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An ethnobotanical survey of mosquito repellent plants in uMkhanyakude district, KwaZulu-Natal province, South Africa

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ABSTRACT

Ethnopharmacological relevance: The aim of the study was to document plants traditionally used to repel mosquitoes in the uMkhanyakude district, KwaZulu-Natal, South Africa. The specific objectives of the study were to: (1) identify plant species and their parts being used; (2) determine the condition of plant material used and the method of application.
Materials and methods: Data was collected from 60 respondents in five villages in the district using standardised and pre-tested questionnaires.
Results: Thirteen plant species are used in the study area to repel mosquitoes. These species belong to 11 genera from 9 families. Meliaceae and Anacardiaceae were the most represented families with two species each. The most frequently recorded species were *Lippia javanica* (91.67%), followed by *Aloe ferox* (11.67%), *Sclerocarya birrea* (5%), *Melia azedarach* (3%), *Balanite maughamii* (3%) and *Mangifera indica* (3%). Leaves were the most (38%) common plant part used. The majority (82%) of the plant parts were used in a dry state. Burning of plant materials to make smoke was the most (92%) common method of application. Nine plant species, namely: *A. ferox*, *Calausena anista*, *Croton menyharthii*, *S. birrea*, *B. maughamii*, *Olax dissitiflora*, *Trichilia emetic*, *M. indica*, and *Atalaya alata* are documented for the first time as mosquito repellents.
Conclusion: This documentation provides the basis for further studies in developing new, effective, safe and affordable plant-derived mosquito repellents especially for Africa where malaria is highly prevalent. The study also plays a part in documenting and conserving traditional knowledge of mosquito repellent plants for future use.

1. Introduction

Mosquitoes constitute a major public health problem as they serve as vector of serious human diseases such as malaria, filariasis, Japanese encephalitis, dengue fever, and yellow fever. Mosquito-transmitted diseases remain a major source of illness and death worldwide, particularly in tropical and subtropical countries (Becker et al., 2003). Mosquitoes alone transmit diseases to more than 700 million people annually (Taubes, 2000). Among these, malaria is the most important, affecting 300–500 million people and killing over 1 million persons annually throughout the world (Snow et al., 2005). About 90% of deaths occur in sub-Saharan Africa, mostly children under 5 years old (Skinner-Adams et al., 2008). Malaria is transmitted by female mosquitoes of the genus *Anopheles* (Gosoniu et al., 2009).

Despite significant efforts to control malaria in South Africa since 1930 (Blumberg and Frean, 2007), the disease remains a serious health problem (Maharaj et al., 2005). An estimated 4.3 million people are at risk of contracting malaria (Blumberg and Frean, 2007). In 2000, the highest number (61,934) of malaria cases were reported, the worst levels of malaria recorded since the epidemics of the 1930s (DOH, 2007). In South Africa, malaria is currently confined to the low-altitude regions of Limpopo, Mpumalanga and KwaZulu-Natal provinces, in the north-eastern part of the country, along the border with Mozambique and Swaziland (Coleman et al., 2008; Gerritsen et al., 2008; Pillay et al., 2008). Malaria transmission in South Africa is distinctly seasonal (Gerritsen et al., 2008; Pillay et al., 2008), with *Anopheles arabiensis* being the major vector (Maharaj et al., 2005). Repellents play an important role in preventing the transmission of vector-borne diseases by minimizing the contact between humans and vectors (Pitasawat et al., 2003; Das et al., 2003). The most common mosquito repellent formulation available on the market contain DEET (N,N-diethyl-3-methylbenzanmide), which has shown excellent repellence against

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mosquitoes and other biting insects (Walker et al., 1996). However, side effects after the application of DEET vary from mild to severe, it has an unpleasant smell, oily feel and high skin penetration, and it can dissolve plastic and synthetic rubber (Qui et al., 1998). These effects highlight the urgent need for development of new, effective, safe, and eco-friendly repellents.

Plants may be an alternative source of mosquito repellent agents because they constitute a rich source of bioactive chemicals (Kim et al., 2002). Plant products have been used traditionally to repel or kill mosquitoes in many parts of the world (Seyoum et al., 2003). The repellent properties of plants to mosquitoes and insects were well known before the advent of synthetic chemicals (Karunamoorthi et al., 2008). Plant-derived repellents usually do not pose hazards of toxicity to humans and domestic animals and are easily bio-graded. Compared to synthetic compounds, natural products are presumed to be safer for human use (Sharma et al., 1993; Sharma and Ansari, 1994). Moreover, in contrast with synthetic repellents, natural products are usually simple, cost effective and accessible to communities with minimal external input (Seyoum et al., 2002; Yarnell and Abascal, 2004).

The use of traditional repellents is widespread in different cultures and communities of Africa and beyond (Seyoum et al., 2002). Different communities use different plants in various forms to protect themselves against mosquitoes and other insect bites (Hebbalkar et al., 1992). The knowledge and usage customs of the repellent plants has been passed from one generation to another chiefly through word of mouth (Karunamoorthi et al., 2009a). Although there is widespread use of plants as mosquito repellents, scientific understanding of these plants is, however, largely unexplored and therefore there is a need to collect ethnobotanical information on these plants as a first step prior to evaluation of their efficacy and safety as mosquito repellents. In South Africa, ethnobotanical study of mosquito repellent plants has been conducted in Mpumalanga province (Govere et al., 2000). To the best of our knowledge, however, there has been no study in the KwaZulu-Natal province. Comprehensive data on mosquito repellent plants as well as information on efficacy and safety is lacking. The present study therefore was conducted to document plants that are used to repel mosquitoes in the uMkhanyakude district, KwaZulu-Natal province, South Africa. The specific objectives of the study were to: (1) identify plant species and their parts being used; (2) determine the condition of plant material used and the method of application.

2. Materials and methods

2.1. Study area

The study was carried out in five rural villages, namely; Mbadleni, Ndumu, iziPhosheni, Makhanisi and Mziki in the uMkhanyakude district, KwaZulu-Natal province, South Africa. The district is located in the north-eastern part of KwaZulu-Natal, sharing a boundary with Mozambique in the north, Swaziland in the north-west and the Indian Ocean in the east (Fig. 1). Named after the uMkhanyakude Tree (*Acacia xanthophyllous*, Fever Tree which translated to English means "the light in the distance"), the district covers a total land area of approximately 13,859 km^2. The population of uMkhanyakude district is estimated to be 573,341. The population consist of 45.2% male and 54.8% female (Statistic South Africa Census, 2001). The major ethnic group in the district is the Zulu. Most of the area is rural, with the majority of people depending on subsistence agriculture and animal husbandry as sources of livelihood. Malaria is one of the leading causes of morbidity and mortality in the study area. Of 4193 malaria cases reported in the 2003/2004 transmission season in KwaZulu-Natal province, 43% were from uMkhanyakude district (DOH, 2007). With the majority of people being too poor to afford commercial repellents, they use plant materials to protect themselves from mosquito bites.

Fig. 1. Map of South Africa showing uMkhanyakude district within KwaZulu-Natal province and villages visited.

2.2. Data collection

The study was undertaken as a descriptive cross-sectional survey between April and May 2011. Before conducting this survey, the leadership of each village was consulted in order to gain their trust and help to identify respondents. Data was collected using a standardised and pre-tested structured questionnaire. In each village, the questionnaire was administered to 12 respondents. One local person conversant with the language and culture of the area, and identified by the leadership of each village was recruited to help locate the selected respondents and to introduce the investigators to them. To ensure clarity and accuracy, questions prepared in English were translated into isiZulu, the principal language spoken in the study area. The questionnaire collected locality, sociodemographic data, knowledge of malaria and prevention practices, vernacular plant names, plant parts used, condition of the plant material (dried or fresh), and methods of application. All plant species mentioned by the respondent were collected with the help of traditional healers and the voucher specimens were deposited at the Bews Herbarium, School of Biological and Conservation Sciences, University of KwaZulu-Natal, Pietermaritzburg Campus. The plants were identified by Dr. C. Potgieter of this Herbarium. Collected data were double entered into EpiData version 3.1 and analyzed using STATA version 11.

2.3. Ethical consideration

Ethics clearance for this study was obtained from the Humanities and Social Sciences Research Ethics Committee, University of KwaZulu-Natal (Reference number: HSS/0098/011D). Ahead of data collection, the aim and the objectives of the study were clearly explained and informed consent was obtained from each respondent. Participation in this study was entirely voluntary and participants were assured that they could withdraw at any time without any consequences.

Table 1
Socio-demographic characteristics of respondents in villages visited in the uMkhanyakude district, north-eastern KwaZulu-Natal province, South Africa.

Characteristics	*n*	%
Gender		
Male	34	56.67
Female	26	43.33
Age		
26–35	6	10
36–45	18	30
46–55	14	23.33
56–65	11	18.33
66–75	8	13.33
≥76	3	5
Relationship to household head		
Head of household	37	61.67
Spouse	18	30
Children	5	8.33
Highest level of education attained		
No education	37	61.67
Primary	9	15.00
Secondary	11	18.33
Abet	2	3.33
Post matric	1	1.67
Occupation		
Unemployed	18	30.00
Civil servant	10	16.67
Pensioner	9	15.00
Traditional healer	17	28.33
Other	6	10.00

3. Results

3.1. Socio-demographic characteristics of respondents

All selected respondents in each village were interviewed during this survey, yielding a response rate of 100%. Table 1 is showing demographic characteristics of respondents. Most (61.7%) of the respondents interviewed were heading households. Of the sixty respondents, 56.7% were male and 43.3% were female. Their ages ranged from 26 to 78 years with a mean of 52 ± 13.3 years. The majority (61.7%) of the respondents were illiterate, while 15.00, 18.33, 3.33, and 1.67% had attained primary, secondary, abet and post matric education, respectively. About 30% of the respondents were unemployed.

3.2. Knowledge of malaria and its prevention measures

Malaria is locally known as "Malaleveve", meaning malaria fever. Most respondents (95%) associated malaria transmission with mosquito bites. However, few thought that water swamps were responsible for transmitting malaria. All respondents mentioned that malaria transmission can be prevented. Repellents was the most (98%, $n = 59/60$) mentioned prevention measure, followed by bed-nets (65%, 39/60), indoor residual spraying (25%, 15/60), and creating a clean environment (15%, 9/60). uMkhanyakude district is one of the major malaria endemic areas in KwaZulu-Natal; therefore high numbers of community members have good knowledge of malaria and its prevention measures. Table 2 illustrates the respondents' knowledge about malaria and prevention measures that can be used.

3.3. Plant species used for repelling mosquitoes

All respondents knew/used plant materials to repel mosquitoes. Seventy percent of the respondents obtained knowledge of repellent plants from their family elders while 30% got it from their ancestors (they are traditional healers). Knowledge of traditional medicines accumulated over a long time is transmitted from one generation to another through oral communication (WHO, 2000). The reasons for using plants as repellents were that they were cost-free and accessible. The use of traditional medicines is prevalent in regions where western medicines are inaccessible due to their unavailability and high cost (Light et al., 2005).

Table 2
Respondents' knowledge of malaria and its prevention measures in villages visited in the uMkhanyakude district, north-eastern KwaZulu-Natal province, South Africa.

Variable	*N*	%
Mode of malaria transmission		
Mosquitoes	57	95
Water swamps	3	5
Prevention measures		
Using IRS	15	25
Using repellents	59	98.33
Chemoprophylaxis	2	3.33
Using bed nets	39	65
Other	2	3

The survey documented 13 plant species which were used to repel mosquitoes by the local inhabitants in the study area; 2 of these plants remain to be identified (Table 3). The identified plant species belong to 11 genera in 9 families. Among these families, Meliaceae and Anacardiaceae were most represented with two species each. Pålsson and Jaenson (1999) reported that 8 plant species belonging to 8 genera and 6 families were being used to repel mosquitoes in Guinea Bissau. In a similar study, 5 plant species belonging to 4 genera and 4 families were identified in Tanzania (Kweka et al., 2008). Karunamoorthi et al. (2009a), in Ethiopia documented 9 mosquito repellent plants belonging to 8 genera and families. The family Meliaceae was represented in all of these studies, indicating its importance as a source of mosquito repellents.

The most frequently mentioned mosquito repellent plants were *Lippia javanica* (91.67%, $n = 55/60$), followed by *Aloe ferox* (11.67%, $n = 7/60$), *Sclerocarya birrea* (5%, $n = 3/60$), *Melia azedarach*, *Balanite maughamii* and *Mangifera indica* (3%, $n = 2/60$). The use of *L. javanica* as mosquito repellents has also been reported in Mpumalanga province, South Africa (Govere et al., 2000) and Zimbabwe (Lukwa et al., 1999) and was found to have repellent activity. In a recent study, Karunamoorthi et al. (2009a) reported that *M. azedarach* was among the most frequently cited plant species used by the Oromo ethnic group to repel mosquitoes in Ethiopia. However, to the best of our knowledge, 9 plant species, namely, *Aloe ferox*, *Calausena anista*, *Croton menyharthii*, *Sclerocarya birrea*, *Balanite maughamii*, *Olax dissitiflora*, *Trichilia emetic*, *Mangifera indica*, and *Atalaya alata* are documented for the first time as mosquito repellents.

3.4. Plant parts used, state of plant material and method of application

The majority (69.2%) of plants used were trees, while 30.8% were shrubs. Leaves were the most (39%) common plant part used in repelling mosquitoes. Similar to the results of this study, leaves were the most common plant parts used to repel mosquitoes in Addis Zemen town, North Western Ethiopia (Karunamoorthi et al., 2009b). Other plant parts used were roots, bark and seeds (Fig. 2). Interesting is that leaves are frequently used. Harvesting roots and bark can threaten local plant populations unless a sustainable harvesting strategy is developed (Cunningham, 2001).

The majority (82%) of plant parts were dried before use. The exception being leaves of *L. javanica*, *C. anista*, *M. azedarach*, *C. menyharthii* and *A. ferox* which are used in a fresh state. Burning of plant materials to make smoke was the most (92%) common method of application. Similar results were reported in Ethiopia (Karunamoorthi et al., 2009a,b) and Guinea Bissau (Pålsson and Jaenson, 1999). Smoke is a most widely used method of repelling

Table 3
Plant species used to repel mosquitoes in villages visited in the uMkhanyakude district, KwaZulu-Natal province, South Africa.

Family	Species (voucher specimen number)	Local name (isiZulu)	Frequency	%	Habit	Plant part	State	Method of application
Aloaceae	*Aloe ferox* Mill. (EM08)	iNhlaba	7	11.67	Shrub	Leaves	Fresh	Smoke
Anacardiaceae	*Mangifera indica* L. (EM11)	Umango	2	3.33	Tree	Seeds	Dried	Smoke
Anacardiaceae	*Sclerocarya birrea* (A.Rich.) Hochst. (EM10)	Muganu	3	5.00	Tree	Seeds	Dried	Smoke
Balanitaceae	*Balanites maughamii* Sprague. (EM09)	uGobendlovu	2	3.33	Tree	Bark	Dried	Smoke
Euphorbiaceae	*Croton menyarthii* Pax (EM05)	Hubeshani	1	1.67	Shrub	Leaves	Fresh	Smoke
Meliaceae	*Melia azedarach* L. (EM01)	Umsilinga	2	3.33	Tree	Leaves	Fresh	Smoke
Meliaceae	*Trichilia emetica* Vahl (EM06)	Umkhuhlu	1	1.67	Tree	Seeds	Dried	Smoke
Olacaceae	*Olax dissitiflora* Oliver (EM04)	Mampuzane	1	1.67	Shrub	Bark	Dried	Smoke
Rutaceae	*Clausena anisata* (Willd.) Hook. f. (EM02)	Umsanga	1	1.67	Tree	Leaves	Fresh	Hanging
Sapindaceae	*Atalaya alata* (Sim) H.H.L. Forbes (EM07)	Umnondo	1	1.67	Tree	Roots	Dried	Smoke
Unidentified		Umuzaneno	1	1.67	Shrub	Roots	Dried	Smoke
Unidentified		Khokhelo	1	1.67	Tree	Roots	Dried	Smoke
Verbanaceae	*Lippia javanica* (Brum.f) Spreng. (EM03)	Umsuzwane	55	91.67	Shrub	Leaves	Fresh	Smoke

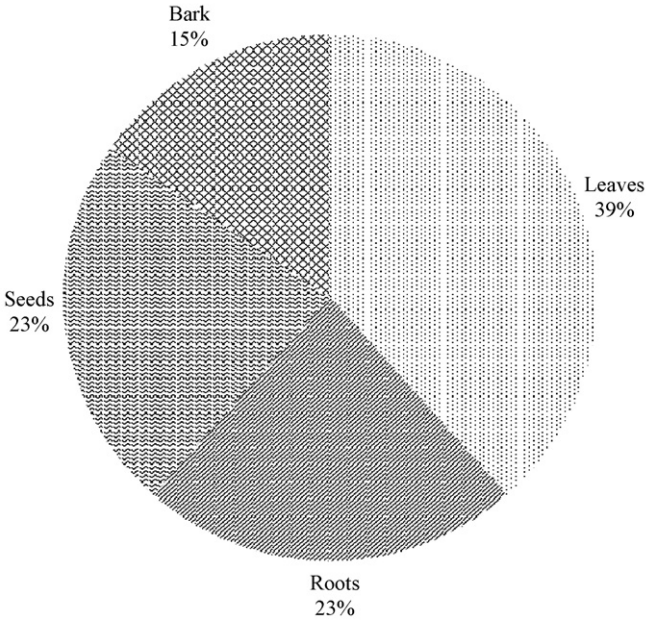

Fig. 2. Percentage of plant parts used to repel mosquitoes in villages visited in the uMkhanyakude district, north-eastern KwaZulu-Natal province, South Africa.

biting insects throughout the world (Karunamoorthi et al., 2008). The burning of some herbs such as *Artemisia* (Asteraceae) and *Calmus* species in rural areas in China is used to repel mosquitoes and protect cattle from blood sucking insects (Hwang et al., 1985). Smoke produced by burning dried leaves of *Azandirachta indica* has been used to repel mosquitoes since ancient times (Sukumar et al., 1991). Hanging plants inside the house or sprinkling leaves on the floor is another method used (Sangat-Roemantyo, 1990). In our findings, leaves of *C. anista* were the only plant part used for hanging inside the house. In East Africa, Lua communities lay the branches of *Ocimum basilicum* (Labiatae) inside the house to drive away mosquitoes (Kokwaro, 1976).

4. Conclusion

The present study shows that people of uMkhanyakude district use plant materials to repel mosquitoes. Plant materials were commonly used because they are cost-free and easily accessible. Thirteen plant species were documented and 9 of them are documented for first time as mosquito repellents. This documentation will provide the basis for further studies in developing new, effective, safe and affordable plant-derived mosquito repellents especially for Africa where malaria is highly prevalent. Knowledge of traditional medicines is passed from one generation to another by oral communication, posing the danger of losing this tradition practice because of no documentation. This study will therefore play an important role in documenting and conserving traditional knowledge of mosquito repellent plants for future use.

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References

Becker, N., Petrić, D., Zgomba, M., 2003. Mosquitoes and Their Control. Kluwer Academic/Plenum Publishers, New York.
Blumberg, L., Frean, J., 2007. Malaria control in South Africa – challenges and successes. South African Medical Journal 97, 1193–1197.
Coleman, M., Coleman, M., Mabuza, A.M., Kok, G., Coetzee, M., Durrheim, D., 2008. Evaluation of an operational malaria outbreak identification and response system in Mpumalanga province, South Africa. Malaria Journal 7, 69.
Cunningham, A.B., 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan Publishers Limited, London.
Das, N.G., Baruah, I., Talukdar, P.K., Das, S.C., 2003. Evaluation of botanicals as repellents against mosquitoes. Journal of Vector Borne Diseases 40, 49–53.
DOH., 2007. Prevalence and distribution of malaria in South Africa, 2007 Annual Report, Department of Health, South Africa.
Gerritsen, A.A.M., Kruger, P., Van der Loeff, M.F.S., Grobusch, M.P., 2008. Malaria incidence in Limpopo Province, South Africa, 1998–2007. Malaria Journal 7, 162.
Gosoniu, L., Vounatsou, P., Sogoba, N., Maire, N., Smith, T., 2009. Mapping malaria risk in West Africa using Bayesian nonparametric non-stationary model. Computational Statistics and Data Analysis 53, 3358–3371.
Govere, J., Durrheim, D.N., Du Toit, N., Hunt, R.H., Coetzee, M., 2000. Local plants as repellents against *Anopheles arabiensis*, in Mpumalanga Province, South Africa. Central African Journal of Medicine 46, 213–216.
Hebbalkar, D.S., Hebbalkar, G.D., Sharma, R.N., Joshi, V.S., Bhat, V.S., 1992. Mosquito repellent activity of oils from *Vitex negundo* Linn. leaves. Indian Journal of Medical Research 95, 200–203.
Hwang, Y.S.M., Wu, K.H., Kumamato, J., Akerlord, J., Mulla, M.S., 1985. Isolation and identification of mosquito repellent in *Artemisia vulgaris*. Journal of Chemical Ecology 11, 1297.
Karunamoorthi, K., Mulelam, A., Wassie, F., 2008. Laboratory evaluation of traditional insect/mosquito repellent plants against *Anopheles arabiensis*, the predominant malaria vector in Ethiopia. Parasitology Research 103, 529–534.
Karunamoorthi, K., Ilango, K., Endale, A., 2009a. Ethnobotanical survey of knowledge and usage custom of traditional insect/mosquito repellent plants among the Ethiopian Oromo ethnic group. Journal of Ethnopharmacology 125, 224–229.
Karunamoorthi, K., Mulelam, A., Wassie, F., 2009b. Assessment of knowledge and usage custom of traditional insect/mosquito repellent plants in Addis Zemen Town, South Gonder, North Western Ethiopia. Journal of Ethnopharmacology 121, 49–53.
Kim, D.H., Kim, S.I., Chang, K.S., Ahn, Y.J., 2002. Repellent activity of constituents identified in *Foeniculum vulgare* fruit against *Ades aegypti* (Diptera: Culcidae). Journal of Agricultural and Food Chemistry 50, 6993–6996.

Kokwaro, J.O., 1976. Medicinal Plants of East Africa. East African Literature Bureau, Nairobi.
Kweka, E.J., Mosha, F., Lowassa, A., Mahande, A.M., Kitau, J., Matowo, J., Mahande, M.J., Massenga, C.P., Tenu, F., Feston, E., Lyatuu, E.E., Mboya, M.A., Mndeme, R., Chuwa, G., Temus, E.A., 2008. Ethnobotanical study of some of mosquito repellent plants in north-eastern Tanzania. Malaria Journal 7, 152.
Light, M.E., Sparg, S.G., Stafford, G.I., Van Staden, J., 2005. Riding the wave: South Africa's contribution to ethnopharmacological research over the last 25 years. Journal of Ethnopharmacology 100, 127–130.
Lukwa, N., Nyazema, N.Z., Curtis, C.F., Mwaiko, G.L., Chandiwana, S.K., 1999. People's perceptions about malaria transmission and control using mosquito repellent plants in a locality in Zimbabwe. Central Journal of African Medicine 45, 64–68.
Maharaj, R., Mthembu, D.J., Sharp, B.L., 2005. Impact of DDT reintroduction on malaria transmission in KwaZulu-Natal. South African Medical Journal 95, 871–874.
Pålsson, K., Jaenson, T.G.T., 1999. Plant products used as mosquito repellents in Guinea Bissau, West Africa. Acta Tropica 72, 39–52.
Pillay, P., Maharaj, V.J., Smith, P.J., 2008. Investigating South African plants as a source of new antimalaria drugs. Journal of Ethnopharmacology 119, 438–454.
Pitasawat, B., Choochote, W., Tuetun, B., Tippawangkosal, P., Kanjanapothi, D., Jitpakdi, A., Riyong, D., 2003. Repellency of aromatic turmeric *Curcuma aromatica* under laboratory and field conditions. Journal of Vector Ecology 28, 234–240.
Qui, H., Jun, H.W., McCall, J.W., 1998. Pharmacokinetics, formulation, and safety of insect repellent N,N-diethyl-3-methylbenzamide (DDET): a review. Journal of American of the American Mosquito Control Association 14, 12–27.
Sangat-Roemantyo, H., 1990. Ethnobotany of *Javanese incense*. Economic Botany 44, 413–416.
Seyoum, A., Pålsson, K., Kunga, S., Kabiru, E.W., Lwande, W., Killeen, G.F., Hassanali, A., Knols, B.G.J., 2002. Traditional use of mosquito-repellent plants in western Kenya and their evaluation in semi-field experimental huts against *Anopheles gambiae*: ethnobotanical studies and application by thermal expulsion and direct burning. Transactions of the Royal Society of Tropical Medicine and Hygiene 96, 225–231.
Seyoum, A., Killeen, G.F., Kabiru, E.W., Knols, B.G., Hassanali, A., 2003. Field efficacy of thermally expelled or live potted repellent plants against African malaria vectors in western Kenya. Tropical Medicine and International Health 8, 1005–1011.
Sharma, V.P., Nagpal, B.N., Srivastava, A., 1993. Effectiveness of neem oil mats in repeling mosquitoes. Transactions of Royal Society of Tropical Medicine and Hygiene 87, 627–628.
Sharma, V.P., Ansari, M.A., 1994. Personal protection from mosquitoes (Diptera: Culicidae) by burning neem oil in kerosene. Indian Journal of Medical Entomology 31, 505–507.
Skinner-Adams, T.S., McCarthy, J.S., Gardiner, D.L., Andrews, K.T., 2008. HIV and malaria co-infection: interactions and consequences of chemotherapy. Trends in Parasitology 24, 264–270.
Snow, R.W., Guerra, C.A., Noor, A.M., Myint, H.Y., Hay, S.I., 2005. The global distribution of clinical episodes of *Plasmodium falciparum* malaria. Nature 434, 214–217.
Statistic South Africa Census, 2001. http://www.statssa.gov.za/census01/html/default.asp.
Sukumar, K., Perich, M.J., Boobar, L.R., 1991. Botanical derivatives in mosquito control: a review. Journal of American Mosquito Control Association 7, 210.
Taubes, G., 2000. Vaccines. Searching for parasites weak spot. Science 290, 434–437.
Walker, T.W., Robert, L.L., Copeland, J.I., Klein, T.A., 1996. Field evaluation of arthropod repellents, DEET and a piperidine compound, A13-37220, against *Anopheles arabiensis* in western Kenya. Journal of the American Mosquito Control Association 12, 172–176.
WHO, 2000. General Guidelines for Methodologies of Research and Evaluation of Traditional Medicine. World Health Organization, Geneva.
Yarnell, E., Abascal, K., 2004. Botanical prevention and treatment of malaria. Part1. Herbal mosquito repellents. Alternative and Complementary Therapies 10, 206–210.