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Ethnobotanical study of pesticidal plants against human harmful insects in Central Burundi

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Abstract

Human harmful insects include mosquitoes, lice, fleas, flea-biters, bedbugs, flies and fire ants. Developing countries, such as Burundi; are challenged in the access of chemical products to control these insects. The present study aims to control human harmful insects with pesticidal plants based on ethnobotanical knowledge of Burundians. A survey on pesticidal plants was carried out using a questionnaire on 250 participants in Gitega province, Central Burundi. The consensus index (CIs) was used to analyse the credibility of the information collected. Seventy five percent of participants recognized at least one pesticidal plant. The present study reveals 69 plant species divided into 35 families. The Asteraceae (8 species) and Euphorbiaceae (6 species) families were the most represented. Of all the plant species recorded, the most exploited part is the leaf (47% of species) and 50% of species are used without prior preparation, while 22% are roasted before use or administration. The local application is most used (for 46% of species). The most cited species are Tetradenia urticifolia (ICs: 0.60), Euphorbia tirucalli L (ICs: 0.10) and Tagetes minuta L (ICs: 0.06) repelling fire ants, Solanum incanum (ICs: 0.60) and Gymnanthemum amygdalinum (ICs: 0.12) treating the flea-bites. The present study showed a large number of pesticidal plants, some of them having a considerable potential in the control and treatment of these insects and their bites. The preferred use of the leaves leads to a promising valorisation with less impact on sustainable conservation of the reported plant species.The present study reveals the importance of pesticidal plants knowledge with an emphasis on plants against flea-bites and fire ants (31 and 23 species respectively).
Our results suggest the need of phytochemical studies aiming at the production of effective and affordable plant-based pesticides..

Keywords: *Burundi; biopesticides; human harmful insects; pest control*

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Introduction

Some insects are among the vectors of disease and represent a major threat to human health worldwide. These include mosquitoes, phlebotomines, reduvae, simulidae, ticks, tsetse flies, acarids, gasteropods and lice (WHO, 2017). In developing countries, disease-carrying insects are growing quickly due to non-decent habitats, increased population movement as well as their possessions (WHO, 2019) . Some of these insects cause about 76% of infections of diseases communicable to humans (OMS, 2021).

According to the World Health Organization, insect pest control remains a significant barrier to the implementation of the regional disease vector control framework in the Great Lakes sub-region (OMS, 2019).

In Burundi; human harmful insects include mosquitoes, lice, fleas, fleas-biters, bedbugs, flies, and fire ants. (PND, 2018) emphasizes the low household income of Burundian populations and the difficulty of access to chemical insecticides for the control of these insects. An additional great challenge is that the large proportion of these insects are resistant to synthetic insecticides (OMS, 2019). To address these challenges, the population use pesticidal plants. These represent an important group of natural compounds which are generally safer for humans and the environment than synthetic insecticides (Stevenson et *al*., 2017). The use of pesticidal plant extracts in the control of harmful insects has several advantages in terms of preventing the growth of these insects; their low levels persistence in nature and their usually low cost (Tembo et *al*., 2018). They are also successful and their use may be an alternative to chemical insecticides, likewise could reduce the harm of these insects (Rioba et *al*., 2020)

In this regard, a study was carried out in the province of Gitega, in central Burundi, to document the knowledge of the local population on pesticidal plants. And the aims of this study were: (i) to inventory the species of pesticidal plants used by the local population of Gitega; (ii) to identify the different parts of the plants (used), the mode of preparation, the mode of application and/or use, (iii) to identify the most used pesticidal plants in the study area. (iv) to evaluate the availability of these pesticide plants in nature. These findings of this study will serve as a database on pesticidal plants in Burundi.

Materials and methods

Study area

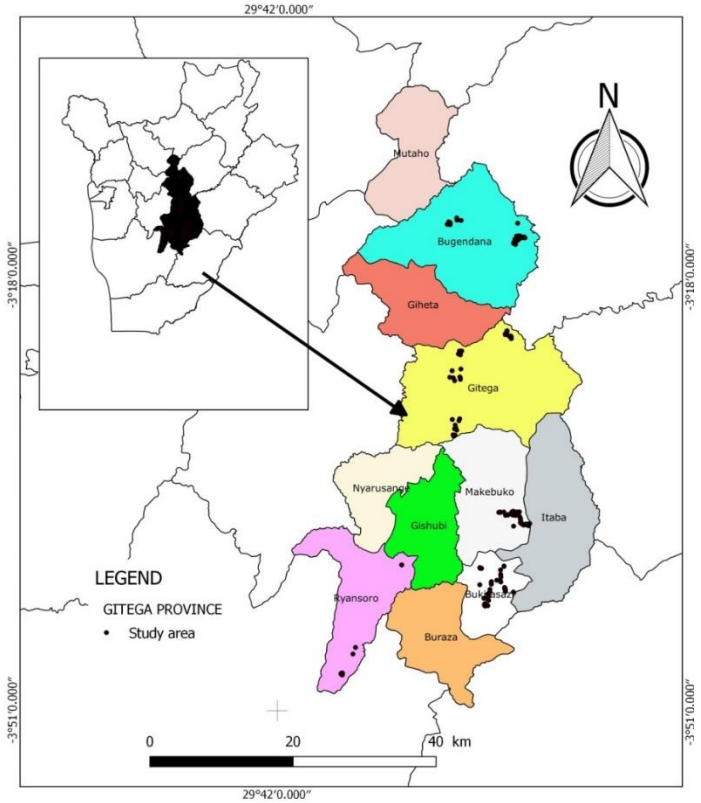

Figure 1. Map of study area

The study was conducted in the province of Gitega, which is located in the central plateau zone with an altitude varying between 1600 and 2000 m. The climate is characterized by two seasons: the dry season and the rainy season. The work was carried out in five communes, including Bugendana, Gitega, Makebuko, Bukirasazi and Ryansoro (Figure 1). The digitizing of the study area was done using Quantum GIS software version 2.18.13.

Data collection

Data was collected from 250 persons in five communes of Gitega (see fig.1) chosen on the basis of their differences in terms eco-climatic diversity. Data was carried out in November-December 2020. The respondents included women (n=149) and men (=101) with ages ranging from 20 to 90 years.

First, permission was obtained from local authorities in each commune to carry out this research. We selected all age categories including elders who are known to have greater botanical knowledge. During the survey, the different socio-economic environments (rural, urban or semi-urban) were also considered. A survey questionnaire was designed for this purpose and the interviews done in Kirundi as all respondents understood the language.The participants were to share their knowledge of pesticidal plants against seven human pests: mosquitoes, lice, fleas, ticks, bedbugs, flies and fire ants, the ecology and availability of those plants.

Plant samples were collected and taken to the Herbarium of the University of Burundi and/or the herbarium of the Office Burundais pour la Protection de l'Environnement (OBPE) for identification. Prior to herbarium identification, scientific names has been checked from Nzigidahera *et al*., (2020). Plant nomenclature followed the African Plant Database (version 3.4.0, African Plant Database, 2020).

Data analysis

All data were entered and processed in Microsoft Excel. The study allowed us to present the results in the form of a summary table gathering all the information on those pesticidal plants. For these results the flat sorting method was used (Chardon, 1981).

To confirm the pesticidal property of the plant species identified during the survey, the confirmation index or consensus factor of the informants was calculated (Masengo et *al*., 2021; Ngbolua et *al*., 2016).

$$ICs = Na/Nt$$

Where Na and Nt are the number of people who cited a species and the total number of people interviewed with knowledge (Lassa et *al*., 2021). A high value, close to 1, indicates most respondents know about the use of the plant. A low value, close to 0, indicates respondents do not have much knowledge about the plant.

Results

Inventory of pesticidal plants against insects harmful to humans

The results of our study revealed 69 species of pesticidal plants used by the local population in Gitega province. Among these species, 31 were used for the treatment of flea-biters; 23 for repelling fire ants; 14 for repelling mosquitoes; 13 for repelling fleas; 8 for killing bed bugs; 7 for killing lice and 6 for repelling flies. The plant species inventoried were classified into 35 families. The Asteraceae family was most represented with 8 species followed by Euphorbiaceae (6 species), Fabaceae and Solanaceae (5 species respectively).

Figure2. Distribution of species in family

Table 1 provides information on the pesticide plant species inventoried, their taxonomy, the parts of the plant used for the control of human pests, their mode of preparation and their mode of use. The habitat and availability of these plant species as well as the confirmation index of the informants corresponding to each species are also mentioned.

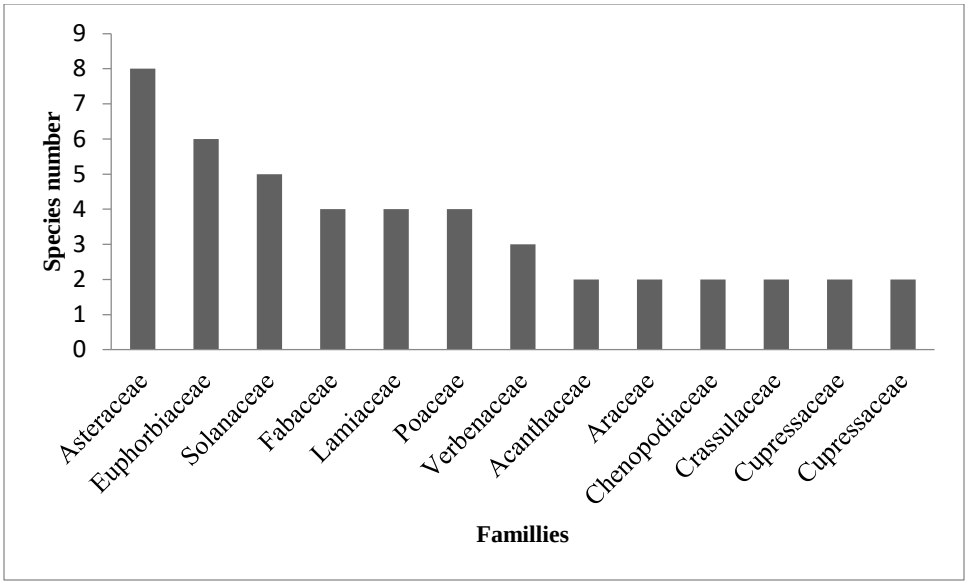

Figure 2. Families of species inventoried

Table 1. Species of pesticidal plants against the seven human pests cited during the interviews in Gitega province with their taxonomy, their preparation methods; their utilization mode and their consensus index

Scientific name	**local name**	**families**	Insects	Habitat	Part used	Method of preparation	Mode of use	ICs
Acanthus pubescens (Thomson ex Oliv.) Engl.	Igitovu	Acanthaceae	Fl M FA	Sa[a] Fa[c] Bu[b]	LS L	-	Hanging on walls Expansion of volatile compounds by beating, Put plants in colony	0,05 0,01° 0,01¶
Afromomum angustifolium	Intaki	Zingiberaceae	FB	S R[d]	Fr	Grinding	Local application	0,01
Ageratum conyzoides L.	Akarura	Asteraceae	FB	Fa[a]	L	Hand rubbing	Local application	0,01
Aloe macrosiphon BAKER.	Ingagari	Aloaceae	FB	Fi[c]	L	-	Local application	0,01
Aspilia africana subsp. magnifica (Chiov.) Wild	Icumwa co ku musozi	Asteraceae	FB	Sa[b]	L	Burning	Local application	0,01
Bothriocline Longipes(Oliv et Hiern) .N.E.Br	Umubebe	Asteraceae	FB	Fa[a]	L	Hand rubbing	Local application	0,01
Bridelia scleroneura Müll. Arg.	Umunemberi	Solanaceae	FB	Fa[c]	Fr	Grilling	Local application	0,01
Callitris glaucophylla	Icedrela	Cupressaceae	M F	Fo[b]	LS	- Burning	Smoke expansion in the house Smoke expansion	0,01 0,05•
Capsicum fructescens	Agapiripiri	Solanaceae	FB FA	Fi[b]	Fr	Grinding Piloting	Local application Spraying	0,01* 0,01¶

Carica papaya L.	Ipapayi	Caricaceae	B	Fi[b]	L	Expression	Spraying	0,01
Sesbania sesban (L.) Merr.	Umunyegenyege	Fabaceae	FB	Fi[b]	L	Grinding	Local application	0,01
Casuarina equisetifolia L.	Akajwari	Casuarinaceae	Fl	Fo[c]	LS	-	Put plants in colony	0,01
Chenopodium procerum Hochst. ex Moq.	Umuncekе	Chenopodiaceae	FA	Fi[c]	W	-	Put plants in colony	0,01
Chenopodium ugandae (Aellen) Aellen	Umugombe	Chenopodiaceae	FB FA	Fi[c]	L	Hand rubbing maceration	Local application	0,01 0,01¶
Citrus limon (L.) Burm. f.	Indimu	Rutaceae	M	Fi[b]	Fr	-	Put plants in colony	0,01
Clerodendrum Johnstonii Oliver	Umunyankuru	Verbenaceae	F	Sa[c]	LS L	-	Put plants in colony	0,01
Clerodendrum rotundifolium Oliver	Ikiziranyenzi	Verbenaceae	F	Sa[b]	LS	-	Put plants in colony	0,01
Conyza sumatrensis (Retz.) E. Walker	Akarurase mukobwandagowe	Asteraceae	FB	Fi[b]	L	Hand rubbing	Local application	0,01
Colocasia esculenta (L.) Schott	Itekery'ikirundi	Araceae	FA	Fi[b]	P L	Burning in the fireplace	Expansion of volatile compounds	0,01
Colocasia esculenta (L.) Schott	Itekery'ikizungu	Araceae	FA	Fi[a]	L	Burning in the fireplace	Expansion of volatile compounds by beating	0,01
Cupressus sp.	Isederi	Cupressaceae	M Fl	Fo[b]	LS	-	Smoke expansion in the house	0,03° 0,01
Cymbopogon citratus (DC.) Stapf	Icayicayi	Poaceae	M FA	Fi[c]	w	-	Put plants in colony	0,01; 0,01¶
Cyperus papyrus	Inkorogoto	Cyperaceae	FA	SR[d]	S	-	Put plants in colony	0,01
Dracaena afromontana Mildbr.	Inganigani	Dracaenaceae	FA	HF	LS	-	Volatile compounds extension Local application Smoke expansion in the house	0,01 0,01
Elaeis guineensis f. androgyna A. Chev	Ikigazi	Arecaceae	FB M B Fl	Fi[d]	Oil Fr B	Extracting oil	Spraying Application on wounds	0,01° 0,01* 0,01**
Eleusine coralana	Ururo	Poaceae	F	Fi[b]	S E	Piloting	Put plants in colony	0,01

Eragrostis olivaceae K. Schum	Ishinge	Poaceae	M	Sa[a]	L	-	Smoke expansion in the house Put plants in colony	0,01
Eucalyptus globulus subsp. maidenii (F. Muell.) Kirkp.	Umukuaratusi wera	Myrtaceae	M F	Fo[c]	LS L	-	Smoke expansion in the house Put plants in colony	0,01 0,01•
Euphorbia Candelabrum Welw.	Igihahe	Euphorbiaceae	FB	Fi[c]	La L	Grinding Burning	Local application	0,02
Euphorbia grantii	Imamburra	Euphorbiaceae	FB	HF[b]	La	-	Local application	0,02
Euphorbia tirucalli L.	Umunyari	Euphorbiaceae	FB FA	HF[a]	L La	- -	Local application Volatile compounds extension	0,02 0,10¶
Gnidia kraussiana Meisner	Agasakuza	Thymelaeaceae	FB	Sa[d]	Rz	Grinding Piloting	Local application	0,04
Gymnanthemum amygdalinum (Delile) Sch. Bip. ex Walp.	Umubirizi	Asteraceae	FB L B FA	Fi[b] HF[b]	L	Hand rubbing Piloting Expression	Local application Decoction Spraying Expansion of volatile compounds by beating	0,12* 0,01 0,01** 0,01¶
Heteromorpha arborescens Cham. & Schltdl.	Umuvyintira	Apiaceae	FA	Sa[c]	LS	-	Put plants in colony	0,01
Ipomea patatas	Ikijumbu	Convolvulaceae	FB FA	Fi[a]	w	-	Local application	0,01
Isoberlinia Angolensis	Umurembera	Fabaceae	M	Sa[d]	R	Expression	Spraying	0,01
Jatropha curcas L.	Ikivurahinda	Euphorbiaceae	FB	Fi[c]	La	-	Local application	0,01
Justicia subsessilis Oliv.	Umbazibazi	Acanthaceae	M F	Sa[c]	R	Burning	Smoke expansion in the house	0,01 0,01•
Kalanchoe crenata (Andrews) Haw.	Ikinete(igitenetene)	Crassulaceae	FB	Sa[d]	L	Hand rubbing	Local application	0,01
Kalanchoe grantii	Umukoni	Crassulaceae	FB	HF[a]	La	-	Local application	0,01
Lantana camara L.	Mavyiyakuku	Verbenaceae	FA	HF[a]	L	-	Put plants in colony	0,01
Laportea alatipes Hook.f.	Igisuru	Urticaceae	FA	Fi[d]	L	-	Expansion of volatile compounds by beating	0,01
Manihot esculenta Crantz	Umwumbati	Euphorbiaceae	FA	Fi[a]	S	-	Burning in the fire place	0,02
Melinis minutiflora P. Beauv.	Ikinyamavuta	Poaceae	F	Sa[a]	W	-	Put plants in colony	0,01
mimosoideae sp	Umubaragasa	Fabaceae	F	FBS[d]	L	Burn	Smoke expansion in the house	0,01

Mirabilis jalapa L	karifumu	Nyctaginaceae	FB	Fi[c]	Se	-	Local application	0,01
Momordica foetida Schumach.	Umwishwa	Cucurbitaceae	FA	HF[c]	W	Maceration	Spraying Hanging on the wall or above the door	0,03
Musa sp.	Igitoki	Musaceae	FA	Fi[a]	Bu	Burning in the fireplace	Put plants in colony	0,01
Neorautanenia mitis (A. Rich.) Ver dc.	Intembe	Fabaceae	M FB B	Fa[c]	Rz	Expression Grinding	Spraying Local application	0,01 0,01 * 0,01**
Persicaria nepalensis (Meisn.) H.Gross	Akaboza	Polygonaceae	FA	Fi[b]	w	-	Volatile compounds extension	0,01
Phytolacca dodecandra L'Herit	Umwokora	Phytolaccaceae	FB	Fi[c]	L	Hand rubbing	Local application Suspend under mats in the bed	0,03
Plectranthus barbatus Andrews	Igicuncu	Lamiaceae	F FB FA	Fi[c]	L	Hand rubbing	Volatile product expansion Local application	0,01 0,03* 0,02¶
Plectranthus defoliatus Hochst. ex Benth.	Umukuyangoma	Lamiaceae	L F	Sa[c]	LS	warm water decoction	Applied directly into the hair Volatile compounds extension	0,02 0,01*
Plectranthus zatarhendii (Forsskal) E. A Bruce	Twamanyama	Lamiaceae	F	Fi[c]	w	-	Expansion of volatile compounds by beating	0,01
Polygala ruwenzoriensis Chodat	Urwijo	Polygalaceae	B	Sa[c]	L	Expression	Spraying	0,01
Psorospermum febrifugum Spach	Umukubarwa	Hypericaceae	FB	Sa[b]	B	Infusion	Local application	0,01
Rauvolfia mannii Stapf.	Ibamba	Apocynaceae	B	Sa[d]	L	Expression	Spraying	0,01
Ricinus communis L.	Ikibonobono	Euphorbiaceae	M	Fi[c] Fa	Se	Extraction	Smoke expansion in the house	0,01
Senecio maranguensis O. Hoffm.	Imbatura	Asteraceae	FB	Sa[d]	L	Grinding	Local application	0,01
Sensevieria parva	Imbogobogo	Agavaceae	L	Fa[b]	L	-	Rub on the head	0,01
Sesamum angolense Welw	Umurendarenda	Pedaliaceae	L	Fa[b]	L	-	Rub on the head	0,01
Solanum incanum L	Intobotobo	Solanaceae	L F FB	Sa Fa Bu[b]	Fr	Grilling Expression Piloting	Application to clothing Spraying Local application	0,01 0,01• 0,60*
Solanum tabacum	Itabi	Solanaceae	FA	Fi[b]	L	Burning	Smoke extension around the fire ants	0,02

							Expansion of volatile compounds by beating	
Solanum aethiopicum L	Intore	Solanaceae	B	Fi[b]	L	Expression	Spraying	0,01
Sonecio cydoniifolius O.hoffin	Irarire	Asteraceae	FB	Fi[c]	L	Hand rubbing	Local application	0,01
Tagetes minuta L	Igisumurenga(Ikimogimogi)	Asteraceae	FA	Fi[b]	W	-	Expansion of volatile compounds by beating	0,06
Tephrosia nana			Fl					0,01
Kotschy ex Schweinf.	Ntibuhunwa	Fabaceae	M		W		Put plants in colony	0,01°
			B	Fi[c]	L	Expression	Spraying	0,01**
							Expansion of volatile compounds ,	0,01° 0,01•
			M			Burning	Spraying	0,018
			F			Expression	Local application ,	*
Tetradenia urticifolia (Baker) Phillipson	Umuravumba	Lamiaceae	FB Fl FA	Fi HF[b]	L LS	Decoction Hand rubbing	Expansion of volatile compounds by beating	0,01 0,60¶
Virectaria major (K.Schum.) Verdc.	Umukizikizi	Rubiaceae	FB	Sa[b]	L	Grinding	Local application	0,01

Key: Insect control: FA fire ant, FB flea-biters, M mosquitos, F flea, Fl flies, L lice, B bedbugs; habitat: Sa savannah, Fa fallow, Bu bruch, Fi field, HF house fencing, FBS field border stone, SR side of river, Fo forest; parts used: S stem, LS leaf stem, Bu bud, Fr fruit, PL pestiole &limb, W whole plant, B bark, Se seeds, La latex, L leaves, R root.

b Species reported as abundant

[a] Species reported as very abundant: Informant consensus index for flea ¶: Informant Consensus Index for fire ants

: Informant consensus index for flea-biters *: Informant Consensus Index for bedbugs °: Informant consensus index for mosquitos

[c] Species reported as less abundant [d] Species reported as rare

Pesticidal plants with a high consensus index for each insect were *Solanum incanum* (0.60) for flea - biters, *Tetradenia urticifolia* (0.60) for fire ants, *Acanthus pubescens* (0.05) for flies, *Cupressus sp*. (0.03) for mosquitoes, *Plectranthus defoliatus* (0.02) for fleas. *Solanum incanum* was also cited for the control of lice with a consensus index of 0.01. All pesticidal plant species cited for bed bug control had the same consensus index of 0.01.

Identification of most cited pesticidal plant species for different human harmful insects

Our results show a good knowledge on pesticidal plant species by the local population of Gitega Province and the importance of species varies according to the consensus index. They cited a total of 69 plant species with their pesticidal properties. The most mentioned species were found to be of multiple uses in the control of at least three insects. This underlines their great usefulness in the treatment of insects harmful to humans in Gitega province.

Among the pesticidal plant species most represented on each insect are *Solanum incanum* (ICs: 0.60), *Tetradenia urticifolia* (ICs: 0.60), *Gymnanthemum amygdalinum* (ICs: 0.12), *Capsicum fructescens* (ICs: 0.05),

Euphorbia Candelabrum (ICs : 0 ,03), *Euphorbia tirucalli* (ICs : 0,10), *Tagetes minuta* (ICs : 0,6), *Colocasia esculenta* (ICs : 0,05), *Acanthus pubescens* (ICs : 0,05).

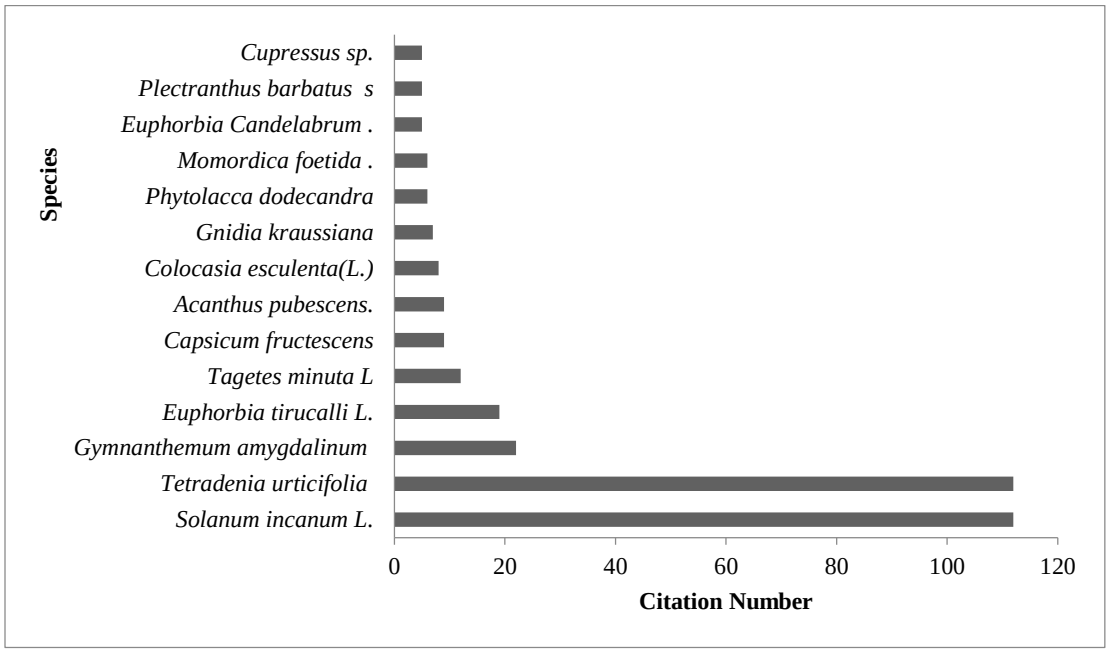

Figure 3. Most pesticidal plant species mentioned

Parts used, preparation and use mode of the inventoried plants

The plant parts used against the seven insects were leaves, branches, fruit, stem and bud, bark, root, seed, rhizome and eleusin sound. For some plants, extracts such as latex and oil are sometimes used. It should be noted that for some pesticide species the whole plant is used (4%). For all these parts, the leaf was the most used part in control of the seven insects harmful to humans (47%) (Figure 4)

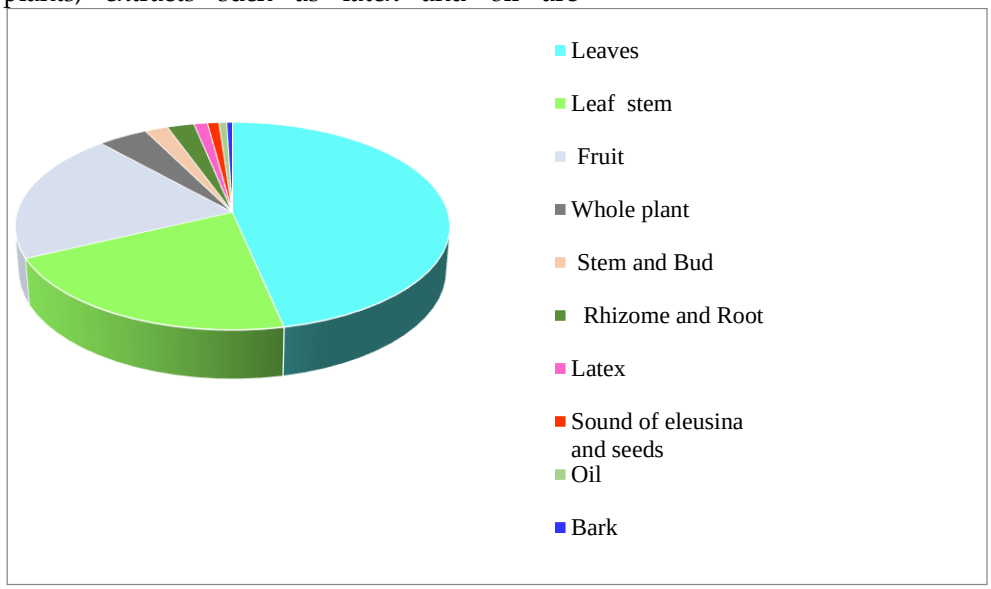

Figure 3. Parts of plant used for insect activity

The preparation methods of the pesticidal plants are shown in Figure 5a. Half of the pesticidal plants are used without prior preparation. Plants with pesticidal properties are used directly on the

insect and/or the local infested area. Local application is the most used mode of administration (46%) (Figure 5b).

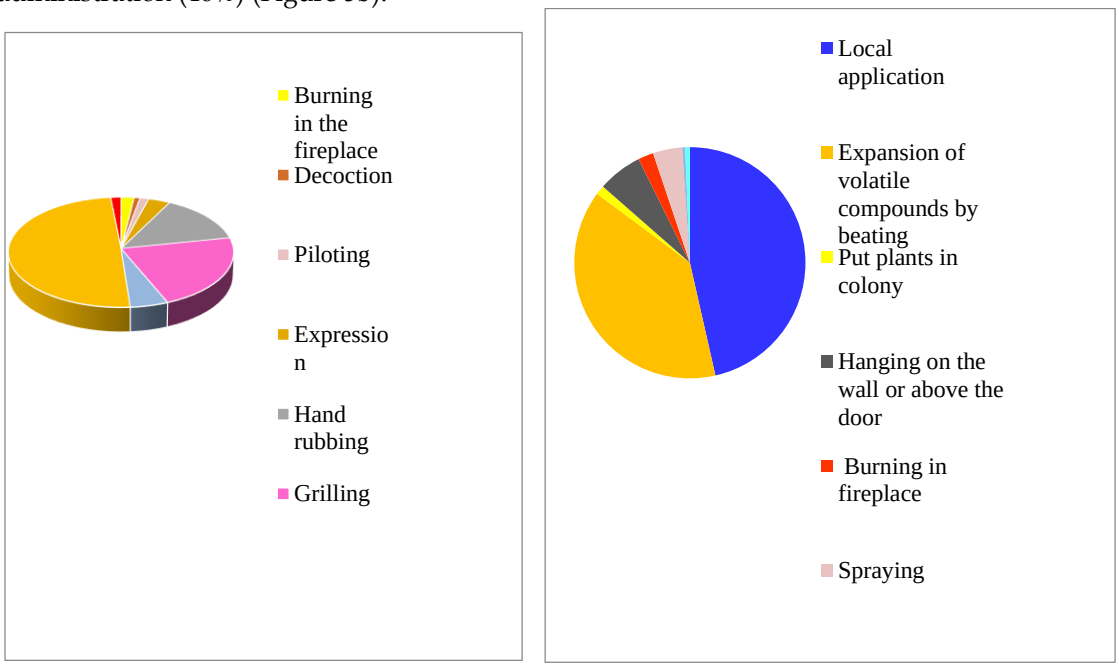

Figure 5. Mode of preparation of plant (a) and application method (b)

Habitats, availability of pesticide plants mentioned

The local population mentioned 69 pesticide plant species.The habitats of these species are forests, savannahs, fields, fallows and bushes. Some species are also found along rivers. The others are domesticated by the population and planted around households as household fences. Half of the species mentioned are found in crop fields and on household fences. These species include *Tetradenia urticifolia, Gymnanthemum amygdalinum, Capsicum fructescens, Phytolacca dodecandra, Euphorbia Candelabrum, Euphorbia tirucalli, Tagetes minuta, Colocasia esculenta, Momordica foetida, Plectranthus barbatus, Solanum tabacum*. Other species are found in fallows, savannahs and rarely in artificial forests and bushes.

Discussion

Diversity of pesticide plants

The study area has a diverse flora used in the control of various human harmful insects. The local population of Gitega has a huge traditional knowledge of pesticidal plants. The families Asteraceae, Euphorbiaceae, Fabaceae, Solanaceae, are the most represented in the control of these insects. These results corroborate with those of others including (Galabuzi et *al.*, 2016; Lassa et *al.*, 2021; Ngezahayo et *al.*, 2015) who reported the importance of these plant families in traditional medicine.

The Lamiaceae and Solanaceae families were most cited for the treatment of fire ants and flea-biters respectively. Previous work has also shown the importance of these families in the treatment of coronavirus in Morocco (Alami et *al.*, 2020) Indeed, the richness of Fabaceae, Poaceae and Asteraceae has also been reported to be very diverse in terms of species in Burundi (Masharabu et *al.*, 2012). The Asteraceae, Fabaceae and Euphorbiaceae families are important in traditional medicine for the treatment of mosquitoes and ticks in Ethiopia (Kazaba et *al.*, 2020) The reason behind the high use of pesticidal plant species could be attributed to their richness in bioactive compounds (Hammadi et *al.*, 2021; Zardeto-Sabec et *al.*, 2020). The Asteraceae family are rich in bioactive compounds (Alara et *al.*, 2019)

The majority of the pesticidal plants inventoried control more than one insect pest. This is the case

of Tetradenia urticifolia for the control of mosquitoes, fleas, flea beetles, flies and fire ants. This is probably attributed to the presence of many metabolites in a particular plant and also to the fact that the same active molecule controls several insect pests to humans (Zardeto-Sabec et *al.*, 2020)

Most cited pesticidal plant species for different pests

The results of this studyshows the most commonly used pesticidal plant species in Gitega province, such as Solanum incanum, which is recognized as an insecticide against lice, fleas and flea beetles. This species of plant is the most used for the treatment of fleas and ticks with a very high consensus index. The use of this plant may be attributed to its richness in bioactive compounds (Sbhatu & Abraha, 2020). The importance of Solanum incanum has also been reported in Ethiopia in the control of cattle ticks (Sbhatu et *al.*, 2021). The study also observed that Tetradenia urticifolia was used for control of several insects including mosquitoes, fleas, flea-biters, flies and fire ants with a very high consensus index as an insect repellent for fire ants.

These properties could be attributed to its phytochemical composition. Other research has shown the importance of Tetradenia urticifolia in attracting fruit flies (Blythe et *al.,* 2020) Gymnanthemum amygdalinum, on the other hand, is known as an insecticidal plant against lice, fleas-biters, and bedbugs and insect repellent against fire ants. This can be explained by its richness in bioactive compounds essential for the control of insects (Alara et *al.*, 2019)

Parts used, preparation and use mode of the inventoried plants

The results of this study shgow that the leaf is the most used part followed by the leafy stem. Recent studies have shown that the leaf is the seat of photosynthesis is responsible for biological properties (Lassa et *al.*, 2021; Obakiro et *al.*, 2020; Tugume et *al.*, 2016). These results are similar to those of Bekele et *al.*,(2012); Ngbolua et *al.*,(2016) who reported that the leaf is the most used part in traditional medicine. The use of leafy stems could cause the disappearance of native plants, which was very rare in our study area.

The results reveal that 50% of the plants were used without prior preparation, the most used mode of preparation being grilling while other research on pesticidal plants have shown that the most used preparation mode is decoction (Bouredja et *al.*, 2020; Ngbolua et *al.,* 2016).

The most preferred mode of use of these pesticidal plants is local application followed by expansion of volatile compounds by beating. These results are almost similar to the results of Bekele et al. (2012) who reported that house spraying with plants followed by local application by rubbing are the most reported modes of use for the control of insect pests to human and animals.

Habitat and availability of pesticidal plant species

The present study shows that half of the pesticide plant species inventoried are grown in the farmers' fields or along the household fence, indicating that the inhabitants of Gitega were aware of the importance of these plants. These results are consistent with those in northern Morocco that most of the plants inventoried are grown in the fields (Brahim et *al.*, 2020) in contrast to the study in Congo that showed that the most dominant pesticide plant species are found in the forest (Ipona et *al.*, 2019)

Conclusions

Our study is a contribution to a good knowledge of pesticidal plants against human harmful insects. The local population of Gitega has an enormous knowledge about pesticidal plants used in the control of insect pests, especially the pesticide plants against fleas-biters and fire ants. The most used part is the leaf for the control of these insects. Half of these plants are cultivated and used without prior preparation. The pesticide plants will play a role as an alternative to the synthetic pesticides used in Burundi. The use of pesticide plants in the control of insect pests will result in good health and a clean and healthy environment.

The present work gives additional contribution to the existing knowledge on the pesticidal plants in the control of human pests in Burundi. Our study suggests that new research should help to find more effective and powerful phytochemicals

that are easily accessible for all Burundians. Awareness sessions on the importance of these pesticidal plants would be of great help to ensure sustainable management and conservation of pesticidal plants.

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