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Plants with insecticidal potential used by ethnic groups in North-Central Nigeria for the management of hematophagous insects

OLUKAYODE JAMES ADELAJA[1,♥], ADEDAYO OLATUBOSUN ODUOLA[1], OYINDAMOLA OLAJUMOKE ABIODUN[2], ADENIYI KAZEEM ADENEYE[3], ABIODUN OBEMBE[4]

[1]Department of Zoology, University of Ilorin. Ilorin, Kwara State, Nigeria. ♥email: kayadelaja@gmail.com
[2]Department of Pharmacology and Therapeutics, University of Ibadan. Ibadan, Oyo State, Nigeria
[3]Public Health and Epidemiology Department, Nigeria Institute of Medical Research. Yaba, Lagos State, Nigeria
[4]Department of Biosciences and Biotechnology, Kwara State University. Malete, Kwara State, Nigeria

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Abstract. *Adelaja OJ, Oduola AO, Abiodun OO, Adeneye AK, Obembe A. 2021. Plants with insecticidal potential used by ethnic groups in North-Central Nigeria for the management of hematophagous insects. Asian J Ethnobiol 4: 65-75.* Studies on the traditional knowledge of insecticidal plants are vital in the discovery of bioactive components for the management of hematophagous insects. This study investigated the ethnobotany and traditional knowledge of insecticidal plants among nine ethnic groups in North-Central Nigeria. Information on identifying insecticidal plants and their traditional knowledge among community leaders, elders, herb sellers, and herbalists was collected between January and December 2017, using a semi-structured questionnaire. The mentioned plants were collected and identified. A total of 388 respondents were interviewed from nine ethnic groups. All the respondents had knowledge of medicinal and insecticidal plants in their communities. The respondents mentioned 17 insecticidal plants. The most frequently mentioned plants were *Hyptis suaveolens* (19.6%, 76/388), *Ocimum gratissimum* (18.7%, 73/388), and *Citrus sinensis* (10.8%, 42/388). Hanging of plants in homes was reported among 52.9% of the respondents and smoldering for personal protection among 47.1%. The respondents also acknowledged that these plants were available (88.4%), accessible (77%), and very effective (76.3%) in controlling hematophagous insects. There was a significant relationship ($P<0.05$) between the perceived efficacy of these plants and the gender, age, educational status, and ethnicity of respondents. This study documented the knowledge and evidence of insecticidal plants among ethnic groups in North-Central Nigeria.

Keywords: Ethnobotany, ethnicity, insecticidal, insects, plants

INTRODUCTION

Traditional African communities have long relied on plants with insecticidal potential for personal protection against hematophagous insects responsible for the transmission of disease-causing parasites and pathogens (Kidane et al. 2013). This knowledge is built on close observation and long-term use of these plants in local communities and has been passed down over several generations (Karunamorthi and Hailu 2014). Such research-based documentation is required for knowledge preservation and transfer of sustained insecticidal plants cultivation and conservation and discovering the plants' insecticidal bioactive components against hematophagous insects.

Vector-borne diseases transmitted by hematophagous insects impose a massive burden on the world's populace in terms of indisposition and mortality contributing 17% of total infectious diseases affecting mankind with more than 700,000 deaths yearly (WHO 2019). West Nile Virus, Malaria, Encephalitis, Filariasis, Dengue, Zika, and Yellow Fever are the most transmitted vector-borne diseases with debilitating outcomes and the vectors are mosquitoes (Becker et al. 2003) with most of Nigeria's population at risk of mosquito-borne diseases (Oduola et al. 2016). Nigeria accounts for 24% of the 94% malaria cases in the African region, 106 million people at risk of lymphatic filariasis and 106 confirmed cases and 20 confirmed deaths from yellow fever (WHO 2019).

Since the beginning of the millennium, there has been a stimulating search for the discovery of new and active insecticidal compounds of plant origin and their traditional use (David 2010; Uperty et al. 2010). In a bid to achieve this, ethnobotanical surveys were carried out all around the world and in some countries in Africa, i.e., Ethiopia, Tanzania, Kenya, Cameroon, and South Africa to identify plants with insecticidal potential for the management of hematophagous insects (Karunamorthi et al. 2009a; Mavundza et al. 2011; Kidane et al. 2013; Karunamorthi and Hailu 2014; Youmsi et al. 2017). The survey has also been carried out in South-Eastern Nigeria where plants with insecticidal potential were identified (Edwin-Wosu et al. 2013).

Predominant plants with insecticidal potential used in the management of hematophagous insects documented in ethnobotanical surveys conducted in Africa include; *Lippia jaranica* in South Africa (Mavundza et al. 2011), *Boswellia papyrifera*, and *Ostostegia integrifolia* in Ethiopia (Karunamorthi et al. 2009a; Kidane et al. 2013), *Canarium schweinfurthii* in Cameroon (Youmsi et al. 2017), *Azadirachta indica* in Tanzania (Innocent et al. 2016), and *Ocimum americanum* in Kenya (Seyoum et al. 2002). Similarly, *Duranta repens*, *Duranta pulmeri* and *Ocimum gratissimum* were the predominant plants with insecticidal

potential against hematophagous insects documented in South-Eastern Nigeria (Edwin-Wosu et al. 2013).

A report emanating from South Africa showed that 70% of respondents traced the source of knowledge of plants having the insecticidal potential to family members (Mavundza et al. 2011). Meanwhile, ethnobotanical studies carried out in Ethiopia and Tanzania associated usage customs of insecticidal plants with sex and monthly income but not with educational status (Karunamorthi et al. 2009a; Karunamorthi and Hailu 2014). However, the only documented study of an ethnobotanical survey of plants with insecticidal potential against hematophagous insects carried out in Nigeria was done in the South-Eastern part (Edwin-Wosu et al. 2013) and ethnicity was not a factor considered hence the need to carry out this in North-Central Nigeria.

Despite ethnobotanical information on insecticidal plants from a geopolitical zone in Nigeria, we felt a need to present a first report on the ethnobotany and traditional knowledge of plants with insecticidal potential among nine ethnic groups in North-Central Nigeria. We hope that information generated from this study will go a long way in aiding the management of hematophagous insects in Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in the North-Central geopolitical region of Nigeria which is composed of six states, namely Benue, Plateau, Kogi, Nasarawa, Kwara, and Niger. A total landmass of 296,898 km^2 and a total population of 20.36 million people. Forty-eight percent of the people in the region live in rural communities. North-Central Nigeria is situated between latitudes 6^{0}30″ N and 11^{0}20″ N and longitudes 7^{0}E and 10^{0}E, the region has average annual rainfall that ranges from 1,500 mm to 1,800 mm, with average annual temperature varying between 20^{0}C and 35^{0}C (NPC 2016). These six states are found around the river Niger and Benue and some of the states are richly endowed with natural mineral resources. The major ethnic groups in this region are Tiv, Yoruba, Idoma, Igala, Ebira, Nupe, Gbayi, Berom, and Mangu. Farming is the mainstay of the rural communities' economy found in North-Central Nigeria.

Experimental design and procedure

The study was undertaken as a descriptive cross-sectional survey between January and December 2017. Communities were selected based on ethnicity in the states found in North-Central Nigeria. After which, the geographical positioning system (GPS) for the surveyed communities was captured (Figure 1). Before the survey was conducted, community leaders were consulted to gain their trust and help identify possible contact persons and respondents. People conversant with plants used for health care were the target of this survey, grouped into community leaders, elderly villagers, herb sellers, and herbalists adopting Dike et al. (2012) groupings. With the aid of a local contact person conversant with the language and culture of the locality, respondents were identified, oral interviews were carried out and data were collected using semi-structured questionnaires.

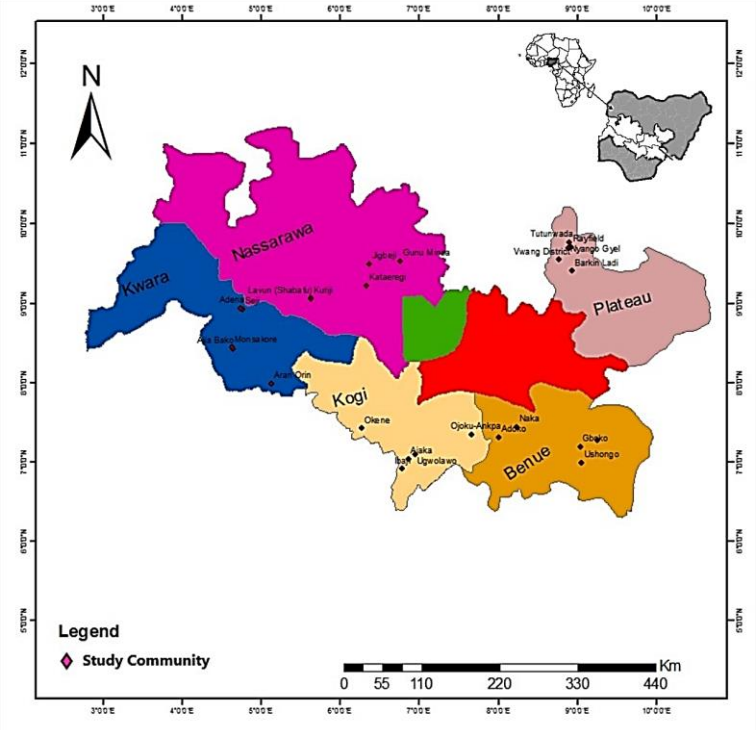

Figure 1. Map of North-Central Nigeria showing states and selected communities surveyed

Data collection and analysis

The questionnaires were filled out using oral interviews with translation done by a contact person where necessary. The questionnaire gathered information on locality, sociodemographic data, insects of public health importance, plants used for insects' control, vernacular names of the plant, plant parts used, the condition of the plant material (dried or fresh), methods and frequency of application, accessibility, availability, source of knowledge and efficacy of insecticidal plants. The local importance of each plant species was calculated based on the Relative Frequency of Citation (RFC) (Iyamah and Idu 2015; Youmsi et al. 2017).

$$\mathrm{RFC} = \frac{UR}{N}$$

Where UR: number of respondents who claim the use of plants, and N: total number of respondents interviewed.

ArcGis 10.1 was used to locate the GPS coordinate of questionnaire survey communities and generate a spatial map. Summary statistics were performed using Origin 2019, SPSS ver. 20 (IBM) and Microsoft Office Excel 2016. The range and means of the data obtained from the administered questionnaire were analyzed. Chi-square analysis was performed to test statistical significance at a 95% confidence interval (P = 0.05) using Origin 2019.

Plant identification and authentication

All plant species mentioned were collected with the help of the villagers and identified at the Herbarium of the Department of Plant Biology, University of Ilorin. The identified plants were allocated authentication numbers afterward.

Ethical statement

The ethnobotanical survey was approved by the University of Ilorin ethical review committee (UERC/ASN/2017/898). Prior to the study, the aims and objective of the study were clearly explained, and informed verbal consent was obtained from each respondent to record and publish findings from this study.

RESULTS AND DISCUSSION

Demographic information of the respondents

A total of 388 respondents were interviewed from nine ethnic groups in North-Central Nigeria. The communities were selected based on their ethnicity and the possibility of getting the required information as suggested by contact persons who are natives of the regions. The ethnic groups include Tiv (12.4%), Nupe (24.7%), Yoruba (9.8%), Berom (13.9%), Igala (11.9%), Ebira (8.2%), Gbayi (2.6%), Mangu (4.1%), and Idoma (12.4%) with the most respondents being Nupe which is found in both Kwara and Niger state followed by Berom and Tiv in Plateau state and Idoma in Benue state. The demographic data collected showed that 54.1% of the respondents were males and 45.9% were females. Religious affiliation showed that 52.6% of the respondents were Christians, 40.7% Muslims and 6.7% were Traditionalists. It was also noticed that most of the respondents had a form of education with the highest (33.5%) having secondary education followed by those who had primary education (30.9). The predominant age group was between 41 to 60 years (48.5%) with most of the respondents being between 41 to 50 years (25.8%) followed by above 70 years (24.7%). The majority of the respondents were married (85.1%) (Table 1). All the respondents had ample knowledge of plants used for health care in their communities and they were grouped into herb sellers (31.96%), traditional healers (15.98%), community heads (4.64%), and elders (47.42%) (Figure 2).

Table 1. Socio-demographic characteristics of respondents in North-Central Nigeria

Socio-demographic characteristics of variables		Frequency (n = 388)	Percentage (%)
Gender	Male	210	54.1
	Female	178	45.9
Ethnicity	Tiv	48	12.4
	Nupe	96	24.7
	Yoruba	38	9.8
	Berom	54	13.9
	Igala	46	11.9
	Ebira	32	8.2
	Gbayi	10	2.6
	Mangu	16	4.1
	Idoma	48	12.4
Educational status	None	78	20.1
	Primary	120	30.9
	Secondary	130	33.5
	Tertiary	28	7.2
	Adult education	32	8.3
Religion	Christianity	204	52.6
	Islam	158	40.7
	Traditional	26	6.7
Age	Less than 20 years	12	3.1
	21-30 years	6	1.5
	31-40 years	38	9.8
	41-50 years	100	25.8
	51-60 years	88	22.7
	61-70 years	48	12.4
	Above 70 years	96	24.7
Marital status	Single	28	7.2
	Married	330	85.1
	Widowed	30	7.7

Note: n: total number of respondents

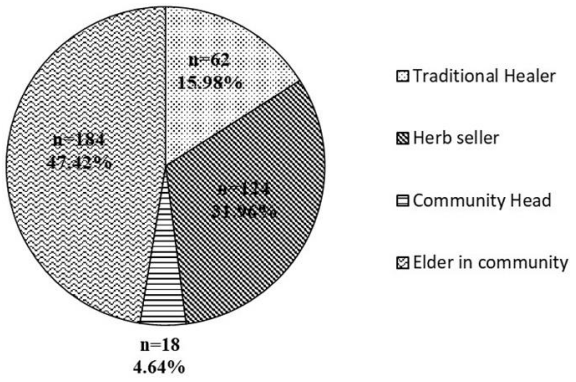

Figure 2. Category of respondents interviewed

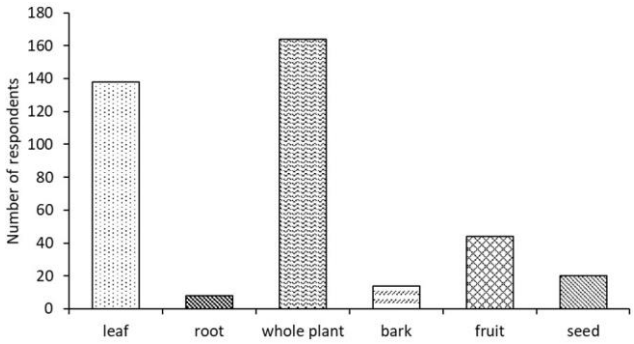

Figure 3. Insecticidal plant parts used by respondents for the management of hematophagous insects

Information on identified plants

Local inhabitants mentioned 17 plant species in the study area for personal protection against hematophagous insects. The identified and shortlisted plants belonged to 12 families among which Lamiaceae was the most represented with three species, namely *Hyptis suaveolens*, *Ocimum gratissimum*, and *Thymus vulgaris*. This was followed by Solanaceae (*Capsicum annuum* and *Nicotiana tabacum*), and Fabaceae (*Cassia mimosoides* and *Parkia biglobosa*). The most frequently mentioned plants were *Hyptis suaveolens* (19.6%, UR = 76/388, RFC = 0.196) followed by *Ocimum gratissimum* (18.7%, UR = 73/388, RFC = 0.187), *Citrus sinensis* (10.8% UR = 42/388, RFC = 0.108), *Ageratum conyzoides*, *Cymbopogon citratus* and *Thymus vulgaris* (6.2%, UR = 24/388, RFC = 0.062 each) and *Nicotiana tabacum* (5.6%, UR = 22/388, RFC = 0.057). Least mentioned plants were *Lantana camara* (1.5%, UR = 6/388, RFC = 0.015) and *Moringa oleifera* (1.0%, UR = 4/388, RFC = 0.010) (Table 2). Most of the plants identified were shrubs (58.8%) while the others were trees (35.3%). Whole plants (42.3%) were the most used plant parts followed by leaves (35.6%) (Figure 3). Fifty-three percent of the respondents reported that they used plants in their fresh states by hanging them inside their abode while the rest of the respondents reported that the plants were used dried (47.1%) by smoldering the plant materials to make smoke (Table 2).

Distribution of identified plants by ethnicity

Hyptis suaveolens and *Ocimum gratissimum* were the most represented insecticidal plant used by all of the eight ethnic groups for personal protection against hematophagous insects followed by *Citrus sinensis* which was mentioned in six ethnic groups, namely Berom, Idoma, Mangu, Nupe, Tiv, and Yoruba while *Nicotiana tabacum* mentioned in four ethnic groups (Berom, Ebira, Idoma, and Yoruba), and *Thymus vulgaris* was mentioned in three ethnic groups (Idoma, Nupe, and Tiv) (Table S1). *Hyptis suaveolens* and *Thymus vulgaries* were the only plants mentioned by all the target respondents as having insecticidal potential. The majority of the shortlisted plants were mentioned by Herb sellers and Elders in communities (Table S2).

Usage customs of identified plants

Eighty-eight percent of the respondents acknowledged that the plants were available around the community while the other respondents (8.8%) reported that they collected the plants from the forest or bought them from the market (2.8%). The majority (77%) of the respondents claimed that the insecticidal plants used for personal protection were accessible within one km radius. Information on the source of knowledge on plant use among respondents indicated that 83.8% of them obtained the information from family members while 12.6% of the respondents obtained the information from friends and neighbors (Table 3). The assessment of knowledge on how plants are applied showed that 99% of the respondents applied the plants inside their houses while 1% of the respondents applied it in sewage systems found around their houses (Table 4). The frequency of application of the plants ranged from once a week (21.7%) to once a day (71.6%). The respondents (76.3%) ascertained that the identified insecticidal plants were very effective while 23.2% of the respondents felt that the insecticidal plants were effective in controlling hematophagous insects. There was significant relationship in the perceived efficacy of these insecticidal plants for personal protection against haematophagous insects and; gender (P value = 0.000, df = 2, χ^2 = 31.396), age (P value = 0.007, df = 112, χ^2 = 64.445), educational status (P value = 0.000, df = 8, χ^2 = 102.405), and ethnicity (P-value = 0.000, df = 16, χ^2 = 116.865) of respondents (Table 5).

Discussion

An ethnobotanical survey was carried out to evaluate knowledge associated with the traditional use of plants with insecticidal potential against hematophagous insects in North-Central Nigeria. This study showed that all of the respondents interviewed from the nine ethnic tribes knew the cultural uses of plants in the control of hematophagous insects. A similar study conducted in Ethiopia showed that 97.2% of the respondents had adequate knowledge about the usage customs of traditional insecticidal plants used to repel hematophagous insects (Karunamorthi et al. 2009a). This shows that the wealth of knowledge of plant species used to control hematophagous insect dwells with the respondents surveyed in communities in North-Central Nigeria.

The observed 100% awareness of insecticidal plants' use among respondents in this study is attributable to the selection of residents (community leaders and elders, herb sellers, and traditional healers) perceived to be endowed with knowledge of plant species used for health care purposes. Iyamah and Idu (2015) acknowledged that herb sellers play a vital role in making herbs and are open to sharing their knowledge of these herbs and their uses with researchers. This might be the reason why they ranked second in the list of the most interviewed group of respondents after community elders. Also, herb sellers are helpful as sources of knowledge of plants because that is their trade making them very familiar with plant species around them and their usage customs. Iyamah and Edu (2015) also reported that herb sellers acknowledged obtaining regular feedback from their customers on the effectiveness of plants used for the treatment of malaria and personal protection against blood-sucking insects hence the authenticity of the information they present.

Table 2. Information on plants with insecticidal potential used for management of hematophagous insects in North-Central Nigeria

Family name	Scientific name	Local name	Voucher number	UR (%)	RFC (n = 388)	State of use	Habit	Application Method
Asteraceae	*Ageratum conyzoides* L.	Itanajuwe (I), Hurhur (T)	UILH/013/140	24(6.2)	0.062	Fresh	Shrub	Hanging
Amaryllidaceae	*Allium cepa* L.	Lubasakuchi (B)	UILH/008/1332	8(2.1)	0.021	Fresh	Herb	Hanging
Annonaceae	*Annona senegalensis* Pers.	Abobo (Y), Gwandar daji (N)	UILH/004/499	12(3.1)	0.031	Fresh	Tree	Hanging
Solanaceae	*Capsicum annuum* L.	Akpoko (I)	UILH/015/532	16(4.1)	0.041	Fresh	Shrub	Smoke
Fabaceae	*Cassia mimosoides* L.	Gabaruwankasa (B)	UILH/017/534	16(4.1)	0.041	Dried	Tree	Smoke
Rutaceae	*Citrus sinensis* L.	Ekpo Osan (Y)	UILH/010/159	42(10.8)	0.108	Dried	Tree	Smoke
Poaceae	*Cymbopogon citratus* L.	Ile (I), Ganyenti (B)	UILH/011/949	24(6.2)	0.062	Fresh	Shrub	Hanging
Leguminosae	*Erythrophleum suaveolens* Guill. & Perr.	Goska (B) Gwaska (N), Obo (Y)	UILH/016/221	8(2.1)	0.021	Dried	Tree	Smoke
Myrtaceae	*Eucalyptus globulus* Labill.	Turare (N) Raskata (B)	UILH/006/1073	12(3.1)	0.031	Fresh	Tree	Hanging
Malvaceae	*Hibiscus rosa-sinensis* L.	Roase mosquita (B)	UILH/007/710	9(2.3)	0.023	Dried	Shrub	Hanging
Lamiaceae	*Hyptis suaveolens* (L.) Poit.	Tamwotswagi (N), Jogbo (Y), Olufofo (I), Daddoya tadaji (B), Hurhur (T)	UILH/003/931	76(19.6)	0.196	Fresh	Shrub	Hanging
Verbenacae	*Lantana camara* L.	Latana (B)	UILH/009/509	6(1.5)	0.015	Dried	Shrub	Smoke
Moringaceae	*Moringa oleifera* Lam.	Zogole (B)	UILH/002/559	4(1.0)	0.010	Dried	Tree	Smoke
Solanaceae	*Nicotiana tabacum* L.	Taba (N)	UILH/005/504	22(5.6)	0.057	Dried	Shrub	Smoke
Lamiaceae	*Ocimum gratissimum* L.	Efirin (Y), Anyeba (I), Daidoya (T), KunguraKu-u-tamen (N)	UILH/012/984	73(18.7)	0.188	Fresh	Shrub	Hanging
Fabaceae	*Parkia biglobosa* Jacq.	Nungoro (N), Ekunigba (Y)	UILH/001/948	12(3.1)	0.031	Dried	Tree	Smoke
Lamiaceae	*Thymus vulgaris* L.	Tamwotswagi (N), Efrin wewe (Y)	UILH/012/851	24(6.2)	0.062	Fresh	Shrub	Hanging

Table 3. Perception of respondents to insecticidal plant accessibility, effectiveness, and source of information in North Central Nigeria

Scientific name	Respondents		Availability			Distance travelled to harvest the plant			Source of Knowledge		
	UR (n = 388)	%	Forest	Around community	Market	< 1Km	1-2 Km	>5 Km	Family members	Divination	Friend/ neighbour
Parkia biglobosa	12	3.0	2(16.7)	10(83.3)	NR	10(83.3)	2(16.7)	NR	10(83.3)	NR	2(16.7)
Moringa oleifera	4	1.0	NR	4(100)	NR	4(100)	NR	NR	4(100)	NR	NR
Hyptis suaveolens	76	19.6	NR	76(100)	NR	76(100)	NR	NR	72(94.7)	NR	4(5.3)
Annona senegalensis	12	3.3	NR	12(100)	NR	12(100)	NR	NR	12(100)	NR	NR
Nicotiana tabacum	22	5.6	NR	22(100)	NR	22(100)	NR	NR	10(45.5)	NR	12(54.5)
Eucalyptus globulus	12	3.3	2(16.7)	6(50)	4(33.3)	8(66.7)	4(33.3)	NR	12(100)	NR	NR
Hibiscus rosa-sinensis	9	2.3	2(22.2)	4(44.5)	3(33.3)	4(44.5)	5(55.5)	NR	9(100)	NR	NR
Allium cepa	8	2.1	8(100)	NR	NR	NR	8(100)	NR	8(100)	NR	NR
Lantana camara	6	1.5	4(66.7)	2(33.3)	NR	NR	2(33.3)	4(66.7)	4(66.7)	NR	2(33.3)
Citrus sinensis	42	10.8	2(4.8)	40(95.2)	NR	42(100)	NR	NR	20(47.6)	2(4.8)	20(47.6)
Cymbopogon citratus	24	6.1	NR	24(100)	NR	22(91.7)	2(8.3)	NR	24(100)	NR	NR
Ocimum gratissimum	73	18.7	2(2.7)	71(97.3)	NR	47(64.4)	20(27.4)	6(8.2)	69(94.5)	4(5.5)	NR
Ageratum conyzoides	24	6.2	NR	24(100)	NR	24(100)	NR	NR	24(100)	NR	NR
Thymus vulgaris	24	6.2	NR	24(100)	NR	14(58.3)	10(41.7)	NR	15(62.5)	4(16.7)	5(20.8)
Capsicum annuum	16	4.1	NR	12(75)	4(25)	14(87.5)	2(12.5)	NR	12(75)	4(25)	NR
Erythrophleum suaveolens	8	2.1	8(100)	NR	NR	NR	8(100)	NR	8(100)	NR	NR
Cassia mimosoides	16	4.1	4(25)	12(75)	NR	NR	16(100)	NR	12(75)	NR	4(25)
Total			34	343	11	299	79	10	325	14	49
Percentage			8.8	88.4	2.8	77	20.4	2.6	83.8	3.6	12.6

Note: UR: Number of respondents who claim the use of plants, the percentage in parenthesis, NR: No Record of information from respondents, %: Percentage

Table 4. Method and frequency of application of insecticidal plants used for personal protection in North-Central Nigeria

Scientific name	Respondents		Method of Application		Frequency of Application				Efficacy		
	UR	%	Inside houses	Sewage systems	Once a day	Once a week	Once a month	Once a year	Very effective	Effective	Not so effective
Parkia biglobosa	12	3.0	12(100)	NR	12(100)	NR	NR	NR	12(100)	NR	NR
Moringa oleifera	4	1.0	4(100)	NR	NR	4(100)	NR	NR	4(100)	NR	NR
Hyptis suaveolens	76	19.6	76(100)	NR	52(68.4)	16(21.1)	8(10.5)	NR	46(60.5)	30(39.5)	NR
Annona senegalensis	12	3.3	12(100)	NR	12(100)	NR	NR	NR	12(100)	NR	NR
Nicotiana tabacum	22	5.6	22(100)	NR	18(81.8)	4(18.2)	NR	NR	16(72.7)	6(27.3)	NR
Eucalyptus globulus	12	3.3	12(100)	NR	8(66.7)	NR	4(33.3)	NR	10(83.3)	2(16.7)	NR
Hibiscus rosa-sinensis	9	2.3	9(100)	NR	NR	9(100)	NR	NR	9(100)	NR	NR
Allium cepa	8	2.1	8(100)	NR	4(50)	NR	4(50)	NR	4(50)	4(50)	NR
Lantana camara	6	1.5	6(100)	NR	2(33.3)	NR	NR	4(66.7)	4(66.7)	2(33.3)	NR
Citrus sinensis	42	10.8	42(100)	NR	38(90.5)	4(9.5)	NR	NR	36(85.7)	4(9.5)	2(4.8)
Cymbopogon citratus	24	6.1	22(91.7)	2(8.3)	16(66.7)	6(25)	NR	2(8.3)	22(91.7)	2(8.3)	NR
Ocimum gratissimum	73	18.7	73(100)	NR	46(63)	25(34.3)	2(27)	NR	61(83.6)	12(16.4)	NR
Ageratum conyzoides	24	6.2	24(100)	NR	22(91.7)	2(8.3)	NR	NR	24(100)	NR	NR
Thymus vulgaris	24	6.2	24(100)	NR	20(83.3)	4(16.7)	NR	NR	24(100)	NR	NR
Capsicum annuum	16	4.1	16(100)	NR	12(75)	4(25)	NR	NR	4(25)	12(75)	NR
Erythrophleum suaveolens	8	2.1	6(75)	2(25)	NR	6(75)	NR	2(25)	8(100)	NR	NR
Cassia mimosoides	16	4.1	16(100)	NR	16(100)	NR	NR	NR	NR	16(100)	NR
Total			384	4	27.8	84	18	8	296	90	2
Percentage			99	1	71.6	21.7	4.6	2.1	76.3	23.2	0.5

Note: UR: Number of respondents who claim the use of plants, the percentage in parenthesis, NR: No Record of information from respondents

Table 5. Knowledge and effectiveness of insecticidal plants in relation to gender, age, educational status, and ethnicity

Variables		Respondents		Knowledge of plants	Efficacy of plant			P-values
		UR	%		VEF	EF	NSEF	
Gender	Male	210	54.1	210	126	78	NR	p = 0.000
	Female	178	45.9	178	152	24	2	df = 2
								χ^2 = 31.396
Age	Less than 20 years	12	3.1	12	12	NR	NR	p = 0.007
	21-30 years	6	1.5	6	4	2	NR	df = 12
	31-40 years	38	9.8	38	18	20	NR	χ^2 = 64.445
	41-50 years	100	25.8	100	80	20	NR	
	51-60 years	88	22.7	88	44	42	2	
	61-70 years	48	12.4	48	32	10	NR	
	Above 70 years	96	24.7	96	88	8	NR	
Educational status	None	78	20.1	78	70	8	NR	p = 0.000
	Primary	120	30.9	120	88	24	2	df = 8
	Secondary	130	33.5	130	106	24	NR	χ^2 = 102.405
	Tertiary	28	7.2	28	10	18	NR	
	Adult Education	32	8.2	32	4	28	NR	
Ethnicity	Tiv	48	12.4	48	48	NR	NR	p = 0.000
	Nupe	96	24.7	96	40	56	NR	df = 16
	Yoruba	38	9.8	38	26	6	NR	χ^2 = 116.865
	Berom	54	13.9	54	48	4	2	
	Igala	46	11.9	46	28	18	NR	
	Ebira	32	8.2	32	20	12	NR	
	Gbayi	10	2.6	10	10	NR	NR	
	Mangu	16	4.1	16	10	6	NR	
	Idoma	48	12.4	48	48	NR	NR	

Note: UR: Number of respondents who claim the use of plants, the percentage in parenthesis, VEF-Very Effective, EF-Effective, NSEF-Not So Effective, NEF-Not Effective, NR: No Record of information from respondents

About 84% of the respondents in this study acknowledged that the source of their knowledge of insecticidal plants was passed to them from close family members. This suggests that the knowledge of plants used for personal protection against haematophagous insects were sustained from one generation to another verbally and can be distorted or lost in the process. Documentation of this knowledge in our study is needful to conserve it for future generations. Similar observations of respondents obtaining knowledge of insecticidal plants used from family elders were also reported in South Africa (Mavundza et al. 2011).

In this present study, seventeen plant species belonging to twelve families used in controlling hematophagous insects were listed and identified. Similarly, Mavundza et al. (2011) reported 13 plant species used for personal protection against mosquitoes in South Africa belonging to nine families. Kweka et al. (2008) reported five insect repellent plant species belonging to four families in Tanzania while Karunamoorthi et al. (2009a) reported nine mosquito repellent plants belonging to eight families in Ethiopia. Pålsson and Jaenson (1999) reported eight plant species that could keep mosquitoes away from human dwellings in Guinea Bissau while Edwin-Wosu et al. (2013) reported 24 plant species with insecticidal potential in South-Eastern Nigeria. This study was able to document plants used in North-Central Nigeria for the management of haematophagous insects which can be referred to in the future.

Lamiaceae was the most represented plant family used for the management of hematophagous insects. Similarly, Karunamoorthi et al. (2009a) reported that Lamiaceae has the most represented family in an ethnobotanical study carried out in Ethiopia. The Lamiaceae family is important in the management of mosquitoes and other hematophagous insects because of the insecticidal potential of its members. In this study, members of the Lamiaceae family; *Hyptis suaveolens* and *Ocimum gratissimum* were the most frequently used plant species for personal protection purposes against hematophagous insects as mentioned by respondents from all the ethnic groups in North-Central Nigeria. These plants are tropical aromatic herbs with the ability to repel hematophagous insects (Okigbo et al. 2010). Also, Okigbo et al. (2010) reported that *Hyptis suaveolens* commonly known as mosquito plant, because of its insecticidal potential against mosquitoes, is widely used for personal protection against hematophagous insects in several communities in Nigeria.

The use of traditional medicines is rampant in regions where western medicines are inaccessible due to their unavailability and high cost (Iyamah and Idu 2015). The main reason indigenous people depend on plants that have the insecticidal potential for managing hematophagous insects is that they are accessible and available (Innocent et

al. 2016). The majority (77%) of the respondents from the study area indicated that they could easily access the insecticidal plants shortlisted and they were available. It has been speculated that most people living in rural communities in Africa rely on traditional medicine and insecticidal plants due to their availability and affordability in comparison with modern medicine and synthetic insecticides (Karunamoorthi and Hailu 2014). The distance estimated the accessibility of insecticidal plants to locals of the study area they had to travel and to harvest the plants which were less than one kilometer and majorly around the community while the availability was estimated by the source of the plants.

In this study, respondents affirmed the use of the whole plant (42.3%) and leaves (35.6%) for the control of hematophagous insects. Similarly, Karunamoorthi et al. (2009a) reported that leaves were the most used plant's parts for personal protection against mosquitoes in Ethiopia. Kweka et al. (2008) and Mavundza et al. (2011) also reported the same trend in Tanzania and South Africa respectively. Karunamoorthi and Husen (2012) emphasized the use of leaves of insecticidal plants for the control of hematophagous insects against whole plant, roots, and barks because it is a more sustainable option since the natural plant growth would not be disrupted. Hence, the use of the whole plant in North-Central Nigeria is not a sustainable option and should be discouraged. Apart from sustainability, another reason why the use of the leaves of insecticidal plants is more important than other parts is due to the availability of their active components that are more volatile (Mavundza et al. 2011).

Indeed, plants that are usually used for personal protection because of their insecticidal properties are habitually those containing volatile oils. When the leaves are crushed, it releases a strong odor that is unpleasant to biting insects (Youmsi et al. 2017). Usage of plants in their fresh state by hanging inside inhabited houses and smoldering of dried plants were frequent ways in which respondents from this study applied plants for the management of hematophagous insects. This is comparable to other reports where plants were hanged or spread inside habited houses (Kweka et al. 2008) and where the plant's parts were smoldered to manage blood-sucking insects (Karunamoorthi et al. 2008; Karunamoorthi et al. 2009b).

Observations from the present study showed that there was no significant association between the knowledge of plants with insecticidal potential and the gender, educational status, or ethnicity of respondents suggesting that all well know these plants of the elders and traditional health care practitioners notwithstanding their gender, educational status, and ethnicity. This is consistent with an earlier study that established no significant relationship between the gender, educational status or age of respondents, and knowledge and usage custom concerning insect repellent plants (Kidane et al. 2013). In contrast, a significant relationship was observed between the respondents' perceived effectiveness of insecticidal plants used for personal protection and; gender, educational status, and ethnicity. This suggests that gender, educational status, and ethnicity had a part to play in the perception of how effective these insecticidal plants are in the control of blood-sucking insects.

In conclusion, this ethnobotanical survey documented plants perceived to have insecticidal potential in different ethnic groups in North-Central Nigeria. This kind of documentation is required for traditional insecticidal plant knowledge preservation and transfer as well as the discovery of the plants' bioactive components against hematophagous insects. These plants were used because of their availability, accessibility, and perceived efficacy, and should be encouraged. The widespread use of whole plants in this study area should be discouraged to limit over-exploitation and enhance conservation. There is a need to promote the cultivation and conservation of the plants documented in this study.

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Table S1. Distribution of shortlisted plants by ethnicity in North-Central Nigeria

Plants	Berom	Ebira	Gbayi	Idoma	Igala	Mangu	Nupe	Tiv	Yoruba	Total
Ageratum conyzoides	NR	NR	NR	11	NR	NR	NR	13	NR	24
Allium cepa	NR	NR	NR	NR	NR	NR	8	NR	NR	8
Annona senegalensis	8	NR	NR	NR	NR	4	NR	NR	NR	12
Capsicum annuum	NR	4	NR	NR	12	NR	NR	NR	NR	16
Cassia mimosoides	NR	NR	NR	NR	NR	NR	16	NR	NR	16
Citrus sinensis	6	NR	NR	8	NR	2	14	8	4	42
Cymbpogon citratus	16	NR	NR	NR	NR	NR	NR	8	NR	24
Ertyphleum suaveolens	8	NR	NR	NR	NR	NR	NR	NR	NR	8
Eucalyptus globulus	8	NR	NR	NR	NR	4	NR	NR	NR	12
Hibiscus rosa sinensis	6	NR	NR	NR	NR	NR	NR	3	NR	9
Hyptis suaveolens	3	24	4	8	4	4	2	9	18	76
Latanna camara	6	NR	NR	NR	NR	NR	NR	NR	NR	6
Moringa oleifera	4	NR	NR	NR	NR	NR	NR	NR	NR	4
Nicotiana tabacum	4	4	NR	8	NR	NR	NR	NR	6	22
Ocimum gratissimum	3	23	2	8	4	4	2	9	18	73
Parkia biglobosa	NR	NR	NR	NR	NR	NR	5	NR	7	12
Thymus vulgaries	NR	NR	NR	6	NR	NR	12	6	NR	24
Total	72	55	6	49	20	18	59	56	53	388

Note: NR: No Record of information from respondents

Table S2. Distribution of shortlisted plants by target respondents in North-Central Nigeria

Plants	Community head	Elder in community	Herb seller	Traditional healer	Total
Ageratum conyzoides	NR	15	3	6	24
Allium cepa	NR	8	NR	NR	8
Annona senegalensis	NR	3	3	6	12
Capsicum annuum	2	6	8	NR	16
Cassia mimosoides	4	12	NR	NR	16
Citrus sinensis	NR	23	5	14	42
Cymbpogon citratus	NR	12	11	1	24
Ertyphleum suaveolens	NR	2	NR	6	8
Eucalyptus globulus	4	4	4	NR	12
Hibiscus rosa sinensis	NR	5	4	NR	9
Hyptis suaveolens	5	37	21	13	76
Latanna camara	NR	NR	4	2	6
Moringa oleifera	NR	NR	4	NR	4
Nicotiana tabacum	NR	6	8	8	22
Ocimum gratissimum	NR	38	31	4	73
Parkia biglobosa	NR	NR	12	NR	12
Thymus vulgaries	4	12	4	4	24
Total	19	183	122	64	388

Note: NR: No Record of information from respondents