

*Full Length Research Paper*

# ***In vitro* investigation of the repellent effects of the essential oil of *Lippia javanica* on adults of *Hyalomma marginatum rufipes***

**S. R. Magano<sup>1\*</sup>, F. Nchu<sup>2</sup> and J. N. Eloff<sup>3</sup>**

<sup>1</sup>Department of Life and Consumer Sciences, College of Agriculture and Environmental Sciences, University of South Africa, Florida Campus, Johannesburg, South Africa.

<sup>2</sup>Faculty of Applied Sciences, Cape Peninsula University of Technology, Cape Town, South Africa.

<sup>3</sup>Programme for Phytomedicine, Department of Paraclinical Sciences, University of Pretoria, Private Bag X04, Onderstepoort 0110, South Africa.

Accepted 13 June, 2011

**A suitable *in vitro* tick climbing repellency bioassay was developed to evaluate the repellent effects of the essential oil (n-hexane extracts of distillate) of *Lippia javanica* (Burm. F.) Spreng (Verbernaceae) on adults of *Hyalomma marginatum rufipes* Koch, 1844. The GC-MS analysis of the distillate of the essential oil of *Lippia javanica* revealed that myrcene (13.4%), 1,8-cineole (8%), dyhydrotagetone (7.9%), ipsenone (9.6%), bicyclo (3.1.1) heptanes-2-one (20.8%) and 2-butanone (13.3%) were the major constituents. A significant ( $P < 0.05$ ) dose dependent repellency response was observed for the essential oil of *L. javanica* on adults of *H. marginatum rufipes* when data were subjected to Kruskal Wallis analysis.**

**Key words:** *Hyalomma marginatum rufipes*, *Lippia javanica*, repellency bioassay, essential oil, GC-MS.

## **INTRODUCTION**

The biology of ticks and the problems they cause to man and other animals are well documented (de Castro, 1997; Gonzalez et al., 1998). However, in spite of the use of synthetic acaricides such as chlorinated hydrocarbons and organophosphates (Rajput et al., 2006) as the main weapons for tick-control, ticks continue to be amongst the leading ectoparasites and vectors of disease-causing agents. In addition, over-reliance on synthetic acaricides for tick control has led to problems including the emergence of tick strains that are resistant to acaricides (Li et al., 2003), environmental pollution (Bhattacrya et al., 2003) and acaricide residues in products that are destined for human consumption (Karraliede et al., 2003). These problems highlight the need for alternative tick control methods that are environmental friendly yet effective against ticks.

Interest in plant-based products that can be used as alternatives for the control of arthropods is growing rapidly among researchers (e.g. Pascual-Villabos and Robledo, 1998; Lwande et al., 1999; Abdel-Shafy and Zayed, 2002; Fields et al., 2002; Thembo et al., 2010). The basis for this interest is three-fold: firstly, some plant species, for example Neem (Handule et al., 2002; Liang et al., 2003) have been shown to have anti-arthropod properties; secondly, plant-based products are biodegradable and as a result pose lesser problems to the environment; and thirdly, plant-based products may not be susceptible to the existing mechanisms of resistance to arthropocides.

In this study, we investigated the repellent effects of the essential oil of *Lippia javanica* on *Hyalomma marginatum rufipes* ticks. *L. javanica* is widely distributed in southern Africa (van Wyk et al., 1997) and the indigenous people of southern Africa believe that its strong infusions have arthropocidal properties (Matlebyane et al., 2010). *H. m. rufipes* is widely distributed in southern Africa (Walker et al., 2003) and transmits Crimean-Congo haemorrhagic

\*Corresponding author. E-mail: [magansr@unisa.ac.za](mailto:magansr@unisa.ac.za). Tel: +27 11 471 3649. Fax: +27 11 471 2796.

fever virus to humans (Hoogstraal, 1979).

## MATERIALS AND METHODS

### Ticks

Host-seeking (3 to 4 weeks old) *H. m. rufipes* adult ticks used in this study were obtained from the laboratory colonies maintained on rabbits, in the Department of Biology at University of Limpopo, Medunsa campus. These ticks were maintained in glass humidity chambers at  $25 \pm 1^\circ\text{C}$ ,  $75 \pm 5\%$  RH and natural day/night regime.

### Plant material and extraction of essential oil

Leaves, branches and flowers of *L. javanica* were collected in April 2004 from a maize farm managed by the Department of Plant Production and Soil Sciences, at the University of Pretoria.

Fresh leaves, softer branches and inflorescences were sliced into smaller pieces and together were hydrodistilled using a Clevenger-type apparatus with slight modifications (Evans, 1989). Heat supply was provided by heating-mantle equipped with a thermostat and heat was maintained at  $90^\circ\text{C}$ . 200 g of plant materials in 400 ml of distilled water were introduced into the round bottom flask and hydrodistilled for 2 h. The distillate was collected as the essential oil band above water. The yield of the essential oil of *L. javanica* obtained was  $0.08 \text{ ml} / 200 \text{ g} \times 100 = 0.04\%$  (v/w). The essential oil obtained was stored in a refrigerator at  $4^\circ\text{C}$  until used.

The essential oil of *L. javanica* was analyzed using QP 20-10 Shimadzu GC-MS equipment. The gas chromatograph column temperature was programmed to rise from  $50$  to  $300^\circ\text{C}$  at  $10^\circ\text{C}/\text{min}$ . The injector temperature was  $250^\circ\text{C}$ . The total flow rate was  $24 \text{ ml}/\text{min}$  and column flow rate was  $1 \text{ ml}/\text{min}$ . Supelco equity 1 column with a film thickness of  $30 \text{ m} \times 0.25 \text{ microns}$  was used.  $1 \mu\text{l}$  of each of the sample (essential oil) was used. Ultra high purity Helium was used as the carrier gas with injector split ratio of 20:1. The ion source and interphase temperatures were  $200$  and  $250^\circ\text{C}$  respectively. The solvent cut time of  $4 \text{ min}$  and detector gain was  $0.70 \text{ kv}$ . A Wiley 229 library search was conducted on major peaks of each sample in order to identify the components of the sample. The relative percentage of each compound was determined by calculation of the area under the peak (width at  $1/2$  height  $\times$  height) (Houghton and Raman, 1998).

### Anti-tick activity

The repellency bioassay described here below, is a modification of that described by Carroll (1998). However, this bioassay is sufficiently different to merit re-description. This bioassay was based on the climbing behaviour of host-seeking ticks. Except for the genus *Amblyomma*, most ticks climb to vantage positions on grass waiting for the vertebrate hosts. In this bioassay, two glass-rods ( $L = 21.5 \text{ cm}$  and diameter =  $0.5$ ) were vertically and firmly inserted on a single rectangular polystyrene platform ( $L = 19.5 \text{ cm}$ ,  $W = 6 \text{ cm}$ , and  $H = 3.5 \text{ cm}$ ). The two glass-rods were positioned at the opposite ends of the platform ( $15 \text{ cm}$  apart). Water was added into the container to completely surround the platform and to almost reach its height. This was done in order to discourage ticks from moving away from the platform and to stabilize humidity (Carroll et al., 1995). Each of the first (bottom) and the last (top)  $5 \text{ cm}$  of the one glass-rod were covered with a Whatman No. 1 filter paper strip ( $2.5 \text{ cm} \times 5 \text{ cm}$ ). On each test filter paper strips (bottom and top),  $100 \mu\text{l}$  of the distillate was released on the filter papers, which were used to cover the test glass-rods. The rationale of fixing filter papers on the first and last  $5 \text{ cm}$  of the glass rods was to expose ticks to

the essential oil before they started to climb and also when they were questing at the top of the glass rod. Only the hexane solvent ( $100 \mu\text{l}$ ) was released on the filter paper strips applied on the control glass-rods. The filter paper strips were dried prior to been applied on the glass rods. Surgical gloves were used to handle glass rods and filter paper strips. To develop different concentrations, a mixture of n-hexane solvent and the distillate were prepared by making  $1.5 \text{ ml}$  of the solution with  $40$ ,  $80$  and  $160 \mu\text{l}$  quantities of essential oils in varied amounts of the hexane solvent using an adjustable pipette. The concentrations of essential oil of *L. javanica* used were  $2.7$ ,  $5.3$  and  $10.7\%$  (v/v), respectively. There were five replications for n-hexane extracts of the essential oil of *L. javanica* with 15 ticks (at least 5 males and 8 females) per replication. Each tick was placed midway between the glass rods on the platform in a direction that was perpendicular to the imaginary straight line joining the two glass rods. The locations of ticks were recorded at  $30 \text{ min}$  intervals during a  $3 \text{ h}$  testing period. The repellent indexes were calculated using the formula:

$$R = [(Nc - Nt) / (Nc + Nt)] \times 100$$

Where,  $Nc$  = number of ticks on the control glass rod and  $Nt$  = number of ticks on the treatment glass rod (Lwande et al., 1999).

### Data analysis

Data collected at each time interval in each replicate were grouped together and tested for significance using the non-parametric Mann-Whitney U test. The non-parametric Mann-Whitney U test was used because the number of ticks in each replication varied and transformation of data into  $\text{Log } X+1$  did not yield normal distribution in some of the data, when analyzed with Shapiro-Wilk test for normality. Also the number of ticks recorded varied from one replication to the other. To determine the effect of increasing concentration on repellency at different time intervals, non-parametric Kruskal-Wallis test (Hammer et al., 2001) was used.

## RESULTS AND DISCUSSION

### Essential oil composition

Among the constituents of the essential oil of *L. javanica* identified by GC/MS analysis, myrcene ( $13.4\%$ ), 1,8-cineole ( $8\%$ ), dyhydrotagetone ( $7.9\%$ ), ipsenone ( $9.6\%$ ), bicyclo (3.1.1) heptanes-2-one ( $20.8\%$ ) and 2-butanone ( $13.3\%$ ) occurred in large quantities (Figure 1 and Table 1).

### Tick repellency

The repellent indexes increased with increasing concentrations of *L. javanica* (Tables 2, 3 and 4). A significant dose-dependent response was observed between the essential oil of *L. javanica* and adults of *H. m. rufipes* at all the time intervals. The median repellent indexes increased with increasing concentration. However, for each concentration of the essential oil of *L. javanica*, differences in repellent indexes at different time intervals were not statistically significant (Tables 2, 3 and 4). A significant difference ( $P < 0.05$ ) was observed at all

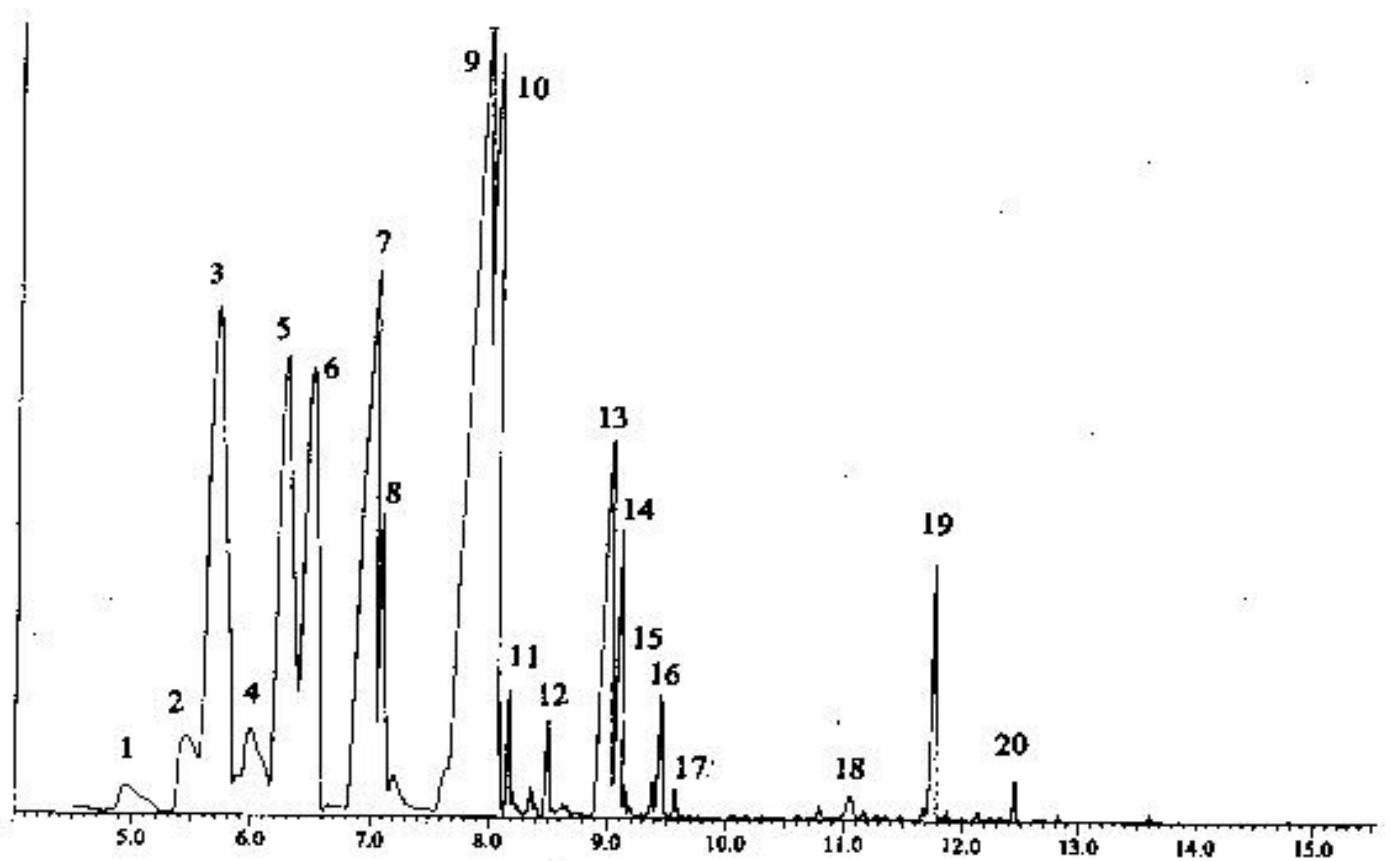


Figure 1. GC-MS chromatogram of the essential oil of *L. javanica*.

Table 1. Constituents of the essential oil of *L. javanica* and the relative amount in a GC-MS analysis.

Compound	Relative percentage
$\alpha$ -Pinene	5.33
Sabinene	2
Myrcene	13.4
Cyclooctene	2.2
1,8-Cineole	8
Dehydro tagetone	7.9
Ipsenone	9.6
Z and E epoxy-ocimene	2.7
Bicyclo(3.1.1)heptan-2-one	20.8
2-Butanone	13.3
Unknown	0.57
B-Fenchyl alcohol	0.4
3-methyl-2-(2-methyl-2-butenyl)-furan	3.3
3-methyl-2-(2-methyl-2-butenyl)-furan	2.5
Thiophene	1.7
2-Cyclohexen-1-one	0.5
Unknown	0.01
Unknown	0.02
Carryophellene	1.13
Germacrene-D	0.17

**Table 2.** Tick repellent indexes (RI) at a concentration of 2.7% (v/v) of the essential oil of *L. javanica* at different time intervals.

Time (min)	Median RI (%)	Range of RI from lowest to highest value	P-value Man-Whitney U test
30	33.3	9.1 – 81.8	0.0122
60	33.3	7.7 – 85.7	0.0122
90	33.3	0 – 85.7	0.0126
120	33.3	0 – 85.7	0.0126
150	33.6	7.7 – 85.7	0.0122
180	33.3	7.7 – 85.7	0.0122

**Table 3.** Tick repellent indexes (RI) at a concentration of 5.3% (v/v) of the essential oil of *L. javanica* at different time intervals.

Time (min)	Median RI (%)	Range of RI from lowest to highest value	P-value Man-Whitney U test
30	66.6	60 – 100	0.0122
60	63.36	50 – 100	0.0122
90	63.63	50 – 100	0.0122
120	50	50 – 84.6	0.0122
150	69.2	50 – 86.6	0.0122
180	69.2	50 – 86.6	0.0122

**Table 4.** Tick repellent indexes (RI) at a concentration of 10.7% (v/v) of the essential oil of *L. javanica* at different time intervals.

Time (min)	Median RI (%)	Range of RI from lowest to highest value	P-value Man-Whitney U test
30	100	85.7 – 100	0.0122
60	100	85.7 – 100	0.0122
90	100	86.7 – 100	0.0122
120	100	85.7 – 100	0.0122
150	100	100	0.0122
180	100	86.7 – 100	0.0122

intervals between the number of ticks in the control and test replications for *L. javanica*'s essential oil (Table 5). Also, the results showed that the range of RI became smaller as concentration was increased from the lowest at 2.7% (v/v) (0 to 85.7) to 10.7% (v/v) (85.7 to 100).

The main goal of this study was to investigate the repellent effects of the essential oil of *L. javanica* on *H. m. rufipes* ticks. Data obtained from this study suggest that the essential oil of *L. javanica* has repellent properties against *H. m. rufipes*. The repellency properties of the essential oil of *L. javanica* have been shown to be effective also against non-tick arthropods (Lukna et al., 1998).

The potency of the essential oil of *L. javanica* to repel ticks in this study, persisted for 3 h, a duration longer than those established for most botanicals against mosquitoes (Frandin and Day, 2002). Considering the

design of the bioassay used in this study, the bioactive compounds in the essential oil of *L. javanica* should have been volatile in nature since ticks avoided coming into contact with the treatment filter papers. In addition, hexane which was used as a carrier of the essential oil in this study is known to extract non-polar volatile compounds such as essential oils (Houghton and Raman, 1998).

The major constituents of *L. javanica* in this study were bicyclo (3.1.1) heptan-2-one, myrcene and 2-butanone. Amongst these, only myrcene has been identified as a major constituent of *L. javanica* by other studies. The variation in chemical composition of *L. javanica* has been noted by other authors. According to Viljoen et al. (2005), *L. javanica* displays quantitative and qualitative variations both within and between natural plant populations. Other chemical constituents of the essential oil of *L. javanica*

**Table 5.** Dose dependent tick repellency response at each time interval for increased concentrations of the essential oil of *L. javanica*.

Time	Concentrations (% v/v)	Kruskal Wallis at intervals (min) 95% CI
30	2.7, 5.3 and 10.7	s
60	2.7, 5.3 and 10.7	s
90	2.7, 5.3 and 10.7	s
120	2.7, 5.3 and 10.7	s
150	2.7, 5.3 and 10.7	s
180	2.7, 5.3 and 10.7	s

's' Indicates significant difference ( $P < 0.05$ ) of concentration-response relationship for each time interval.

such as alpha-pinene, sabinene, myrcene and 1,8 cineole determined in this study, have been identified in the essential oils of *Eucalyptus saligna* and *Cupressa sempervirens* which were shown to have repellent properties against arthropod pests (Taponndjou et al., 2005). Although the need to know the effect of each individual chemical constituent on ticks exists, Lwande et al. (1999) showed that the crude essential oil possesses increased bioactivity compared to its individual constituents. It is therefore reasonable to suspect that the repellent effects of the essential oil of *L. javanica* observed in this study were a result of the synergy among the chemical constituents.

In summary, the results of this study, further strengthens the view that *L. javanica* is a potential source of anti-arthropod agents and also to some extent validates the traditional use of the plant for insect pest control by the people of southern Africa (Matlebyane et al., 2010). However, it is important that future studies should include field trials in order to confirm laboratory results.

## ACKNOWLEDGEMENTS

The National Research Foundation funded the project. The University of Limpopo (MEDUNSA Campus) and the University of Pretoria provided the laboratory equipment. We thank the colleagues in the Department of Biology, University of Limpopo. We extend our gratitude to Dr D. Katerere and Dr. P. Soundy for their valuable contributions.

## REFERENCES

Abdel-Shafy S, Zayeb AA (2002). *In vitro* acaricidal effect of plant extract of neem seed oil (*Azadirachta indica*) on egg, immature and adult stages of *Hyalomma anatolicaum excavatum* (Ixodidae). *Vet. Parasitol.* 106: 89-96.

Bhattacharya B, Sarkar SK, Mukherjee N (2003). Organochloride pesticide residues in sediments of a tropical mangrove estuary, India;

implications for monitoring. *Environ. Int.* 1052: 1-6.

Carroll JF (1998). Kairomonal activity of White-tailed deer metatarsal gland substances: A more sensitive behavioral bioassay using *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 35: 90-93.

Carroll JF, Klun JA, Schmidtman ET (1995). Evidence for kairomonal influence on selection of host-ambushing sites by Adult *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 32: 119-125.

De Castro JJ (1997). Sustainable tick and tick-borne disease control in livestock improvement in developing countries. *Vet. Parasitol.* 71: 77-97.

Evans WC (1989). Trease and Evans' Pharmacognosy. Thirteenth edition. Oxford University Press, London.

Fields PG, Xie YS, Hou X (2002). Repellent effect of pea (*Pisum sativum*) fractions against stored-product insects. *J. Stored Products Res.* 37: 359-370.

Frandin MS, Day JF (2002). Comparative efficacy of insect repellents against mosquito bites. *New Engl. J. Med.* 347: 13-18.

Gonzalez JP, Camicas JL, Cornet JP and Wilson ML (1998). Biological and clinical responses of West African sheep to Crimean-Congo haemorrhagic fever virus experimental infection. *Res. Virol.* 149: 445-455.

Hammer Ø, Harper DAT, Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, (1): 9. [http://palaeo-electronica.org/2001\\_1/past/issue1\\_01.htm](http://palaeo-electronica.org/2001_1/past/issue1_01.htm) (accessed in May 2004).

Handule IM, Ketavan C, Geb S (2002). Toxic effect of Ethiopian neem oil on larvae of cattle tick, *Rhipicephalus pulchellus* Gertaeker. *Kasetsart. Nat. Sci.* 36: 18-22.

Hoogstraal H (1979). The epidemiology of tick-borne Crimean-Congo haemorrhagic fever in Asia, Europe and Africa. *J. Med. Entomol.* 15: 307-417.

Houghton PJ, Raman A (1998). Laboratory handbook for the fractionation of natural extracts. Chapman and Hall, London.

Karraliede LD, Edwards P, Marrs TC (2003). Variables influencing the toxic response to organophosphates in humans. *Food Chem. Toxicol.* 41: 1-13.

Li AY, Davey RB, Miller RJ, George JE (2003). Resistance to Coumaphos and Diazinon in *Boophilus microplus* (Acari: Ixodidae) and evidence for the involvement of an oxidative detoxication mechanism. *J. Med. Entomol.* 40: 482-490.

Liang GM, Chen W, Liu TX (2003). Effects of three neem-based insecticides on diamondback moth (Lepidoptera: Plutellidae). *Crop Prot.* 22: 333-340.

Lukna M, Masedza C, Nyazema NZ, Curtis CF, Amairo GL (1998). Efficacy and duration of *Lippia javanica* Spreng, *Ocimum camum* Sides and a commercial repellent against *Aedes aegypti*. *Parasitol. Int.* 47: 133.

Lwande W, Ndakala AJ, Hassanali A, Moreka L, Nyandat E, Ndungu M,

- Amiani H, Gitu PM, Malonza MM, Punyua DK (1999). *Gynandropsis gynandra* essential oil and its constituents as tick (*Rhipicephalus appendiculatus*) repellents. *Phytochemistry*, 50: 401-405.
- Matlebyane MM, Ngambi JWW, Aregheore EM (2010). Indigenous knowledge (IK) ranking of available browse and grass species and some shrubs used in medicinal and ethnoveterinary practices in ruminant livestock production in Limpopo province, South Africa. *LRRD*: 22: 2010
- Pascual-Villalobos M J, Robledo A (1998). Screening for anti-insect activity in Mediterranean plants. *Ind. Crop. Prod.* 8: 183-194.
- Rajput ZI, Hu S, Chen W, Arijo AG, Xiao C (2006). Importance of ticks and their chemical and immunological control in livestock. *J. Zhejiang Univ. Sci.* 7: 912-921.
- Tapondjou AL, Adler C, Fontem DA, Bouda H, Reichmuth C (2005). Bioactivities of cymol and essential oils of *Cupressus sempervirens* and *Eucalyptus saligna* against *Sitophilus zeamais* Motschulsky and *Tribolium confusum* du Val. *J. Stored Prod. Res.* 41: 91-102.
- Thembo KM, Magano SR, Shai LJ (2010). The effects of aqueous extracts of *Senna italica* subsp *arachoides* on the feeding performance of adults of *Hyalomma marginatum rufipes*. *Afr. J. Biotechnol.* 9: 1068-1073
- Van Wyk BE, van Oudtshoorn B, Gericke N (1997). Medicinal plants of South Africa. Briza Publications, Pretoria.
- Viljoen AM, Subramoney S, van Vuuren SF, Baser KHC, Demirci B (2005). The composition, geographical variation and antimicrobial activity of *Lippia javanica* (Verbenaceae) leaf essential oils. *J. Ethnopharmacol.* 96: 271-277.
- Walker AR, Bouattour A, Camicas J-L, Estrada-Peña A, Horak IG, Latif AA, Pelgram RG, Preston PM (2003). Ticks of domestic animals in Africa: A guide to identification of species. Bioscience Reports. Edinburgh.