Ethnobotanical knowledge and practices of pastoralist communities on plants used as repellents and/or insecticides against insect vectors in the Korahaye zone of the Somali Regional State, eastern Ethiopia

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Abstract

Background

Combined efforts to combat both outdoor and indoor transmission of malaria parasites are hampered by emerging vector resistance in a wide range of endemic malaria settings in Ethiopia and the rest of the world, stressing the need for developing and implementing alternative control measures. This study aimed to document indigenous pastoralist knowledge on the use of repellent and insecticidal plant species against insect vectors in a number of kebeles in the Somali Regional State, eastern Ethiopia.

Methods

Data were collected by interviewing a total of 120 informants (105 men and 15 women) through face-to-face interviews guided by a semistructured questionnaire, observing information on the preparation method, and performing a guided field walk with a guide to collect plant specimens. The ethnobotanical survey was carried out 5 May 2018-12 April 2019. Medicinal plant specimens were collected following a standard approach, and voucher specimens were deposited in the Jigjiga University mini herbarium. The data were analyzed using descriptive statistics, preference rankings, paired comparisons and direct matrix rankings.

Results

A total of 52 voucher specimens belonging to 47 genera and 34 families were obtained. Of these, 42 were reported to be repellents against mosquitoes or insects in general. Among the plant families recorded, Fabaceae had the highest number of plant species, 5 (9.61%). The best-represented life forms were herbs (21, 41.96%), followed by shrubs (17, 32.69%). Leaves were the most commonly used plant part for remedy preparation and accounted for 18 (33.96%) of the total plants. Among the repellent plant species documented, 57.68% were reported to be burned to produce in-house smoke, 20.37% were mashed, and the paste was applied on the body to repel insects. The plants that were commonly mentioned by respondents were *Amaranthus sparganiocephalus* (27 mentions, 22.5%), *Phytolacca dodecandra* (18, 15%), and *Commiphora rostrata* (26, 21.66%) for repellent, insecticidal, and both repellent and insecticidal uses, respectively.

Conclusion

The present study showed that pastoralist communities have valuable indigenous knowledge and practices related to the use of plants as repellents. This knowledge should be validated and confirmed experimentally and possibly promoted as a sustainable and ecosystem-friendly insect vector control tool.

Background

Mosquito-transmitted diseases, including malaria, filariasis, Japanese encephalitis, dengue and yellow fever, occur in many tropical and subtropical countries [1]. An estimated 247 million cases of malaria were reported worldwide in 84 malaria-endemic countries in 2021, up from 245 million cases in 2020. This increase was mainly observed in African nations [2]. Despite considerable efforts to control mosquito-transmitted diseases in Ethiopia, malaria is still one of the leading causes of morbidity and mortality in the country [3–6].

In resource-poor countries or communities, the use of plants with insect- or mosquito-repelling and mosquito-killing potential is a very important component of the traditional way to address disease transmission [7–9]. Communities in poor countries use insect- or mosquito-repellent plants in various forms [1, 10, 11]. For example, in northwestern Ethiopia, local communities have been utilizing smoked plant materials of *Olea europaea* subsp. *cuspidata*, *Ostostegia integrifoli*a and neem (*Azadirachta indica*) to repel insects and/or mosquitoes [12]. At a wider country level, several ethnobotanical studies have identified plants that are used to manage vectors of different parasitic infections [10, 13, 14].

Several chemical insect or mosquito repellent formulations with mild to severe side effects on human health and ecosystems are available on the market [15]. The side effects highlight the need for the development of safe but also effective, low-cost and eco-friendly products. Research has shown that various plant species are rich in a number of bioactive chemicals, showing promising results as insect- or mosquito-repelling agents in different African countries and elsewhere [1, 7]. Although the use of insect- or mosquito-repellent plants has been extensively studied in some parts of the country, the use of local plants for these purposes has been shown to be very site specific, whereas research on this topic in the Somali Regional State of Ethiopia has received very little attention [16]. Consequently, we hypothesized that new insect- or mosquito-repellent plants could be identified by documenting the knowledge of pastoralists in the malaria-endemic zone of the Somali Regional State, Ethiopia.

Therefore, the objectives of this study were to (1) identify local plant species and their parts used in the management of insects or mosquitoes and (2) assess the method of application among pastoralist communities in selected kebeles of the Somali Regional State.

Methods

Study area

An ethnobotanical survey was conducted among the residents of the Korahaye Zone, Somali Regional State, eastern Ethiopia. Its administrative center, Kebri Dahar, is located 420 km away from Jigjiga, the capital town of the Somali Regional State. The Somali ethnic group predominates (99%), and the majority of people are Muslims [17]. Korahaye is located at an average altitude of 493 m above sea level and has an average annual rainfall and temperature of approximately 700 mm and 21°C, respectively. The climate of the zone is characterized as tropical semiarid [18]. The region experiences two distinct rainy seasons, known as "Gu" (lasting from mid-April to the end of June) and "Deyr" (the second rainy season that lasts from early October to late December) [18]. Korahaye is divided into ten administrative districts. Malaria is a major public health problem in this zone. Recent studies have shown that an Asian malaria vector, *Anopheles stephesni*, was present in the region; it is most likely the urban malaria vector in the area [19, 20]. In 2017, dengue outbreaks affecting several people were also reported in the study area [21]. The disease is primarily transmitted by the *Aedes aegypti* mosquito [22].

The area is characterized by Vachellia-Commiphora woodland vegetation. The most common species included *Vachellia bussei*, *Commiphora alaticaulis*, *C. boranensis*, and *C. obovata*. Additional common families in this ecosystem include Balanitaceae, Burseraceae, Combretaceae and Fabaceae [23]. The prevalence of *Prosopis juliflora*, which is an invasive species that has expanded in the Korahaye zone of the Somali Regional State, is high, and this species has negatively affected the livelihood of pastoralists [18].

Selection of study sites and informants

Site selection

Permission was obtained from different administrative levels in the study area to conduct the study. A reconnaissance survey was performed before starting the research proper to obtain a representative picture of the study area. Eventually, a total of eight kebeles (Wechewach, Shekosh, Kebredahar, Sebedele, Dumale, Qorahele, Beyoele and Anoele) were selected from four districts, mainly based on the presence of traditional medicinal practices, recommendations by local elders and the number of traditional medicine practitioners in the kebeles; these data were obtained from health workers and ethnic leaders in the rural communities (Fig. 1).

Informant selection

A total of 120 informants (105 men and 15 women) were selected from the eight kebeles. Of these, ninety-six informants were selected randomly, whereas 24 key informants were selected purposefully based on recommendations from local people.

Ethnobotanical data collection

Ethnobotanical data were collected during three different field visit campaigns within the eight kebeles between 5 May 2018 and 12 April 2019. The data were compiled through semi-structured interviews, during guided field walks, and group discussions. The interviews used a semi-structured checklist of topics, which was prepared in English and translated to the *Somali* language. The interviews covered the following main components: (a) personal data of the respondents, e.g., name, address, age, gender and literacy status; (b) respondent knowledge of local names of the plants and parts used and the conditions of the plant parts used (fresh/dried); and (c) methods of remedy preparation and administration of the medicinal plant species. Photographic records were also taken in the field to capture field sites, plants and other useful information, such as preparation methods and storage methods (Fig. 2).

All the semi-structured interviews were followed by guided walks-in-the-forest, which allowed us to collect and identify traditionally used plants. During these guided field walks that were guided by respondents, all relevant data, including vernacular names of plants, habits and parts used, were collected. Additionally, eight group discussions (one group discussion per kebele in the district) were conducted. Voucher specimens of these medicinal plants were collected, identified and stored at the National Herbarium, Addis Ababa University. In addition, plants were identified based on taxonomic keys and various volumes of the flora of Ethiopia and Eritrea and validated using databases such as the IPNI [24] and POWO [25].

Data analysis

Informant consensus

Informants were interviewed twice on the same plant species used as insect repellents to confirm the reliability of the information. As a result, information inconsistent with previously shared information was rejected as irrelevant.

Preference ranking

Preference ranking for the seven medicinal plants used to repel mosquitoes was calculated in accordance with [26]. Five informants were selected for the preference ranking. The selected informants assigned values from 0 to 5 for the most preferred to the least preferred plant species used to repel mosquitos. The values were then summed, and ranks were assigned to each plant species.

Direct matrix ranking

Following Martin [26], we carried out direct matrix ranking to compare the multiple uses of plant species in the study area. Four key informants first identified five medicinal plant species that were used by the community for multiple

purposes, including insect or mosquito repellent use, firewood use, charcoal preparation, fodder use, and construction. Each of the selected key informants was asked to assign use values (5 = best, 4 = very good, 3 = good, 2 = less used, 1 = least used and 0 = not used). The values given by each key informant were summed and ranked.

In addition, descriptive statistics were used to summarize the data on the medicinal plants used as insect or mosquito repellents. The analysis concentrated on the most commonly used plants, their routes of application, their parts used and their habits.

Results

Sociodemographic characteristics of the informants

A total of 120 informants were interviewed. The gender distributions of the respondents were 105 (87.5%) and 15 (12.5%) for men and women, respectively. Overall, 104 (86.66%) informants were older than 31 years, whereas 16 (13.33%) were aged 18–30 years (Table 1). A total of 44 plant species were identified in respondents older than 30 years of age, while 8 were identified in younger respondents.

Table 1
Basic information on the informants in the study area

Kebele	Sex		Age range (years)		Literacy status	
	Male	Female	18–29	> 30	Illiterate	Literate
Wechewach	13	2	2	13	8	7
Shekosh zuria	14	1	0	15	11	4
Kebredahar zuria	13	2	1	14	13	2
Sebedele	13	2	6	9	8	7
Dumale	13	2	2	13	11	4
Qorahele	14	1	1	14	13	2
Beyoele	14	1	4	11	10	5
Anoele	11	4	0	15	14	1
Total	105	15	16	104	88	32

Diversity of plants used as repellents and insecticides

A total of 52 species belonging to 47 genera and 34 families were reported to have insect- or mosquito-repelling or insecticidal activities against insect vectors for tropical diseases. As an insecticides, communities of Korahaye zone use plant species to kill harmful insects. The most highly represented family was Fabaceae, which included five species. Three families (Burseraceae, Euphorbiaceae and Solanaceae), two families (Amaranthaceae and Lamiaceae), and one family (Asteraceae) were represented by four, three and two species, respectively, whereas the 27 remaining families had only a single species. Among these, 35 (67.30%) repellent and 10 (19.23%) insecticidal species and 7 (13.46%) repellent and insecticide species were documented (Appendix 1).

Insect- or mosquito-repellent and insecticide plant life forms

Most of the repellent and insecticide plants in the study area were herbal (21, 41.96%) species (Fig. 3).

Plant parts used as repellents and insecticides

Herbal remedies can be prepared from either freshly collected or dry plant samples. Although different plant parts were shown to be useful for remedy preparation, leaves were the most commonly used plant part for remedy preparation (18 species, 33.96%), followed by roots (7,13.20%) (Table 2).

Table 2
Frequencies of insect- or mosquito-repellent and insecticide plant parts used

Plants parts	Frequency	% of total
Leaves	18	33.96
Roots	7	13.20
Gum/Resin	6	11.32
Whole plant	4	7.54
Seeds	2	3.77
Roots and Stems	2	3.77
Bark	2	3.77
Others	12	22.56
Total	**53**	**100**

Method of application of insect or mosquito repellents

In the study area, smoking was the main method applied to 30 (57.68%) preparations, followed by rubbing the body to repel insects (11, 20.37%), as indicated in Table 3. The plant species were either fresh or dried form. The findings of the study indicated that in the study area, 43 species (90.90%) were used in fresh form and 9 (9.09%) were dry in form.

Table 3
Method of application of plant remedies

Route of Administration	Number	% of total
Burnt to produce in-house smokes	30	57.68
Rubbing the paste	11	20.37
Bathing	6	11.11
Others	7	12.95
Total	54	100

Most important repellent and insecticide plants

Informant consensus

Informant consensus results are useful in prioritizing plants for further studies. Among the species reported here, *Amaranthus sparganiocephalus* took the lead, where it was cited by 27 (22.5%) informants, followed by *Euploca rariflora* and *Senna italica* (24, 20%) for their mosquito- or insect-repellent use. On the other hand, *Phytolacca dodecandra* was cited by 18 (15%), followed by *Carica papaya* 16 (13.33%) for its use as an insecticide. The informants reported

Commiphora rostrata (26, 21.66% of the informants), *Aloe* spp. and *Cyphostemma niveum* (cited by 25 (20.83%) and 24 (15.89%) informants) for their use as repellents and insecticides, respectively (Table 4).

Table 4
Consensus values for plant species used as insecticides, repellents and both repellents and insecticides

Scientific name	No. of informants reporting insect repellent use		No. of informants reporting insecticide use		Both insect repellent and insecticide use	
	Number	% of total	Number	% of total	Number	% of total
Abutilon figarianum	20	16.66	-	-	-	-
Momordica spinosa	2	1.66	-	-	-	-
Allium sativum	11	9.16	-	-	-	-
Aloe spp.	-	-	-	-	25	20.83
Amaranthus caudatus	5	4.16	-	-	-	-
A. palmeri	5	4.16	-	-	-	-
A. sparganiocephalus	27	22.5	-	-	-	-
Asparagus africanus	5	4.16	-	-	-	-
Balanites rotundifolia	3	2.5	-	-	-	-
Boswellia rivae	-	-	-	-	19	15.83
Brucea antidysenterica	9	7.5	-	-	-	-
Cadaba glandulosa	-	-	-	-	21	17.5
Calotropis procera	-	-	14	11.66	-	-
Calpurnia aurea	2	1.66	-	-	-	-
Carica papaya	-	-	16	13.33	-	-
Rotheca myricoides	-	-	-	-	13	10.83
Combretum pisoniiflorum	7	5.83	-	-	-	-
Commelina latifolia	12	10	-	-	-	-
Commiphora kataf	19	15.83	-	-	-	-
C. myrrha	-	-	-	-	23	19.16
C. rostrata	-	-	-	-	26	21.66
Croton macrostachyus	11	9.16	-	-	-	-
Cucumis prophetarum	17	14.16	-	-	-	-
Cyphostemma niveum	-	-	-	-	24	15.89
Datura stramonium	-	-	4	4.39	-	-
Alantsilodendron pilosum	4	1.14	-	-	-	-
Dodonaea viscosa subsp. *angustifolia*	10	2.86	-	-	-	-
Euphorbia tirucalli	7	5.83	-	-	-	-

Scientific name	No. of informants reporting insect repellent use		No. of informants reporting insecticide use		Both insect repellent and insecticide use	
	Number	% of total	Number	% of total	Number	% of total
Foeniculum vulgare	17	14.16	-	-	-	-
Gladiolus candidus	8	6.66	-	-	-	-
Euploca rariflora	24	20	-	-	-	-
Indigofera articulata	13	10.83	-	-	-	-
Jatropha curcas	-	-	5	4.16	-	-
Laggera tomentosa	6	5	-	-	-	-
Leucas neuflizeana	3	2.5	-	-	-	-
Melia azedarach	16	13.33	-	-	-	-
Moringa stenopetala	-	-	8	6.66	-	-
Ocimum forskolei	-	-	9	7.55	-	-
Opuntia ficus-indica	11	9.16	-	-	-	-
Phytolacca dodecandra	=	-	18	15	-	-
Pluchea somaliensis	5	4.16	-	-	-	-
Ricinus communis	=	-	9	7.5	-	-
Ruta chalepensis	6	5	-	-	-	-
Schinus molle	4	3.33	-	-	-	-
Senna alexandrina	19	15.83	-	-	-	-
S. italic	24	6.87	-	-	-	-
Solanum somalense	=	-	4	4.39	-	-
Tamarindus indica	3	2.5	=	-	-	-
Verbascum sinaiticum	3	2.5	=	-	-	-
Withania somnifera	3	2.5	=	-	-	-
Xanthium spinosum	-	-	4	4.39	-	-
Ziziphus mauritiana	8	6.66	-	-	-	-

Ranking of repellent and insecticide plants

Preference ranking of plants used as repellents

The informants mentioned seven medicinal plants that effectively repel mosquitoes. Five informants ranked the seven plant species based on their perception of effectiveness. The highest value (5) was assigned to the plants considered the most effective, whereas the lowest value (1) was assigned to the least effective medicinal plants. Accordingly, *Amaranthus sparganiocephalus* was the most-preferred medicinal plant for controlling mosquitoes, and *Gladiolus candidus* was the least-preferred medicinal plant (Table 5).

Table 5
Preference ranking of seven medicinal plants for repelling mosquitoes

Respondents	Mosquito Repellent plants						
	Commiphora myrrha	*Senna italic*	*Amaranthus sparganiocephalus*	*Commiphora kataf*	*Melia azedaarch*	*Allium sativum*	*Gladiolus candidus*
I_1	2	1	5	4	1	4	1
I_2	3	2	3	4	2	3	2
I_3	4	1	3	2	3	1	1
I_4	3	3	5	1	2	1	2
I_5	3	1	1	1	1	1	1
Total	14	8	17	12	9	10	7
Rank	2nd	6th	1st	3rd	5th	4th	7th

Preference ranking of plants used to kill insects

Preference ranking of five medicinal plants used to kill mosquitoes in the study area (Table 6) revealed that *Commiphora rostrata* ranked first followed by *Aloe* spp. The least-preferred plant species was *Ricinus communis*.

Table 6
Preference ranking of five insecticide plants against malaria insect vectors in the study area

Respondents Labeled 1–5	Insecticide plants				
	Aloe spp.	*Commiphora rostrata*	*Phytolacca dodecandra*	*Ricinus communis*	*Calotropis procera*
I_1	4	5	1	0	3
I_2	3	4	5	2	0
I_3	3	3	4	1	2
I_4	5	4	0	1	2
I_5	3	5	4	1	2
Total	18	21	14	5	9
Rank	2nd	1st	3rd	5th	4th

Direct matrix ranking

A direct matrix ranking of five commonly reported multipurpose plant species for five use categories based on the information collected from four informants showed that *Ziziphus mauritiana* ranked first and hence is the most-preferred plant in the study area for various uses (Table 7).

Table 7
Direct matrix ranking of five plant species by four informants based on five use criteria (5 = best; 4 = very good; 3 = good; 2 = less used; 1 = least used and 0 = no use)

Use category	Medicinal plants				
	Melia azedarch	*Ziziphus mauritiana*	*Calpurnia aurea*	*Schinus molle*	*Commiphora myrrha*
Repellent	7	10	12	3	14
Firewood	19	14	13	9	6
Charcoal	2	16	3	10	1
Construction	8	17	13	5	12
Fodder	6	8	9	3	5
Total	42	65	50	30	38
Rank	3rd	1st	2nd	5th	4th

Discussion

Indigenous people elsewhere in the world have traditionally utilized natural insecticides and repellents against host-seeking mosquitoes, which have helped them treat malaria and other vector-borne illnesses. These practices date back many generations. The development of new natural products can benefit greatly from the knowledge of traditional insect or mosquito repellent and insecticide plants acquired via ethnobotanical studies. Plant species are used as repellents and insecticides in different parts of Ethiopia [14, 13, 27, 28] and in other African nations [29–32].

Fifty-two plant species were documented to be used by local people in the Korahaye zone as insect or mosquito repellents. Compared to similar studies carried out in Ethiopia, a greater number of plant species utilized as insect or mosquito repellents were identified in the study area. For instance, [27] reported that people of the Badiye kebele in the Western Hararghe zone use thirteen plant species as repellents. Twenty-two plant species were mentioned as repellents in the Bechobore Kebele, Jimma zone [13]. Thirty-five plants were recorded in the Raya Azebo district of Tigray [14], nine in the Kofe kebele of the Jimma zone [12], eight in the Jabitehnan District, West Gojjam zone [33] and fifteen in the Addis Zemen town of southern Gonder [34]. The number of medicinal plants reported as insect or mosquito repellent and/or insecticide by the local people in the study area indicates the depth of the local indigenous knowledge on the medicinal plants and their applications.

Here, the family with the greatest number of species was Fabaceae. Likewise, studies conducted elsewhere in Ethiopia [14], Cameroon [31] and Nigeria [35] showed relatively greater numbers of insect- or mosquito- repellent and/or insecticide-related plant families of the Fabaceae. This finding contradicts other findings showing that the Asteraceae family consistently produces a large number of plant species in different parts of Ethiopia [36, 37] and elsewhere [32]. Solanaceae and Lamiaceae were reported to be the highest contributors to insect or mosquito repellent plants in the Assam district of India [38]. In a review compiled by Meragiaw and Asfaw in Ethiopia [39], the Asteraceae and Lamiaceae families were found to have the greatest number of species represented as insect or mosquito repellents. These findings are reasonable since the indicated families are represented by more species in the Ethiopian flora [40, 41].

According to the current study, out of the species evidenced as insect or mosquito repellents and/or insecticides, the majority of the plants were herbs, accounting for 21 (41.96%) species. This may be related to the fact that there are significantly more species of herbs in the study area than there are woody plant species and that they are easier to

collect than trees and shrubs. These findings are in line with studies conducted in Ethiopia [14, 33] and India [38] in the sense that herbs are the greatest contributors to insect or mosquito repellent and/or insecticide plants. However, these findings contrast with those of a review performed in Ethiopia, where shrubs were reported as the most common growth form of insect repellents [39]. A study conducted in Cameroon [31] and Nigeria [35] showed that trees were the most widely used life form for the preparation of insect repellent remedies.

The most widely used plant parts in the Korahaye zone were leaves. Our results were consistent with previous studies reporting leaves as a major medicinal plant part [9, 28, 31, 32, 35, 38, 42, 43]. The widespread use of leaves by local communities in the Korahaye zone may be due to the easy access to their active ingredients [39, 44]. Another explanation might be that leaves serve as the principal site for photosynthetic and other biosynthetic processes in plants, which results in the production and accumulation of photosynthates, which have higher concentrations of bioactive molecules such as tannins and alkaloids with a variety of therapeutic uses [45, 46]. Other studies on similar aspects have shown that the root is the most commonly used plant part for repelling insects or mosquitos [14]. The frequent use of roots for repelling insects or mosquitoes may have a detrimental impact on plant species; thus, a wise approach to the collection or conservation of such medicinal plants is vital [14, 47].

The plant species documented in the study area are also used for the same purposes as insect or mosquito repellents in Ethiopia [12–14, 27] and other parts of the world [8, 32, 38]. The plants *Allium sativum, Asparagus africanus*, *Calpurnia aurea*, and *Datura stramonium* are among the species used for insect repellency and insecticidal in other parts of the world (Table 8).

Table 8
Medicinal plants used as repellents and insecticides other than those in the study area

Scientific name	Vernacular names	Used for		References	Study area
		Repellent	Insecticidal		
Allium sativum	Saeda shegurti (Tigrinya) Qullubbii Adii (Oromic) Nech shinkurt (Amharic)	X	X	[13, 14, 33, 48]	Raya Azebo, Ethiopia Jimma, Ethiopia Jabitehnan, Ethiopia Sasiga, Ethiopia
Asparagus africanus	Qasta ansto (Tigrinya)	X		[14, 39]	Raya Azebo, Ethiopia
Boswellia rivae	Etan (Amharic)	X		[12]	Jimma, Ethiopia
Brucea antidysenterica	Waginos (Amharic)	X		[34]	Addis Zemen, Ethiopia
Calpurnia aurea	Cherenchah (Tigrinya) Liyita (Amharic) Ceekataa (Oromic)	X	X	[14, 33, 49, 50]	Raya Azebo, Ethiopia Jabitehnan, Ethiopia Kolla Tenben, Ethiopia Akaki, Ethiopia
Carica papaya	Papaya	X	X	[9, 13, 33]	Jimma, Ethiopia Jabitehnan, Ethiopia Uganda
Croton macrostachyus	Bisana (Amharic), Bakkannisa (Oromic)	X		[12, 13, 27, 51]	Jimma, Ethiopia Harar, Ethiopia
Datura stramonium	Ats-Faris (Amharic)	X		[34, 38]	Addis Zemen, Ethiopia Fringe Villages, India
Dodonaea viscosa subsp. *angustifolia*	Kitkita (Amharic)		X	[33, 50]	Jabitehnan, Ethiopia Kolla Tenben, Ethiopia
Laggera tomentosa	Alashume (Amharic)		X	[36]	Dalenta, Ethiopia

Scientific name	Vernacular names	Used for		References	Study area
		Repellent	Insecticidal		
Melia azedarach	Lin (Tigrinya), Neem (Amharic)	X	X	[12, 14, 33, 50]	Raya Azebo, Ethiopia Jimma, Ethiopia Kolla Tenben, Ethiopia
Ocimum forskolei	Marba (Kunama)	X		[8]	Eritrea
Opuntia ficus-indica	Shookaa (Oromic)		X	[52]	Gimbi, Ethiopia
Phytolacca dodecandra	Endod (Amharic) Andoodee (Oromic)	X	X	[33, 34, 32, 53]	Jabitehnan, Ethiopia Addiz Zemen, Ethiopia Sasiga, Ethiopia Burundi
Ricinus communis	Qobboo (Oromic) Gulo (Amharic)	X		[13, 34, 49, 53]	Addis Zemen, Ethiopia Fiche, Ethiopia Akaki, Ethiopia Jimma, Ethiopia
Ruta chalepensis	Chena adam (Tigrinya) Cilaaddaama (Oromic)	X		[14, 49]	Akaki, Ethiopia, Raya Azebo, Ethiopia
Schinus molle	Qundu-berbere			[54]	Ethiopia
Verbascum sinaiticum	Gur-harree (Oromic)	X		[55]	Horoguduru, Ethiopia
Withania somnifera	Gulho (Tigrinya)	X		[14]	Raya Azebo, Ethiopia

Our results showed that local inhabitants have knowledge about the mosquito repellent property of a number of plants and their use. Most of the plants recorded (57.68%) were reported to be burned to produce smoke inside the house, aligning with the claims of Palsson and Jaenson [56], who indicated that burning plants might be effective at repelling insects. Similar results were obtained elsewhere in Ethiopia, Burundi and Tanzania, supporting this approach across communities as consistent with driving away mosquitoes [32, 43, 50]. Biran et al. [57] reported mixed evidence, especially for the use of firewood smoke to protect against mosquitoes. The repellent activity of burned plants appears to be caused by the release of certain volatile compounds, which are either present in fresh or dried plants or created during the combustion process [57, 58]. Certain compounds, such as ß-ocimene, which is isolated from *Corymbia citriodora*, *Ocimum suave*, and *Ostostegia integrifolia*, have been shown to have mosquito-repelling properties [58, 59]. In addition, a review by Pohlit et al. [60] showed that extracts from various plant species have mosquito-repelling

properties. For instance, limonene extracted from *Citrus limon* [61] and myrcene from *Cymbopogon citratus* [62] exhibited repellent effects on *Aedes albopictus* and *A. aegypti*, respectively.

According to the preference ranking results, *Commiphora rostrata* was the most common plant species used as an insecticide. In traditional medicine for other parts of Ethiopia, the bark of the plant is chewed to relieve the sore throat [63]. The preference of this plant species as an insecticide should also lead to further phytochemical analysis, pharmacological investigation and conservation measures.

Literature review on frequently cited plant species: Phytochemical and pharmacological analysis

Most plant species identified in the study area for use as insect repellents and insecticides have not been reported elsewhere in the world. However, plant species have been identified for similar purposes in communities in Ethiopia and elsewhere in the world, as indicated in Table 8. Here, we discuss some of these plants and the plants most commonly cited by local communities in the study area during ethnobotanical surveys. *Amaranthus sparganiocephalus* emerged as the most frequently mentioned plant among the insect repellents in the study area, with 27 (22.5%) informants citing this species, followed by *Senna italica*, with 24 (20%) informants citing the plant.

Abutilon pannosum var. *figarianum* (Webb) Verdc. (Malvaceae)

A. pannosum is an erect, 1.5–3 m tall perennial herb. The seeds contain 13.4% oil and 23.0% protein [64]. The native range of this variety is Egypt to Tanzania and Pakistan. The plant is called Balanbaal in the Somali language, and 20 informants cited that it was used to repel insects. Phytochemical analysis of *A. pannosum* revealed the presence of various types of compounds, such as triterpenes, fatty acids, volatile compounds, monoterpenes, aromatic acids, flavoring agents, esters, n- fatty aliphatic hydrocarbons, diterpenes, olefins, monoglycerides, monoterpenoids, phenols, ketones, and polyunsaturated poly acids [65]. Citronellol, which is found in citrenola oils, is also found in the extracts of *A. pannosum*. Citronellol is used as an insect repellent (Mosquito) [66] and a mite attractant [65]. Citronella oil has been shown to demonstrate 100% activity for 2 h against *Anopheles arabiensis* [67]. Field trapping experiments also indicated that racemic and 2,3-butanediol extracted from whole plant parts are powerful attractants for beetles [68].

Senna italica Mill. (Fabaceae)

It is an annual perennial or subshrub and grows primarily in the seasonally dry tropical biome. The plant grows approximately 50 to 75 cm in height with herbaceous branches from the woodystock. It is used as an animal food, a poison and a medicine and has environmental and social uses. The native range of this species is Africa to the Indian Subcontinent. The plant is locally called Salamaki in the Somali language, and communities in the Korahaye zone use the leaves of the plant to repel insects. *S. italica* contains anthraquinone glycosides (sennosides and their aglycones sennidin, emodin, aloe emodin, rhein and chrysophanol), which are responsible for its purgative action [69]. The oil compounds present in the n-hexane extract of *S. italica*, such as 2,6-di-sec-butylphenol, di-n-octylphthalate, eicosane, tetratriacontane, and 2,2'-methylenebis, were isolated and evaluated for insecticidal activity [70]. These oily compounds exhibited potent insecticidal activity against *Callosbluchus analis* [71]. The antimalarial activity of the leaf extract of *S. italica* was previously reported for the Shinile district of the Somali Regional State [72]. In a similar study, Yagi et al. [70] reported that the n-hexane extract of the pod from this species had potent insecticidal activity against *Callosobruchus analis*. Hexane extracted from the leaves of *S. italica* has been shown to be effective as a repellent agent against *Culex pipiens*, which is considered one of the most widely distributed mosquitoes worldwide [73]. A study conducted by Magano et al. [74] demonstrated that the root extract of *S. italica* has an anti-tick agent.

Phytolacca dodecandra L'Her. (Phytolaccaceae)

P. dodecandra is usually a semisucculent, straggling or scrambling evergreen shrub that is up to 4 meter tall. Sometimes, it becomes a climbing plant with stems up to 10, occasionally 20 m long [75]. The native range of this species is Tropical & South Africa, Madagascar. *P. dodecandra*, which is commonly called 'Endod' in Amharic, 'Andoodee' in Afaan oromo, 'Shibti' in Tigrigna, and 'Gisanges' in the Somali language, is among the most important plants in the country [76]. All parts of these plant species are widely used in traditional Ethiopian medicine. The leaves, roots, and barks are used orally to treat abortion, internal parasite, and liver disease [77]. The plant is used to repel and kill insects in Ethiopia [34, 48, 55]. Phytochemical analysis of the parts of *P. dodecandra* revealed that this plant contains terpenoids, phenolics [78, 79], saponins [79, 80, 81], flavonoids [82], genins [83], and polyphenols [79]. Pharmacological analysis of *P. dodecandra* extracts revealed that the extract had larvicidal effects on 3rd -stage larvae of *Anopheles arabiensis* [76, 84]. A similar study conducted by Adinew [85] on the leaf extract of *P. dodecandra* against *Plasmodium berghei* showed that this extract has antimalarial activity in mice. Water and ethanol extracts also showed effectiveness against *Anopheles gambiae* [86, 87]. Resting boxes baited with crude ethanol extracts of *P dodecandra* parts are reportedly effective at capturing and killing indoor resting mosquitoes [88]. The immature water and methanol extracts of *P. dodecandra* berries contain bioactive compounds that kill the immature filarial vector *Culex quinquefasciatus* [89]. *P. dodecandra* extracts potently kill pubic lice [90] and cabbage flea beetles [91].

Carica papaya L. (Caricaceae)

C. papaya is a fruit tree that is known for its medicinal uses. It is used in traditional medicine for the treatment of internal parasites and malaria [51, 92–94], gastritis [44], jaundice [47], and skin infection [94]. In addition, fresh leaf extract was used to kill insects in local communities in the Korahaye Zone. Leaf extracts are also used to repel mosquitoes and ticks in local communities in the Jimma zone [13] and Jabitehnan district [33]. Preliminary phytochemical studies by Amazu et al. [95], [96] and Ilham et al. [97] revealed the presence of alkaloids, saponins, glycosides, phytosterol, phenolic compounds, flavonoids, terpenoids, tannins, and phytosterols. A pharmacological study reported that the administration of *C. papaya* and *Vernonia amygdalina* had synergistic effects on treating mice infected with *Plasmodium berghei*. The larvicidal activity of *C. papaya* against *Aedes aegypti* was evaluated. The results indicated that seed [98] and leaf extracts [97] of *C. papaya* effectively promoted larvicide effects.

Commiphora myrrha (T. Nees) Engl. (Burseraceae)

The shrubs are mostly glabrous or small trees, usually with a distinct, though short, trunk up to 4 m tall. The native range of this species is Ethiopia to Kenya, Somalia and the southern part of Arabia [99]. It is a shrub or tree and grows primarily in desert or dry shrubland biomes. Myrrh, which originated in Arabia, is an extract that is produced from secretory tissues found on the bark of Commiphora species [99]. Myrrh is a natural oleogum resin that produces the characteristic odor, ranging in color from yellowish-brown to reddish-brown [100]. The plant is locally known as Malmal in the Somali language, and gum is widely used as an insect repellent and insecticide. *C. myrrha* has been used since time as an immemorial for treating wounds and other medicinal uses [101]. Resin is also traditionally used to treat stomachaches and repel snakes [102]. Studies on the phytochemicals of resin from *C. myrrha* have shown that this plant contains heerabolene, elemol, acadinene, cuminaldehyde, eugenol, and a multitude of furano-sesquiterpenes, including furanodienone, furanodiene, curzerenone, and lindestrene [103]. With advancements in drug development, hopefully, the rich phytochemical components of these plants can be explored for drug development, especially as formulations for insecticides [99]. A repellency test of *C. myrrha* was performed by Abtew et al. [104], and Hans et al. [105] reported that these extracts repel *Megalurothrips sjostedti* and *Sitophilus zeamais*, respectively.

Conclusion

The present study showed that pastoralist communities in the Korahaye zone have valuable indigenous knowledge and practices related to plants used as repellents and/or insecticides. The findings showed that using these plants (and their active compounds) would help reduce vector bites and stop the spread of the diseases they convey. *Amaranthus sparganiocephalus, Commiphora rostrata* and *Senna italica* are among the most common species in the study area. Therefore, validation through phytochemical and pharmacological studies is recommended. To determine the effects of extracts from various plants on mosquitoes in particular and insect pests in general, additional laboratory research should be conducted.

Abbreviations

CSA
Central Statistical Agency
IPNI
International Plant Names Index
POWO
Plants of the World Online
WHO
World Health Organization

Declarations

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Author Contributions

GA collected and analyzed the data and drafted the manuscript. MM analyzed and edited the manuscript, and PVD revised the language and sequence of the manuscript. All the authors read and approved the final manuscript.

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Availability of data and materials

All the data generated and interpreted for the study are provided in Additional file 1.

Ethics approval and consent to participate

A letter of approval to conduct a study was obtained from Jigjiga University, Department of Biology. Before any field data were collected, the local communities provided oral consent to participate in the research.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Figures

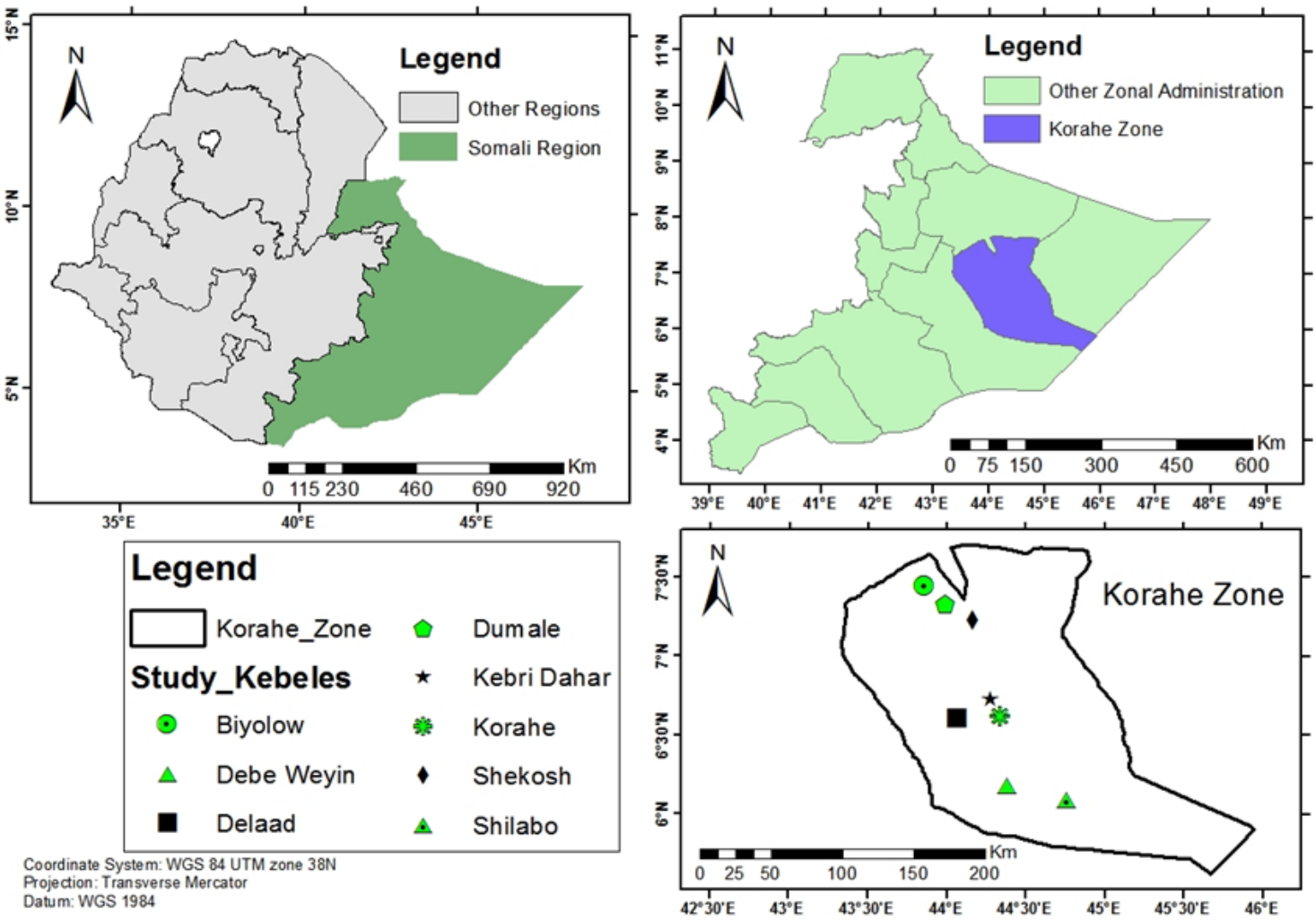

Figure 1

Map of the study area showing surveyed kebeles

Figure 2

Guided field interviews and examples of plants identified as insect repellents

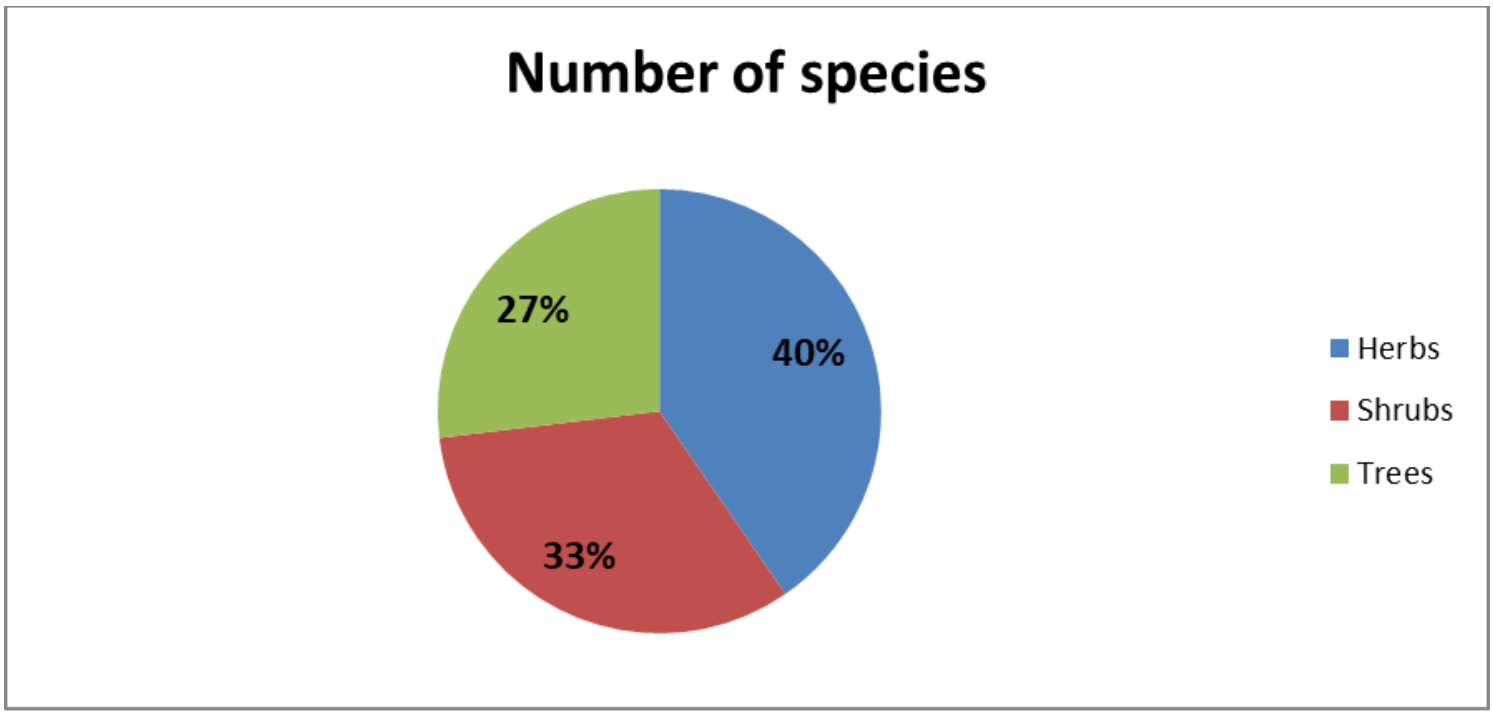

Figure 3

Growth forms of plants in the study area

Supplementary Files

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