg/mL. According to studies conducted in Mali, methanol extracts of *C. procera* showed a lower mortality rate of around 51% at the same concentration (500 µg/mL) (Dahafolo, 2009). Larvicidal activity was monitored against 2nd, 3rd and 4th instar larvae of *Anopheles arabiensis* and *Culex quinquefasciatus* 24 h after treatment with *Calotropis procera* extracts. High, medium and low larval mortality was obtained using three different concentrations of extracts (1000, 500, 200 ppm for *An. arabiensis* and 1000, 500, 100 ppm for *Cx. quinquefasciatus*) (Elimam et al., 2009). According to Govindarajan and Rajeswary (2015), hexane, benzene, chloroform, ethyl acetate and methanol extracts from *Albizia lebbeck* leaf and seed were tested for toxicity against *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi*. All five solvent extracts showed moderate ovicidal activity; however, the methanol extract showed the highest ovicidal activity. Thus, 100% mortality was observed at 250, 200 and 150 ppm for the methanol leaf extract and 375, 300 and 225 ppm for the methanol extract of *A. lebbeck* seed against *Cx. quinquefasciatus*, *Ae. aegypti* and *An. stephensi*, respectively. The insecticidal activity would be due to the cardenolides and cardiotonic glycosides (calotoxin, calotropin, uscharidine) contained in the latex of *C. procera* (Traoré, 2009). This would also be due to the terpenoids, saponins and pyridine glycosides present in *A. lebbeck* (Sujatha et al., 2013). However, insecticidal activity depends on the specificity of mosquito species and life stage, solvents used for extraction and the geographical source from where the plants compounds are derived (Sukumar et al., 1991).

The methanol extract of *C. procera* and *A. lebbeck* leaves has significant larvicidal activity with LC_{50} values of 0.194 mg/mL for L1, 0.251 mg/mL for L2, 0.258 mg/mL for L3 and 0.284 mg/mL for L4. The LC_{90} of *Calotropis procera* were: 0.340 mg/mL, 0.433 mg/mL, 0.444 mg/mL and 0.502 mg/mL for L1, L2, L3 and L4, respectively. The extract of *Albizia lebbeck* recorded the following LC_{50} values: 0.238 mg/mL for L1, 0.264 mg/mL for L2, 0.290 mg/mL for L3 and 0.316 mg/mL for L4. Its LC_{90} were: 0.456 mg/mL, 0.498 mg/mL, 0.531 mg/mL and 0.580 mg/mL, respectively, to L1, L2, L3 and L4. These results are close to those obtained by Elimam et al. (2009) on the larvicidal activity against the 2nd, 3rd and 4th instar larvae of *Culex quinquefasciatus* and therefore the

calculated LC_{50}-LC_{90} values were 187.93–433.51 ppm; 218.27–538.27 and 264.85–769.13 ppm for the 2nd, 3rd and 4th instar larvae of *Cx. quinquefasciatus*, respectively. In Mali, studies based on the dichloromethane extract of *C. procera* leaves on *Anopheles gambiae* larvae revealed that this plant species has a high larvicidal activity with LC_{50} of 372.5 µg/mL (Dahafolo, 2009). By comparing these results, it appears that the methanol extract of *C. procera* leaves has a higher toxic potential than that of the dichloromethane extract of *C. procera* leaves on mosquito larvae. This difference would be due to the nature of the extraction solvent used. In Algeria, Kemassi et al. (2015) observed that aqueous extract of *Euphorbia guyoniana* exhibits larvicidal activity against *Cx. pipiens* stage 3 larvae (LC_{50} = 0.0015 mg/mL and LC_{90} = 0.0094 mg/mL). By comparing these results with ours, it appears that methanol extracts of *Calotropis procera* and *Albizia lebbeck* are less toxic than the aqueous extract of *Euphorbia guyoniana*. This is explained by the fact that the aqueous extract of *Euphorbia guyoniana* registers lower LC_{50} values than our both plant extracts. Rahuman et al. (2009) revealed that *Nicotiana tabacum* leaf extracts exhibited the highest larval mortality against the 4th instar larvae of *Culex quinquefasciatus*. Thus, the LC_{50} and LC_{90} were: acetone (LC_{50} = 163.81 ppm; LC_{90} = 627.38 ppm); hot water (LC_{50} = 76.27 ppm; LC_{90} = 334.72 ppm); methanol (LC_{50} = 105.85 ppm; LC_{90} = 524.39 ppm) and chloroform (LC_{50} = 83.38 ppm; LC_{90} = 709.51 ppm). In Cameroon, the larvicidal tests carried out show that the essential oil of *Cymbopogon citratus* leaves is more active on stage 3 and stage 4 of *Anopheles funestus s.s.* larvae with LC_{50} of 35.5 ppm and 34.6 ppm, respectively (Akono Ntonga et al., 2014). These results are different from ours; this disparity would be linked to the nature of the plant species, to the type of extracts tested and to the extraction process.

Conclusion

This study revealed that methanol extracts of *C. procera* and *A. lebbeck* leaves exhibited larvicidal activity on *Cx. quinquefasciatus*. The mortality rate increases with concentration. These plants are less toxic to humans and the environment. They are available and abundant in the city of Maroua. Therefore, it would be necessary to popularize their use in the fight against mosquito vectors of diseases.

Abbreviations

ANOVA: Analysis of variance; *Ae.*: *Aedes*; *A. Lebbeck*: *Albizia lebbeck*; *An.*: *Anopheles*; *C. procera*: *Calotropis procera*; *Cx.*: *Culex*; kdr: Knock-down resistance; L1: First stage larvae; L2: Second stage larvae; L3: Third stage larvae; L4: Fourth stage larvae; LC_{50}: Lethal concentration causing 50% of mortality; LC_{90}: Lethal concentration causing 90% of mortality; mg: Milligram; mL: Milliliter; N. control mortality: Negative control mortality; P. control mortality: Positive control mortality.

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Authors' contributions

MM**,** BFEM and TNSJ designed the work**.** Extractions were done under the supervision of TNSJ. Bioassays were performed by MM under the supervision of BFEM and TJL. All authors read and approved the final manuscript.

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Availability of data and materials

Data are available and will be made available to all.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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