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RESEARCH

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Ethnobotanical survey of plants locally used in the control of termite pests among rural communities in northern Uganda

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Abstract

Background: Termites are the most destructive pests in many agricultural and forest plantations in Uganda. Current control of termites mostly relies on chemical pesticides. However, the adverse effects of chemical insecticides necessitate the need to search for and popularize the usage of environmentally safer options. Plants represent one of the most accessible resources available for termite control by communities in Uganda. However, limited documented information exists for their contribution in the management of except through verbal sharing. This study aimed at assessing the communities' knowledge about plants traditionally used in controlling termites among selected communities in Apac District, northern Uganda.

Method: An ethnobotanical survey was conducted between November 2016 and February 2017 in 12 randomly selected villages in the sub counties of Apac and Ibuje of Apac District, northern Uganda. Open-ended questionnaire interviews were used to gather ethnobotanical and sociodemographic data. A total of 381 indigenous people were interviewed [male, 281 (73.8); female, 100 (26.2)]. Data were analysed using descriptive statistics and Informant Consensus Factor (ICF), and the relative frequency of citation (RFC) was determined.

Results: Overall, 70.9% of the respondents were knowledgeable about plants used for control of termites. There was a significant association between respondents' knowledge of pesticidal plants with age and gender but not with education status. A total of 11 plant species belonging to eight families were identified to be in use for control of termites in Apac. Solanaceae, Eurphorbiaceae and Asteraceae were the most represented families with two species each, while the rest of the families had only one species mentioned. According to the relative frequency of citation (RFC), *Kigelia africana* (Lam.) Benth. (RFC = 0.43), *Vernonia amygdalina* Delile (0.18) and *Tithonia diversifolia* (Hemsl.) A. Gray (0.10) were the most used in the control of termites in the study area. Fruits (45.9%) and leaves (29.2%) were the most used plant parts. Squeezing, crushing and chopping of the plant materials were the most popular methods of preparation and water extract was the commonest mode of formulation of plant parts.

Conclusions: The study has shown that rural populations of the targeted localities possess indigenous knowledge on anti-termitid plants. However, screening is urgently needed to validate their bioactivity and to determine the bioactive constituents responsible for killing the invertebrates in pest management. Furthermore, simple methods for local propagation and cultivation are needed to ensure a sustainable supply of termicidal plant biomass.

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Keywords: Ethnobotanicals, Indigenous knowledge, Langi, Macrotermes

Background

Termites are the most pestiferous insects in the tropics, causing damage to crops, trees, rangelands and buildings (Okwakol and Sekamatte 2007; Sileshi et al. 2009). Over 2600 and 660 species of termites have been documented worldwide (Sileshi et al. 2009) and from Africa (Kambhampati and Eggleton 2000; Eggleton 2000), respectively. Of the known termite genera, most of the pestiferous species are from the family Termitidae (Sileshi et al. 2009). This family is categorized into four sub-families (Termitinae, Macrotermitinae, Apictotermitinae and Nasutitermitinae) and four distinct groups (damp wood, dry wood, subterranean and arboreal or mound builder termites). The damp wood species are restricted in distribution, and live and feed on moist wood, especially stumps and fallen trees on the forest floor (Kambhampati and Eggleton 2000). Termites can construct shallow subterranean foraging galleries radiating from the nest to a distance of up to 50 m (Abdurahman et al. 2010). The main galleries give rise to a network of small galleries from which foraging parties exploit potential food sources over wide areas, attacking plants at the base of the stems, ring barking or cutting them completely (Osipitan and Oseyemi 2012). Yield losses attributed to termites have been estimated to range between 50 and 100% in various crops in East Africa (Sekamatte 2001; Nyeko et al. 2010). Over 90% of termite damage in agricultural, forestry and urban settings is attributed to species of the sub-family Macrotermitinae (Sileshi et al. 2009; Pomeroy et al. 1991; Mitchell 2002; Adekayode and Ogunkoya 2009; Verma et al. 2009). The Macrotermitinae build large epigeal mounds (also called termitaria) from where the Macrotermes forage outwards (Abdurahman et al. 2010). They feed on dead organic materials such as crop residues, mulches, soil organic matter and live plant materials (Nyeko and Olubayo 2005). The decreasing quantity of litter and soil organic matter, a preferred food source for indigenous termites, compels them to feed on pasture grasses, crops and woody materials (Sekamatte 2001; Mugerwa et al. 2011).

Worldwide, conventional synthetic insecticides are mostly used in termite control (Nyeko and Olubayo 2005). However, many of the synthetic insecticides available to-date are associated with a number of challenges due to toxicity to non-target organisms such as pollinator insects and beneficial microorganisms, resistance development by target insects, environmental pollution and health-related effects including cancer, metabolic diseases such as diabetes, endocrine system disruption and infertility amongst others (Taiwo 2019; Ankit et al. 2020; Anjarwalla et al. 2016). Accessibility to synthetic pesticides for pest control is also limited for many farmers due to high costs and restricted distribution networks (Anjarwalla et al. 2016). This calls for the use of environmentally friendly, readily available, economically viable and culturally acceptable botanical insecticides as an alternative measure, especially for resource-poor farmers (Amoabeng et al. 2013; Isman 2006; Owusu et al. 2008). Many plants have been recognized to have anti-termiticidal and repellent activities against the termites, such as *Cymbopogon citratus* (DC.) Stapf, *Cinnamomum cassia* (L.) J. Presl, *Chrysopogon zizanioides* (L.) Roberty, *Eucalyptus citriodora* Hook., *Eucalyptus globulus* Labill., *Cedrus atlantica* (Endl.) Manetti ex Carriere, *Syzygium aromaticum* (L.) Merr. & L.M. Perry), *Lantana camara* L., Tephrosia vogelii Hook. f., *Vernonia amygdalina* Delile, *Ocimum gratissimum* L., *Tithonia diversifolia* (Hemsl.) A. Gray, *Tagetes minuta* L. and *Azadirachta indica* A. Juss. (Anjarwalla et al. 2016; Zhu et al. 2001; Elango et al. 2012; Nyirenda et al. 2011; Isman 2017).

In Uganda, few studies have focused on anti-termitid plants used in the control of termites. Mwine et al. (Mwine et al. 2011) evaluated the sources of plant-based pesticides in South Western Uganda. Plant-derived products in termite control have traditionally been practised in many parts of Uganda, where farmers have been reported to ferment a mixture of water, tobacco leaves, red pepper and wood ash for 5–14 days to control termites (Mugerwa et al. 2011). Additionally, mixtures of cow urine and plants like *Tephrosia sp, Melia azedarach* L. and *Tagetes* sp have been used by agro-forestry farmers to control termite damage in the country (Nyeko et al. 2004). In Apac district in particular, several locally available plant species have shown pesticidal prospects for termite control and knowledge of pesticidal plants is passed on verbally from one generation to another. However, there is a lack of proper documentation of these plant resources, which could be exploited in developing new standardized bio-pesticides for termite management. Hence, there is an urgent need to survey and document indigenous knowledge and information on the use of these plant species as a cheap and sustainable way to control termites in Uganda and beyond. However, the indigenous knowledge of these plants is fast disappearing because of technical and socio-economic changes. Some of the plants are also being endangered due to the loss of their habitats. The aim of the present study, therefore, was to assess the knowledge of the local people of Apac

District (the Langis) in controlling termites using plants and to identify the plant species they use, as well as the mode of preparation and administration in order to further evaluate their potential for new plant-based anti-termitid products.

Materials and methods

Study area

Apac district is comprised of four sub-counties, namely, Apac, Akokoro, Ibuje and Chegere. The present study was conducted in Ibuje and Apac sub counties (Fig. 1). The district lies within two agro-ecological zones namely the North Western Savannah Grassland in the northern part and the Kyoga Plains in the southern part (Wortmann et al. 1999). There are two rainy seasons and two dry seasons. The lesser rainy season is from April-July and the greater from September to October (Atube et al. 2021). Annual rainfall average is about 1200–1600 mm. The average monthly maximum temperature is 29 °C and the average monthly minimum temperature is 17 °C. The climatic conditions in the district are favorable for termites' growth and development while facilitating the performance of their ecological role. The total population of Apac district, based on 2014 National Census, was 182,975, of which 93,136 were females and 89,839 were males (UBOS 2016). There are 36,152 households and the majority of the population (85%) is engaged in smallholder agriculture, and approximately 94% are rural based. The selected sub counties are major crop producing areas in the district and the crops grown include cereals such as maize, rice, sorghum and millet as well as beans, sunflower, cowpeas, groundnuts, cassava and sweet potatoes.

Population, sampling design and sample size

This study was based on a cross-sectional design carried out using self-administered questionnaires conducted in the selected communities. The target population of farmers was selected using a multistage sampling technique. First, the two sub counties (Ibuje and Apac) were randomly selected out of the list of four sub counties in the district. In each of the selected sub counties, two parishes (Atana and Atik parishes in Apac; Aketo and Amii-Amilo in Ibuje) were randomly selected, totaling four parishes. From each of the parishes, three villages were randomly selected making a total of 12 villages (i.e., Aduni, Ginnery, Otuculuk, Alebtong, Amwonyo-Cao A, Te-itek, Awir, Iwal, Abuli, Arocha, Awiri and Owany Central) for the entire study (Fig. 1). Finally, 381 households (100 females and 281 males) were randomly and proportionally selected from the 12 villages (an average of 33 households per village). In each selected household, household head, spouse or any adult household member (≥ 18 years) was interviewed. The sample size required for the survey was calculated based on Yamane's simplified formula $n = N/1 + N\ (e^2)$ (Yamane 1967), where n is the minimum sample size required, N is the total population in the district, e is the level of precision or acceptable sampling error (5%). Thus, n was determined to be 400.

Data collection

The ethnobotanical survey was carried out from November 2016 to February 2017. The survey was carried out by trained data enumerators. Prior to the survey, meetings with the local leaders from each study site were conducted to inform them about the aims and objectives of the work for authorization to investigate within their communities. The respondents' knowledge of the plants used in the control of termites was assessed using an open-ended questionnaire in the local language (Lango/Luo). Informed consent was obtained from all the participants prior to the administration of the questionnaires. The questionnaires were administered physically to 381 consented respondents (281 males and 100 females). The interviewees are those who were either born in the area or had lived there for most of their lives. The collected data included demographic information such as gender, age and employment status (Table 1). During the interview, questions were asked of each respondent (one per household) to obtain detailed information on the plants that they use to control termites, such as vernacular names, plant part(s) used as well as the methods

Table 1 Description, definition, and values of variables used in the chi-square analysis

Variable	Description	Value and unit of measurement
Dependent variable		
Knowledge	Knowledge of the respondent on anti-termicidal plants	Dummy, 1 = yes (knowledgeable), 0 = No (not knowledgeable)
Independent variablle		
Gender	Gener of the respondent	Dummy variable, 0 = Female, 1 = Male
Age	Age of the respondent (in years)	1 if 18–35, 2 for 36–55, 3 for 56–75 and 4 for greater than 75
Education	Level of education of the respondent	0 for illiterate, 1 for primary, 2 for secondary and 3 for post-secondary

of preparation and modes of administration. Specimens were collected from plants claimed to have anti-termitid activity with the help of actual users. Such plants were later identified by a qualified botanist and voucher specimens deposited at the Makerere University Herbarium, Uganda for future reference. The species names were checked using the catalogue of life (https://www.catalogueoflife.org/data/) and plant families were defined according to the Angiosperm Phylogeny Group classification (APG IV) for the orders and families of flowering plants (Chase et al. 2016).

Data analyses

The ethnobotanical data were entered in Excel and exported to SPSS for Windows, version 26 software, for analysis. Descriptive statistics using frequencies and percentages were used to summarize ethnobotanical and interviewee's socio-demographic data. The association between respondents' knowledge of plants used to manage termites with their gender, educational status and age were tested with Chi-square test. The frequency of citation was calculated to assess the incidence of one particular species used for the control of termites in relation to the overall citations for all plants. The relative frequency of citation index (RFC), calculated as the number of informants/respondents who cited a specific plant species divided by the total number of informants, was used to indicate the local importance of the species for termite control. The Informant Consensus Factor, ICF (Heinrich et al. 1998; Faruque et al. 2018), was calculated to determine the homogeneity in the ethnobotanical information of the respondents using the formula; ICF = Nur − Nt/(Nur − 1), where "Nur" refers to the total number of use reports for each use category and "Nt" refers the total number of species used. The ICF values range from 0 to 1; high ICF values (close to one) are obtained if the species are used by a large proportion of informants or information is exchanged between informants, whereas low ICF values indicate that informants do not exchange information about plants' use or disagree over which plant to use.

Results

Socio-demographic characteristics of respondents and association of traditional knowledge of plants used for controlling termites with gender, age and education status

A total of 381 respondents were interviewed in the study (Table 2), comprising of 100 females (26.2%) and 281males (73.8%). The majority (49.6%) of the respondents were in the age bracket of 36–55 years. 51.4% of the respondents had basic primary education, while 2.4% had post-secondary education. Overall, 70.9% of respondents had some knowledge about using plant to locally control termites. There was a significant association between knowledge of the pesticidal plants with gender ($\chi^2 = 9.2$, df = 1, $P = 0.002$) and age of the respondents ($\chi^2 = 66.5$, df = 3, $P < 0.001$). However, there was no significant association between knowledge of pesticidal plants with the

Table 2 Association of knowledge on pesticidal plants locally used to control termites with age, gender and educational status of the respondents and their socio-demographic characteristics ($n = 381$)

Characteristic	Total number of respondents (%)	Knowledge on pesticidal plants (n)		χ^2	df	P-value	Significance
		No	Yes				
Gender							
Male	281 (73.8)	70	211	9.2	1	0.002	Significant
Female	100 (26.2)	41	59				
Age (years)							
18–35	63 (16.5)	44	19	66.5	3	< 0.001	Significant
36–55	189 (49.6)	47	142				
56–75	100 (26.2)	19	81				
Above 75	29 (7.6)	1	28				
Educational status							
Illiterate	54 (14.2)	9	45	4.8	3	0.186	Not significant
Primary	196 (51.4)	62	134				
Secondary	122 (32.0)	37	85				
Post-secondary	9 (2.4)	3	6				
Knowledge on the plants used to control termites							
Yes	270 (70.9)						
No	111 (29.1)						

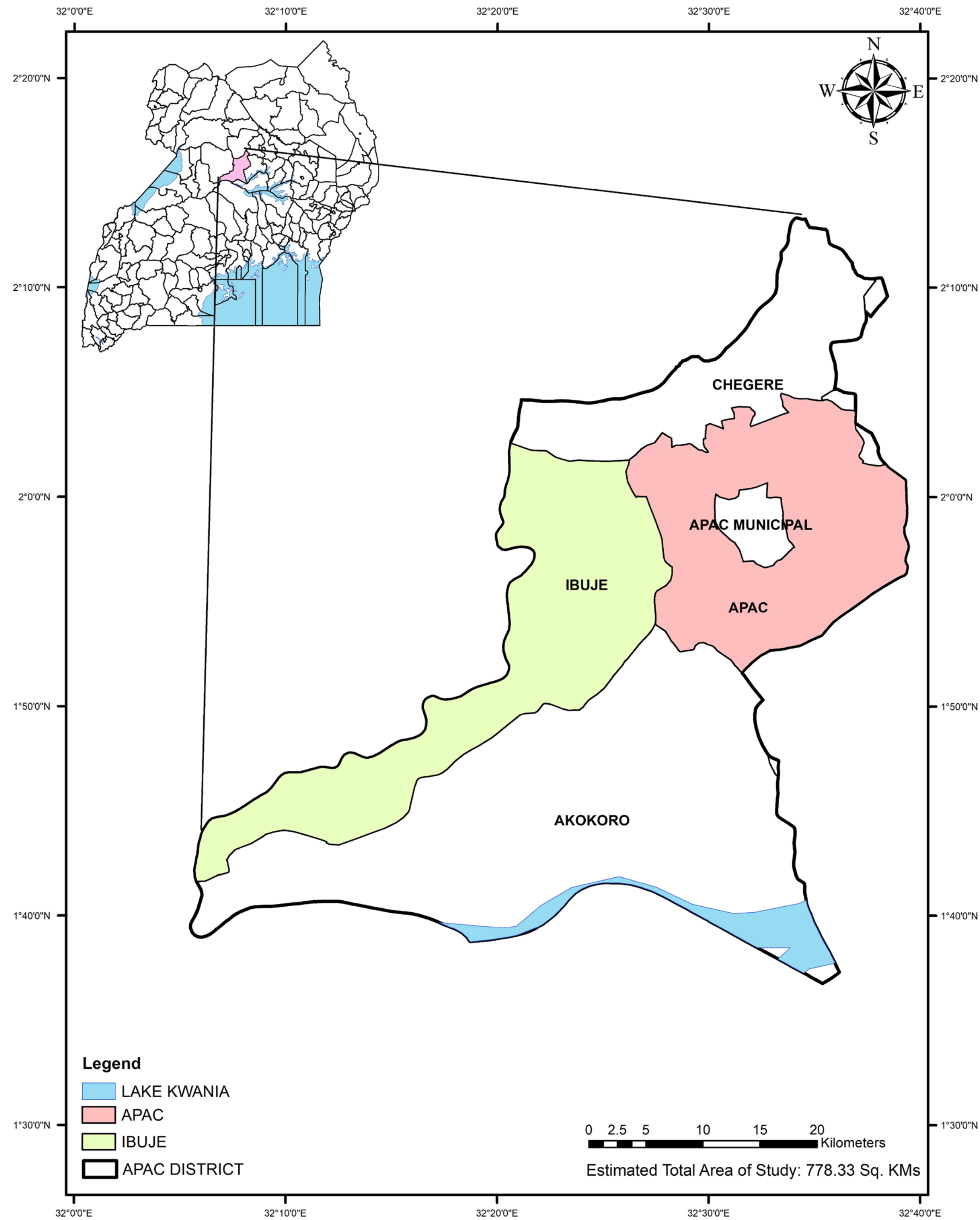

Fig. 1 Location of Apac and Ibuje sub-counties in Apac district, northern Uganda

educational status of the respondents ($\chi^2 = 4.8$, df = 3, $P = 0.186$) (Table 2).

Ethnobotanical plants used for control of termites, their modes of preparation and administration

A total of 11 plant species belonging to eight different families were reported to be used locally in control of termites in Apac District. Table 3 shows the summary of the botanical names of the identified anti-termitid plants, their local names, families, parts employed and frequency of citation. The most used families were Solanaceae, Eurphorbiaceae and Asteraceae (each with two species) while the rest of the families had only one species mentioned (Fig. 2). The ICF value for control of termites was 0.98. The identified species have different growth forms but trees (72.7%) were predominant followed by shrubs (18.2%) and herbs (9.1%). The calculated RFC indicated that plant species such as *Kigelia africana* (Lam.) Benth. (RFC = 0.43), *Vernonia amygdalina* Delile (RFC = 0.18) and *Tithonia diversifolia* (Hemsl.) A. Gray (RFC = 0.10) were the most used in the control of termites while the least used plants were *Nicotiana tabacum* L. (RFC = 0.01) and *Senna siamea* Lam. (RFC = 0.003) in Apac district (Table 3). Different parts of plants were employed for the preparation of pesticidal recipes (Fig. 3), with fruits (45.9%) and leaves (29.2%) the most commonly used plant parts. For some species like *V. amygdalina* and *Senna siamea* Lam., two or more plant parts were used. Fluid extract was the commonest mode of formulation of plant parts accounting for 72.7% of all the plant species used while the least mode (27.3%) was by chopping the plant part into small pieces and inserting into termite mounds. *Vitex doniana* Sweet in particular was used as a trap for termites since termites prefer feeding on the stems/logs. The principal modes of preparation included squeezing, crushing and chopping (Table 3).

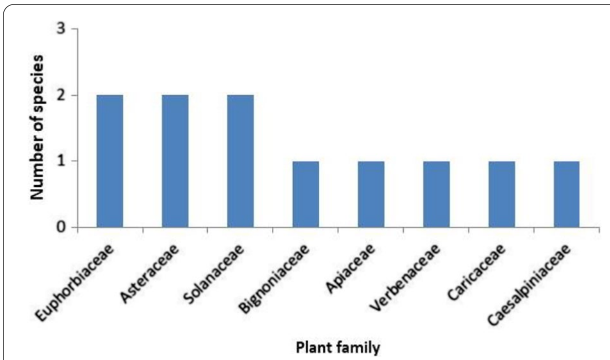

Fig. 2 Number of plant species per family used for control of termites in Apac district, northern Uganda

Discussion

Our study revealed 11 plant species distributed in eight families that are used by the local communities in the study area for control of termites (Table 3). *K. africana*, *V. amygdalina* and *T. diversifolia* were mostly used. Some of the plant species reported in the study area are also known to be used for termite control by farmers elsewhere in Africa e.g., (Anjarwalla et al. 2016; Nyirenda et al. 2011; Isman 2017). The high ICF value (0.98) obtained indicates agreements among respondents on the different plant species used to control termites (Heinrich et al. 1998; Faruque et al. 2018). The three most dominant families (Asteraceae, Solanaceae and Euphorbiaceae) are the best candidates to start from when looking for species with pesticidal importance. Our results to some extent agree with those of Mwine et al. (2011) who found that family Euphorbiaceae was one of the most used sources of plant-based pesticides in South Western Uganda. Several other studies in sub-Saharan Africa have also reported Euphorbiaceae as the dominant family providing biopesticidal plants (Adebayo et al. 2015; Qwarse et al. 2018). The widespread use of these families could be attributed to their range of phytochemical compounds, including polyphenols, phenolic acids, flavonoids, saponins, tannins, acetylenes, coumarins and triterpenes, among others (Rolnik and Olas 2021; Kumar et al. 2010).

Overall, our study shows that generally, the people of Apac district have good knowledge on the use of plants in the control of termites. The possible explanation is that Apac district is dominated by arable farming, with over 80% involved in subsistence farming (UBOS 2016) and all age groups have knowledge on pesticidal plants because of frequent use of these pesticidal plants due to high cost of synthetic pesticides. However, knowledge of pesticidal plants was not associated with the educational status of respondent suggesting that local people have traditional knowledge regardless of their educational status. Males being more knowledgeable about the pesticidal plants compared to the females could be attributed to the men being more engaged in outdoor activities, e.g., farming compared to women (Bello et al. 2019) and because boys are favoured for transfer of traditional knowledge (Kidane et al. 2014). The middle-aged people (36–55 years) being more informed about termite control using plants than the advanced age group (above 55 years) could be attributed to memory loss of ethnobotanical knowledge. A study by Ayantunde et al. (2008) in Southwestern Niger indicated a curvilinear relationship between age of respondents and the number of plant species identified, suggesting that knowledge of plant species drops after a certain age. From a practical point of view, our results emphasize the need for timely transfer of ethnobotanical knowledge to youthful generations.

Table 3 Plants traditionally used for the control of termites among the Langi community in Apac district, northern Uganda

Family and botanical name	Local name (Lango)	Voucher number	Growth form	Plant part (s) used	Mode of preparation and administration	FC	RFC	Reference to similar ethnobotanical use
Bignoniaceae *Kigelia africana* (Lam.) Benth	Yago	OB01	Tr	Fr	Chopping 4–5 large fruits into small pieces and inserting into termite mounds or shred 4–5 large fruits into small pieces, soak for 1–2 days in 5 L of water and pouring into termite mounds	162	0.43	
Apiaceae *Steganotaenia araliacea* Hochst	Ibuc ibuc/ Ilwi ilwi	OB03	Tr	R	Crushing approximately 5 kg of fresh roots, soak in 5 L of water and pouring into termite mounds after 1–2 days	28	0.07	
Asteraceae *Vernonia amygdalina* Delile	Okelo-okello	OB02	SH	L, R	Crushing either a basinful of roots or fresh leaves, (approximately 3 kg), mixing with 5 L of water and pouring into termite mounds after 1–2 days	70	0.18	Anjarwalla et al. (2016); Isman (2017); Mwine et al. (2011)
Tithonia diversifolia (Hemsl.) A. Gray	Akec akec	OB04	Tr	L	Crushing leaves, mix with 5 L of water and pouring into termite mounds in 1–2 days	38	0.10	Osipitan and Oseyemi (2012); Anjarwalla et al. (2016); Isman (2017)
Euphorbiaceae *Euphorbia tirucalli* L	Oligo	OB05	Tr	S, Latex extract from Bark (B)	Crushing approximately 5 kg of tender stems, mix with 5 L of water and pour into termite mounds after 1–2 days, alternatively, extracting approximately 200 mls of latex by injuring stem bark, mixing with 2 L of water and applying immediately into termite mounds	28	0.07	Sileshi et al. (2009); Anjarwalla et al. (2016); Mwine et al. (2011)
Euphorbia candelabrum Trémaux ex Kotschy	Epopong	OB09	Tr	S	Crushing approximately 5 kg of succulent stems/parts, mixing with 5 L of water and pouring into termite mounds after 1–2 days	28	0.07	Mwine et al. (2011)
Solanaceae *Capsicum frutescens* L	Alyera	OB06	H	Fr	Crushing 4–5 mugful of fresh fruit, soak in 5 L of water for 1–2 days and pouring into termite mounds	17	0.04	Mwine et al. (2011)

Table 3 (continued)

Family and botanical name	Local name (Lango)	Voucher number	Growth form	Plant part (s) used	Mode of preparation and administration	FC	RFC	Reference to similar ethnobotanical use
Nicotiana tabacum L	Taba	OB10	SH	L	Soaking 2 mug full of dried leaves in 5 L of water for 1–2 days and pouring into termite mounds	2	0.01	Mwine et al. (2011)
Verbenaceae *Vitex doniana* Sweet	Owelo	OB07	Tr	S, B	Chopping stem into small pieces of 2–3 m long and inserting them into termite mounds	11	0.03	
Caricaceae *Carica papaya* L	Apapalo	OB08	Tr	Fr	Chopping five to six immature fruits with whitish exudates and inserting into termite mounds	9	0.02	Anjarwalla et al. (2016); Mwine et al. (2011)
Caesalpiniaceae *Senna siamea* Lam	Agacia	OB11	Tr	L, B, R	Crushing either a basin full of fresh leaves (about 3 kg of fresh leaves) or approximately 3 kg of fresh root/bark, soaking in 5 L of water for 1–2 days and pouring into termite mounds	1	0.003	

Plant parts used: *L* leaves, *S* stem, *R* roots, *Fr* fruit, *B* bark. Growth form: *Tr* tree, *H* herb, *SH* shrub

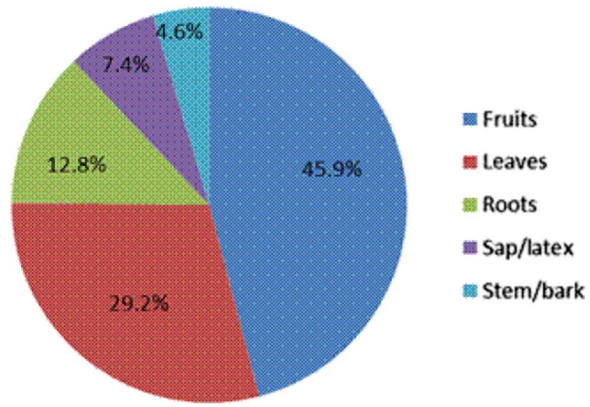

Fig. 3 Plant parts used for control of termites in Apac district, northern Uganda

The use of fruits and leaves mostly for control of termites is in agreement with findings by Mwine et al. (2011) in South Western Uganda. This finding can be attributed to the positioning of these plant parts (leaves and fruits) on the plants. According to the plant defense theory (Massei and Hartley 2000), chemical or structural defenses should be maximized when and where browsing is most likely to occur. Leaves and fruits being exposed parts make them easy targets of attack by herbivores, and for this reason, they tend to deposit and localize a large portion of the secondary substances. From a conservation point of view, harvesting of fruits and leaves for pesticidal use is beneficial since the plant is not destroyed in the process of harvesting. Besides, the collection and processing of leaves and fruits are relatively less laborious and is more sustainable since plants can re-grow new leaves and form new fruits compared to harvesting of roots, bark or whole plants (Rehecho et al. 2011).

Most of the plants were administered through water extract, physical stuffing and latex mixture. This finding is in agreement with previous work in South western Uganda by Mwine et al. (2011), who indicated water extract as the most commonly mentioned mode of formulations against termites. Aqueous extracts of *Citrus sinensis* (L.) Osbeck, *Theobroma cacao* L. and *T. diversifolia* have also been reported to cause mortality and repellency in termites in Ogun state, Nigeria (Osipitan and Oseyemi 2012). The finding is also consistent with a study by Dhang and Sanjayan (2012), which noted that various plant extracts are used under various formulations to control termites and other insect pests.

In conclusion, our study showed that the rural populations in Apac district possess indigenous knowledge on anti-termitid plants. The notable plant species used in termite pest management included *Kigelia africana*, *Vernonia amygdalina*, and *Tithonia diversifolia*. These plants could be utilized for making locally available and effective plant-based anti-termitid pesticides. However, there is need to do systematic screening of the identified plants in order to identify the bioactive compounds responsible for killing the invertebrates in pest management. This will go a long way in improving the agrochemical industry in Uganda. Furthermore, simple methods for local propagation and cultivation are needed to ensure a sustainable supply of termicidal plant biomass.

Abbreviations
RFC: Relative frequency of citation; FC: Frequency of citation; Rt: Roots; Wp: Whole plant; Le: Leaves; St: Stem; Stb: Stem bark; Fr: Fruit.

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Author contributions
BCO, GMM and CO conceived and designed the study; BCO collected field data work and identified plant samples. GMM and RO analysed the data and wrote the initial draft of the manuscript. AA, GIO, KR and ES reviewed the manuscript. All the authors have read and approved the final manuscript.

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Availability of data and materials
These are available whenever required.

Declarations

Ethics approval and consent to participate
Ethical clearance was sought from the Gulu University Research and Ethics committee (Approval No. GUREC-098-18). Written informed consent translated into Luo were sought from the participants after explaining the purpose, expected benefits and associated risks regarding the study. Introductory letters to the sub county authorities were sought from the District's Head of Public Servants (the Chief Administrative Officer). The local chairpersons of the selected villages were informed prior to the study and they were requested to provide the village household registers to enable sampling of the households.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflict of interests.

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References

Abdurahman A, Abraham T, Mohammed D. Importance and management of termites in Ethiopia. Pest Manag J Ethiop. 2010;14:1–20.
Adebayo SE, Samuel AT, Jessica UA. Ethnobotanical survey of pesticidal plants used in Edo State, Nigeria. Afr J Agric Sci Technol. 2015;3(11):448–60.
Adekayode FO, Ogunkoya MO. Comparative study of clay and organic matter content of termite mounds and the surrounding soils. In African Crop Science Conference Proceedings 2009, Vol. 9, pp. 379–384.
Amoabeng BW, Gurr GM, Gitau CW, Nicol HI, Munyakazi L, Stevenson PC. Tri-trophic insecticidal effects of African plants against cabbage pests. PLoS ONE. 2013;8(10): e78651.
Anjarwalla P, Belmain S, Sola P, Jamnadass R, Stevenson PC. Handbook on pesticidal plants. World Agroforestry Centre (ICRAF), Nairobi, Kenya. 2016;64.
Ankit LS, Kishor V, Bauddh K. Impacts of synthetic pesticides on soil health and non-targeted flora and fauna. In: Bauddh K, Kumar Sv, Singh RP, Korstad J, editors. Ecological and practical applications for sustainable agriculture. Singapore: Springer Singapore; 2020. p. 65–88. https://doi.org/10.1007/978-981-15-3372-3_4.
Atube F, Malinga GM, Nyeko M, Okello DM, Alarakol SP, Okello-Uma I. Determinants of smallholder farmers' adaptation strategies to the effects of climate change: evidence from northern Uganda. Agric Food Secur. 2021;10(1):1–4.
Ayantunde AA, Briejer M, Hiernaux P, Udo HM, Tabo R. Botanical knowledge and its differentiation by age, gender and ethnicity in Southwestern Niger. Hum Ecol. 2008;36(6):881–9.
Bello A, Jamaladdeen S, Elder MT, Yaradua SS, Kankara SS, Wagini NH, Stirton CH, Muasya M. Threatened medicinal and economic plants of the Sudan Savanna in Katsina State, northwestern Nigeria. Bothalia-Afr Biodivers Conserv. 2019;49(1):1–7.
Chase MW, Christenhusz MJ, Fay MF, Byng JW, Judd WS, Soltis DE, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. Bot J Linn Soc. 2016;181(1):1–20.
Dhang P, Sanjayan KP. 15 Plants with pest control properties against urban pests. Urban insect pests: sustainable management strategies. 2014;216.
Eggleton P. Global patterns of termite diversity. In Termites: evolution, sociality, symbioses, ecology 2000 (pp. 25–51). Springer, Dordrecht.
Elango G, Rahuman AA, Kamaraj C, Bagavan A, Zahir AA, Santhoshkumar T, Marimuthu S, Velayutham K, Jayaseelan C, Kirthi AV, Rajakumar G. Efficacy of medicinal plant extracts against Formosan subterranean termite, *Coptotermes Formosanus*. Ind Crops Prod. 2012;36(1):524–30.
Faruque MO, Uddin SB, Barlow JW, Hu S, Dong S, Cai Q, Li X, Hu X. Quantitative ethnobotany of medicinal plants used by indigenous communities in the Bandarban District of Bangladesh. Front Pharmacol. 2018;6(9):40.
Heinrich M, Ankli A, Frei B, Weimann C, Sticher O. Medicinal plants in Mexico: healers' consensus and cultural importance. Soc Sci Med. 1998;47(11):1859–71.
Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu Rev Entomol. 2006;51:45–66.
Isman MB. Bridging the gap: moving botanical insecticides from the laboratory to the farm. Ind Crops Prod. 2017;110:10–4.
Kambhampati S, Eggleton P. Taxonomy and phylogeny of termites. In Termites: evolution, sociality, symbioses, ecology 2000 (pp. 1–23). Springer, Dordrecht.
Kidane B, van Andel T, van der Maesen LJ, Asfaw Z. Use and management of traditional medicinal plants by Maale and Ari ethnic communities in southern Ethiopia. J Ethnobiol Ethnomedicine. 2014;10(1):1–5.
Kumar S, Malhotra R, Kumar D. Euphorbia hirta: its chemistry, traditional and medicinal uses, and pharmacological activities. Pharmacogn Rev. 2010;4(7):58.
Massei G, Hartley SE. Disarmed by domestication? Induced responses to browsing in wild and cultivated olive. Oecologia. 2000;122(2):225–31.
Mitchell JD. Termites as pests of crops, forestry, rangeland and structures in southern Africa and their control. Sociobiology. 2002;40(1):47–69.
Mugerwa S, Nyangito M, Nderitu J, Bakuneta C, Mpairwe D, Zziwa E. Farmers ethno-ecological knowledge of the termite problem in semi-arid Nakasongola. Afr J Agric Res. 2011;6(13):3183–91.
Mwine TJ, Van Damme P, Gerard K, Charles K. Ethnobotanical survey of pesticidal plants used in South Uganda: Case study of Masaka district. J Med Plant Res. 2011;5(7):1155–63.
Nyeko P, Stewart J, Franzel S, Barklund P. Farmers' experiences in the management of pests and diseases of *Calliandra calothyrsus* in Uganda. Uganda J Agric Sci. 2004;9(1):520–9.
Nyeko P, Olubayo FM. Participatory assessment of farmers' experiences of termite problems in agroforestry in Tororo District. University of Nairobi; 2005. http://hdl.handle.net/11295/33728. Accessed 7 Jan 2021.
Nyeko P, Gohole LS, Maniania NK, Agaba H, Sekamatte BM. Evaluation of *Metarhizium anisopliae* for integrated management of termites on maize and *Grevillea robusta* in Uganda and Kenya. In second RUFORUM Biennial Meeting 2010 Sep 20 (pp. 333–337).
Nyirenda SP, Sileshi GW, Belmain SR, Kamanula JF, Mvumi BM, Sola P, Nyirenda GK, Stevenson PC. Farmers' ethno-ecological knowledge of vegetable pests and pesticidal plant use in Malawi and Zambia. Afr J Agric Res. 2011;6(6):1525–37.
Okwakol MJ, Sekamatte MB. Soil macrofauna research in ecosystems in Uganda. Afr J Ecol. 2007;45:2–8.
Osipitan AA, Oseyemi AE. Evaluation of the bio-insecticidal potential of some tropical plant extracts against termite (Termitidae: Isoptera) in Ogun State, Nigeria. J Entomol. 2012;9(5):257–65.
Owusu EO, Akutse KS, Afreh-Nuamah K. Effect of some traditional plant components on the control of termites, *Macrotermes* spp (Isoptera: Termitidae). Afr J Sci Technol Innov Dev. 2008;9:83–9.
Pomeroy DE, Bagine RK, Darlington JP. Fungus-growing termites in East African savannas. Afr Wildl Res Manag. 1991:41–50.
Qwarse M, Mihale MJ, Sempombe J, Mugoyela V, Henry L, Sunghwa F. Ethnobotanical survey of medicinal and pesticidal plants used by agropastoral communities in Mbulu District, Tanzania. Tanzania J Sci Technol. 2018;1(1):22–35.
Rehecho S, Uriarte-Pueyo I, Calvo J, Vivas LA, Calvo MI. Ethnopharmacological survey of medicinal plants in Nor-Yauyos, a part of the Landscape Reserve Nor-Yauyos-Cochas, Peru. J Ethnopharmacol. 2011;133:75–85. https://doi.org/10.1016/j.jep.2010.09.006.
Rolnik A, Olas B. The plants of the asteraceae family as agents in the protection of human health. Int J Mol Sci. 2021;22(6):3009.
Sekamatte MB. Options for integrated management of termites (Isoptera: Termitidae) in smallholder maize-based cropping systems in Uganda. PhD dissertation, Makerere University, Uganda. 2001;289.
Sileshi GW, Nyeko P, Nkunika PO, Sekematte BM, Akinnifesi FK, Ajayi OC. Integrating ethno-ecological and scientific knowledge of termites for sustainable termite management and human welfare in Africa. Ecol Soc. 2009. https://doi.org/10.5751/ES-02877-140148.
Taiwo AM. A review of environmental and health effects of organochlorine pesticide residues in Africa. Chemosphere. 2019;220:1126–40.
UBOS. The National Population and Housing Census 2014—Main Report, Kampala: Uganda Bureau of Statistics. 2016. http://www.ubos.org/onlinefiles/uploads/ubos/NPHC/2014%20National%20Census%20Main%20Report.pdf. Accessed 11 Dec 2021
Verma M, Sharma S, Prasad R. Biological alternatives for termite control: a review. Int Biodeter Biodegr. 2009;63(8):959–72.
Wortmann CS, Eledu CS. Uganda's agroecological zones: A guide for planners and policy marker. 1999, Science and Education publishing, Kampala, Uganda pp 55.
Yamane T. Statistics: an introductory analysis. 2nd ed. New York: Harper and Row; 1967.
Zhu BC, Henderson G, Chen F, Fei H, Laine RA. Evaluation of vetiver oil and seven insect-active essential oils against the Formosan subterranean termite. J Chem Ecol. 2001;27(8):1617–25.

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