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Survey on plants used by the population of Fez City (central Morocco) as bioinsecticides in the control of insects responsible for vector-borne diseases

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ABSTRACT

This study was conducted to identify medicinal plants traditionally recommended by herbalists in Fez city, Central Morocco, to fight against insects responsible for vector-borne diseases. The ethnobotanical survey was carried out on medicinal and aromatic plants in 2013 using a structured interview. Thus, 250 herbalists were questioned in order to obtain complete information on the traditional uses of medicinal and aromatic plants used as bioinsecticides against mosquitoes transmitting vector-borne diseases. The results of this study identified 22 species belonging to 13 families. *Lamiaceae* (32%), *Asteraceae* (9%), and *Rutaceae* (9%) were the most represented families. The results have also shown that the leaves (26%), stems (23%), flowers (20%), and the whole plant (14%) constitute the most utilized parts. Moreover, therapeutic (33%) and cosmetic (31%) uses were also mentioned. During the process of fighting against mosquitoes, the plants were used as essential oils (37%), extracts (31%), and cultivates (15%). This study represents a great interest for future research concerning plants used as bioinsecticides. It could also contribute to the study and exploration of the Moroccan medicinal flora as bioinsecticides in the control of insects responsible for the vector-borne diseases, which is poorly known nowadays.

INTRODUCTION

Medicinal and aromatic plants have been considered and always remain as a source of care, medical remedy, and control against various diseases, particularly in developing countries in the absence of a modern and appropriate medicinal system (Tabuti *et al*., 2003), whose effectiveness is very often discussed (Salhi *et al*., 2010).

By everything in the world, the popularity, which the aromatic plants and the essential oils have long enjoyed, generally stayed linked to their medicinal properties: anti-inflammatory, antiseptic, antiviral, antifungal, antibacterial, antioxidant, toxicological, insecticides and repellents, toning, stimulating, soothing, and so on (El Ouali Lalami *et al*., 2013; Kamanzi Atindehou *et al*., 2002; Koné *et al*., 2004; Mayuri Tharanga *et al*., 2018; Soro *et al*., 2010; Tra Bi *et al*., 2008; Zeggwagh *et al*., 2013).

Morocco's geographical position, which is one of the Mediterranean countries, offers a very great floristic and ecological biodiversity. It is fortunate to have such a diversity

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of biotopes wherein almost any plant can grow and be cultivated economically: out of the 7,000 species and subspecies existing varieties, 537 are endemic in the country and 1,625 are rare or endangered (Benabid, 2000).

Currently, medicinal and aromatic plants have been considered and still remain as a source of care and are used in the fight against various pathologies, especially in developing countries in the absence of a modern and appropriate medicinal system. In Fez, traditional herbal medicines have always held a strong position. According to the bibliography and field researches, we can assume that the population in Fez city has long used very important plant species (Zeggwagh *et al*., 2013). It must be noted that the Quarawiyine University in Fez is the mean academic center of Africa and includes the medical section based on plants' use (Bellakhdar, 1985, 1997). Also, the region of Fez includes a National Institute of Medicinal and Aromatic Plants in the city of Taounate, located 70 km of Fez city.

Several ethnobotanical studies, aiming at the therapeutics, the cosmetics, the treatment of diseases of the digestive system, the treatment of diabetes, and cardiac and renal diseases, have been conducted in various regions of Morocco by various authors (Bellakhdar, 1987, 1997; Ben akka *et al*., 2015; Benkhnigue *et al*., 2011, El hilah and Zidane, 2014; Hassan *et al*., 2001; Hseini *et al*., 2007; Kahouadji, 1995; Mehdioui and Kahouadji, 2007; Salhi *et al*., 2010; Slimani *et al*., 2016). However, the surveys on medicinal plants used as complementary medicine and prevention of vector-borne disease are virtually nonexistent.

It is within this framework that the objective of this work was registered. Indeed, the purpose of this research was to investigate and inventory the medicinal and aromatic plants used traditionally by herbalists in Fez (Central Morocco) as complementary medicine and prevention of vector-borne diseases.

In the absence of ethnobotanical studies on the national or international level on the use of the population of aromatic and medicinal plants to fight against mosquitoes, we assume that this study would be an essential means of research carried out on bioinsecticides to fight against vector-borne diseases. Bioinsecticides will be very useful as alternatives to synthetic insecticides in the control of mosquitoes and disease vectors. It would also be crucial for other future studies concerning different Moroccan regions.

MATERIAL AND METHODS

The study region

The study area (Fez) is located in the northern half of Morocco between 5°07′00″ and 4°55′00″ W and 34°00′00″ and 34°05′00″ to the north latitude (Fig. 1). The urban perimeter of the city covers an area of approximately 450 km^2. The climate of Fez is Mediterranean; winter is mild and humid and becomes extremely dry from June to September.

Studied population

According to the sampling plan, an ethnobotanical study was carried out in the city of Fez on medicinal and aromatic plants, using a questionnaire having exhaustive information on local traditional uses of medicinal and aromatic plants, particularly used as bioinsecticides to control the vector-borne disease. For this, our study sample comprised 250 herbalists (n = 250).

Studied variables in ethnobotanical survey

The study, which is the subject of the questionnaire, is part of an ethnobotanical survey. An interview grid was developed, including questions about the plant used as a bioinsecticide to control vector-borne diseases, other uses of the plant, the part used, the form of function, the dose, and the duration of use.

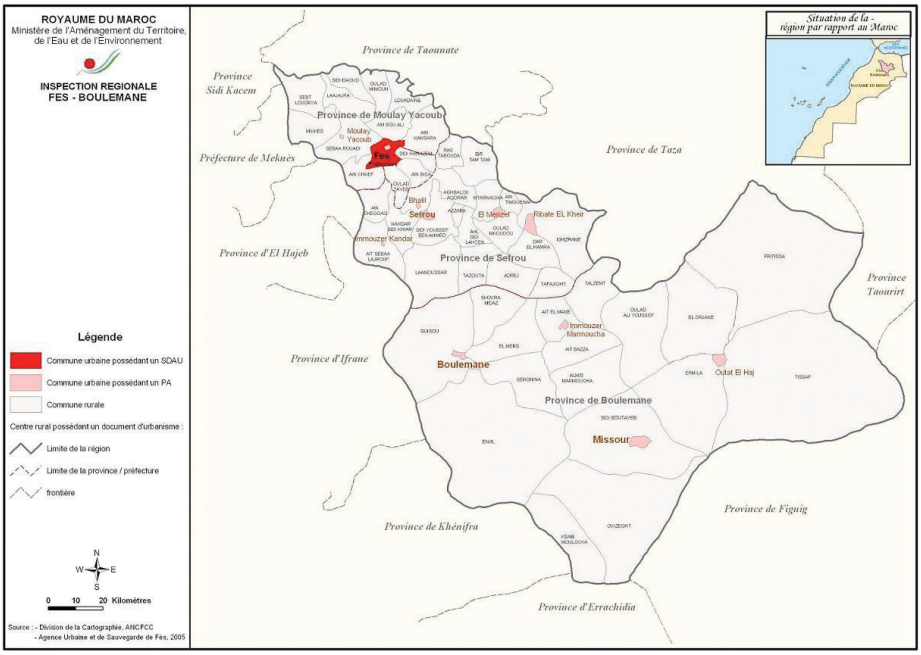

Figure 1. Map of the study region.

Statistical analysis

Pearson's chi-squared test was used at a 95% confidence level to test the significance between the percentages. We used version 20.0 of the Statistical Package for the Social Sciences software for statistical analyses. Excel analysis software was used for data entry and processing.

RESULTS

This study consisted of a sample of 250 herbalists aged between 18 and 70 years. Our sample was taken at random and consisted of people of different and varied intellectual levels, which has allowed realizing our questionnaires on the application and uses of local aromatic plants as complementary medicine and prevention of vector-borne diseases.

A total of 250 herbalists, containing 150 women with a percentage of 60% and 100 men with a percentage of 40%, were interviewed. The difference between men and women was statistically significant (χ^2 = 10; p-value = 0.002). Results have also shown that 83% of interviewed herbalists have a university level of study against 12% and 5% of herbalists with secondary and primary levels, respectively (χ^2 = 281.69; p-value = 0.002).

The analysis of data obtained from the realized survey allowed us to report that 22 important plant species distributed into 13 botanical families were mostly used. *Lamiaceae* (36.7%), *Rutaceae* (13.1%), *Liliaceae* (8.9%), *Asteraceae* (7.3%), and *Apocynaceae* (7%) were the most represented families. The remaining families relied on only one species for each one (2.1%–4.7%) (Table 1). The difference between inventoried families was statistically significant (χ^2 = 936; p-value < 0.001).

Plant type

The result of the analysis grids of our ethnobotanical survey unveiled that most of the plants used for medicinal plants to control the vector-borne disease are cultivated plants (74%), against 26% of wild plants.

Other uses of the plants

Regarding other uses of medicinal and aromatic plants, the analysis of the obtained results has shown that recorded plants are used in other applications, namely, therapeutic (32.8%), cosmetic (31.2%), bactericide (18%), fungicide (16.9%), and others (1%) (Fig. 2). Percentages are statistically different between them (χ^2 = 224.39; p-value < 0.001).

Used part

Our ethnobotanical survey showed that the most used portions of plants are leaves (26%), followed by stems (23%), flowers (20%), whole plant (14%), barks (7%), fruits (5%), and the seeds (4%). The remaining plant parts used are represented by 1% (Fig. 3). A statistically significant difference is observed between these proportions (χ^2 = 434; p-value < 0.001).

Form of employment

The most used form of employment has been in the form of vapor essential oils (37%), extracts (32%), and cultivates (15%). The remainder represents less use of fatty oils (9%) and powders (7%) (Fig. 4). The difference between percentages is significant (χ^2 = 176.47; p-value < 0.001).

Table 1. Medicinal plants mostly used as complementary medicine and in the prevention of vector-borne disease.

Vernacular name	Botanical name	Number of citations	Family of plants
Orange	*Citrus sinensis*	57	*Rutaceae*
Onion	*Allium cepa*	30	*Liliaceae*
Garlic	*Allium sativum*	32	*Liliaceae*
Bitter orange	*Citrus aurantium*	35	*Rutaceae*
Dalmatian pellitory	*Tanacetum cinerariifolium*	29	*Asteraceae*
Lemongrass	*Cymbopogon citratus*	33	*Poaceae*
Basil	*Ocimum basilicum*	71	*Lamiaceae*
Sweet marjoram	*Origanum majorana*	46	*Lamiaceae*
Lavender	*Lavandula dentata*	32	*Lamiaceae*
Thyme	*Thymus vulgaris*	37	*Lamiaceae*
Sarghina	*Corrigiola telephiifolia*	18	*Caryophyllaceae*
Rosemary	*Rosmarinus officinalis*	39	*Lamiaceae*
Cypress	*Cupressus sempervirens*	27	*Cupressaceae*
Cannabis	*Cannabis sativa*	28	*Cannabaceae*
Caper bush	*Capparis spinosa*	15	*Capparidaceae*
Vervain	*Verbena officinalis*	19	*Verbenaceae*
Mint	*Menthe pouliot*	14	*Lamiaceae*
Stinging nettle	*Urtica dioica L.*	21	*Urticaceae*
Absinthe	*Artemisia absinthium*	22	*Asteraceae*
Tobacco	*Nicotiana tabacum*	28	*Solanaceae*
Spearmint	*Mentha spicata*	18	*Lamiaceae*
Nerium	*Nerium oleander*	49	*Apocynaceae*

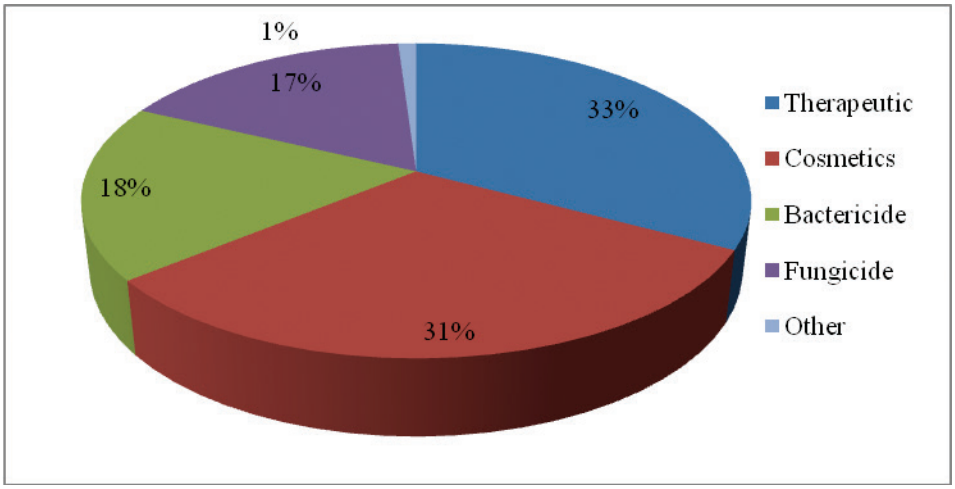

Figure 2. Other uses of the plant as bioinsecticides.

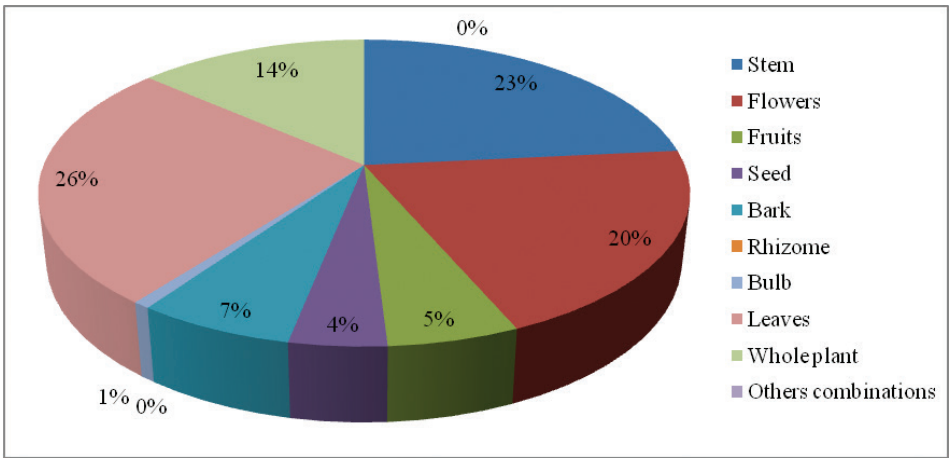

Figure 3. Representation of the percentages of the utilized parts.

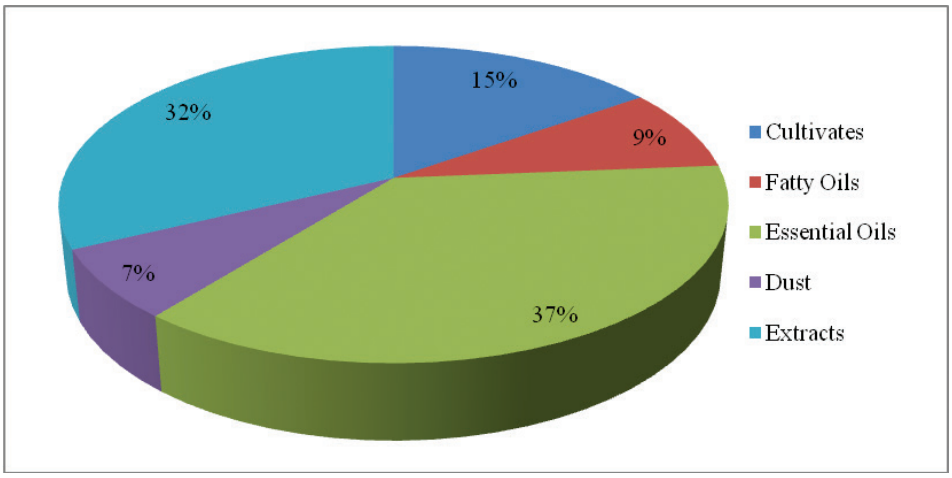

Figure 4. Representation of the percentages of the form of employment.

Mode of preparation

Infusion was the most used mode of preparing plants with 68%, followed by decoction (20%). Furthermore, the rest of the plants are used in cooked and raw forms with 7% and 5%, respectively. This difference between percentages of preparing mode is statistically significant ($\chi^2 = 274.18$; p-value < 0.001)

Used dose

The interviewees indicated that the used dose was in the form of handfuls. It has been represented with a majority percentage of 81% and pinched by 11%, while 8% was attributed to other dosage forms (Fig. 5). Percentages are statistically different ($\chi^2 = 236.5$; p-value < 0.001).

Duration of use of plants

As shown in Figure 6, we observed that the duration of the plants used as medicinal plants to control vector-borne diseases varies from 1 day to another, which is represented by 76%, for 1 week (19%), and up to 1 month (5%). Significant difference between percentages was observed ($\chi^2 = 210.86$; p-value < 0.001).

DISCUSSION

Traditional phytotherapy has always been solicited by a population which generally does not have the means of supporting the methods and costs of care in modern medicine.

Currently, there is a resurgence of interest in alternative medicine and traditional pharmacopeia. The fight against disease vectors is an integral part of it, as vector-borne diseases represent an important part of the infectious diseases.

Many of the technical solutions have been developed by research to improve the efficiency of the management of mosquito vectors of diseases (chemical control, biological control, and varietal resistance), but their appropriation has remained limited.

Chemical control also reached its certain limits with a significant impact on the environment (El Joubari *et al*., 2015; El Ouali Lalami *et al*., 2014; EL-Akhal *et al*., 2016a; Faraj *et al*., 2002; Fianko *et al*., 2011; Jones *et al*., 2012; Karunamoorthi and Sabesan, 2012; Khaliq *et al*., 2007; Ramezani *et al*., 2008; Regnault *et al*., 2008; Schuster and Smeda, 2007; Travis *et al*., 2009). These elements require exploring technical solutions of natural bioactive molecules as alternatives to chemical insecticides.

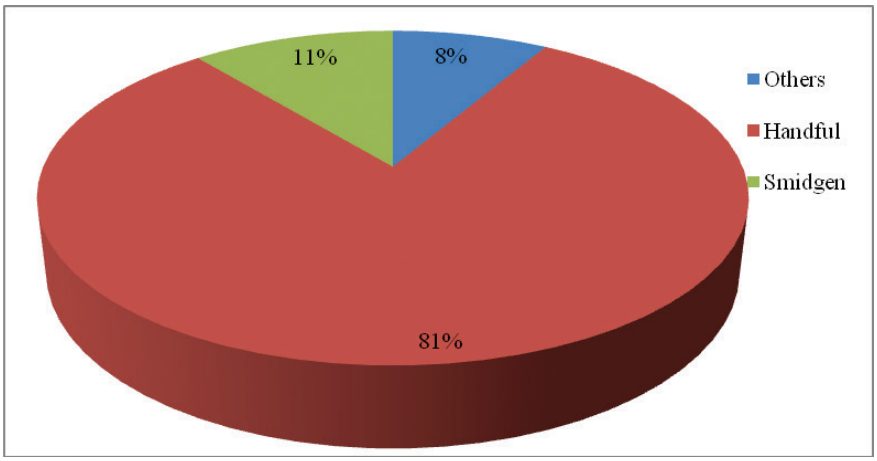

Figure 5. Doses utilized from plants.

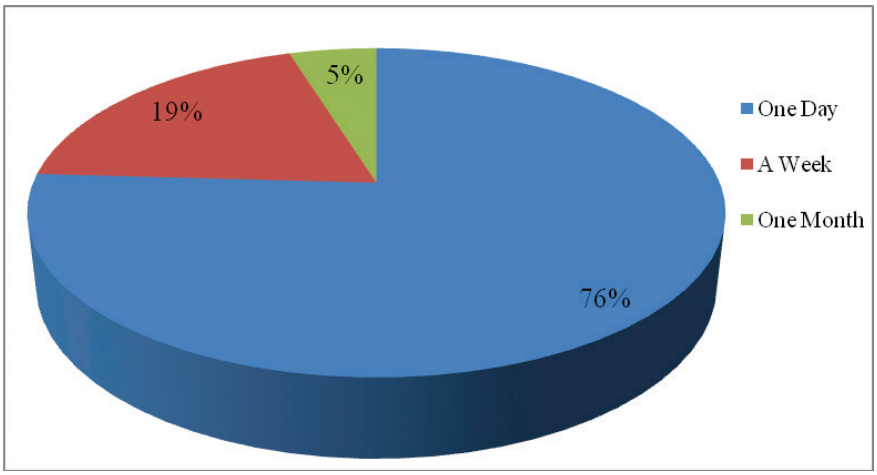

Figure 6. Duration of the use of plants.

The use of vegetable substances as complementary medicine and in the prevention of vector-borne diseases has been the subject of numerous studies (Aba Toumnou *et al*., 2012; El Ouali Lalami *et al*., 2016a; El-Akhal *et al*., 2014, 2015; Gueye *et al*., 2011; Konno, 2011; Raymond *et al*., 2011; Regnault *et al*., 2008).

Recently, in the field of disease prevention, a plant-based repellant, para-methane-3-8-diol (PMDparamethane--diol), has been shown to be suitably effective and safe in competing with N,N-diethyl-3-methylbenzamide DEETN-diethyl (El Ouali Lalami *et al*., 2016a; Ferreira and Moore, 2011).

According to the World Health Organization, these repellents have been recognized as a disease prevention tool to supplement insecticide-based means of vector control. For public use, PMD is the only herbal repellant advocated by the Centers for Disease Control, which is safe for human health (El Ouali Lalami *et al*., 2016a; Zielinski-Gutierrez *et al*., 2010).

Thereby, this study has identified and listed the number of plants used as in control vector-borne disease by herbalists in Fez, namely, Lamiaceae (*O. basilicum*, *O. majorana*, *L. dentata*, *T. vulgaris*, *R. officinalis*, *M. pelugium* and *M. spicata*), *Asteraceae* (*Tanacetum cinerariifolium* and *Artimisia absinthium*), and *Rutaceae* (*C. sinensis* and *C. aurantium*).

The species we have listed, namely, *Lamiaceae* and *Asteraceae*, have also been the most represented among families identified by several realized studies in Morocco (Benkhnigue *et al*., 2011; Hseini *et al*., 2007; Salhi *et al*., 2010), relating to the flora and ethnobotanical studies on medicinal plants in the western region (City of Kenitra and Rabat).

Note that most of the work relating to the use of medicinal and aromatic plants also reported on the anti-inflammatory, antiseptic, antiviral, antifungal, antibacterial, antioxidant, toxicological, toning, stimulating, and soothing properties and so on, cited by the herbalists we interrogated (Bernard Wanjohi *et al*., 2020; El Ouali Lalami *et al*., 2013; Hmamouchi *et al*., 2001; Salhi *et al*., 2010; Soro *et al*., 2010; Tra Bi *et al*., 2008; Zeggwagh *et al*., 2013).

The high use of leaves (26%) can be explained by their availability (Bitsindou, 1986; Yineger and Yewhalaw, 2007), and the leaves are a storage place for secondary metabolites of the plant's biological properties and photosynthesis (Abera, 2014; Bigendako-Polygenis and Lejoly, 1990; Yineger and Yewhalaw, 2007).

According to the analysis of our data, the most cited plants in the fight against insects belong to the family of *Lamiaceae*, *Asteraceae*, and *Rutaceae*. El-Akhal *et al*. (2014, 2015) reported that the larvicidal action of the essential oils of *T. vulgaris* and *O. majorana* (*Lamiaceae*) had a significant effect against mosquito larvae in particular (Diptera: Culicidae). Other plants, such as *Mentha pulegium*, *Salvia officinalis*, and *O. basilicum*, belonging to the family *Lamiaceae*, and *Ammi visnaga*, belonging to the family *Apiaceae*, have also been studied as complementary medicine and in the prevention of vector-borne disease (El Ouali Lalami *et al*., 2016b; El-Akhal *et al*., 2016b, 2016c; Ez Zoubi *et al*., 2016). Among these plants, there are some who were described and mentioned by the herbalists interviewed during our ethnobotanical survey.

The other plant species cited in this study will serve us later for the achievement of mosquito larvicide tests by using plant extracts (either essential oils or aqueous extract).

The results of this type of study will also enable us to identify effective herbal medicine against mosquito vectors of disease and/or liable in nuisance and can be used instead of chemical insecticides widely incriminated in the phenomenon resistance observed in mosquitoes, as well as environmental pollution problems.

Note that we have not carried out the survey on either on a national or international level or on medicinal and aromatic plants used as complementary medicine and in the prevention of vector-borne disease. This has limited the comparison of the results found in our investigation.

This study will contribute to the knowledge of medicinal plants in the north-central region of Morocco and precisely to explore Moroccan medicinal flora, which is poorly known as medicinal plants to control the vector-borne diseases. We also consider that this survey would have a great interest for future work concerning other Moroccan regions.

CONCLUSION

This work was conducted for the purpose of identifying plants used traditionally by the herbalists in the city of Fez as complementary medicine and in the prevention of vector-borne diseases.

The analysis of data obtained from a survey carried out allowed us to report that 22 plant species belonging to 13 botanical families were mostly used, with a clear dominance of the Lamiaceae family. The leaves, stems, and flowers were the most utilized parts.

By observing the results obtained in this study and the richness of our traditional pharmacopeia, it seems interesting from one hand to extend this kind of investigation to other parts of the country in order to identify other plants to use them as medicinal plants and to control the vector-borne diseases. On the other hand, it is necessary to validate experimentally the plant extracts and preparations identified by adequate scientific testing.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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AUTHORS' CONTRIBUTIONS

Fouad El Akhal conducted the ethnobotanical survey and drafted the manuscript. Yassine Ez Zoubi identified the scientific name of plants and read the manuscript. Mouhcine Fadil conducted the statistical data analysis. Raja Guemmouh participated in the configuration and reading of the manuscript. Abdelhakim El Ouali Lalami contributed to the conception and design of the study and

helped in the English writing of the manuscript. All authors read and approved the final manuscript.

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