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Ethnobotanical Survey on Plants Used to Manage Febrile Illnesses among Herbalists in Casablanca, Morocco

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Abstract: Plants have been recognized since antiquity in Morocco as a heritage and a remedy for a variety of ailments with a diverse range of pharmacological effects. The current work is ethnomedicinal research conducted to collect herbalists' knowledge about plants utilized in traditional medicine to treat febrile illnesses. In Casablanca, Morocco, 105 herbalists provided information. The data were examined using seven quantitative indices: The Fidelity Level (FL), Use Value (UV), Frequency of Citation (FC), Relative Frequency of Citation (RFC), and Informant Consensus Factor (ICF). During the current investigation, twenty-two different species of medicinal plants from eleven families have been reported as being used to treat fevers. The most recommended plant with a high Relative Frequency of Citation (RFC = 0.15) is *Dysphania ambrosioides* L., which indicates the importance of this species in controlling fever, especially when it is combined with *Citrus* × *limon* (L.) Osbeck (RFC = 0.139). Hence, the use of these plants was compared to the literature review. This research contributed to documenting and preserving important Moroccan traditional herbalists' knowledge about plants used to cure febrile illnesses.

Keywords: Casablanca; ethnobotany; fever; herbalist's knowledge; medicinal plants

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1. Introduction

Since ancient times, fever has been an important feature of the disease, and it is regarded as a serious public health threat worldwide as well as a source of morbidity in developing countries [1]. It presents a particular challenge for health workers and health systems as it can be caused by a wide range of bacterial, fungal [2], parasitic [3], and viral

infections [4] as well as non-infectious conditions [5,6]. Therefore, understanding fever and the febrile response is essential in the diagnosis, treatment, and monitoring of various conditions and diseases [7]. The febrile response is orchestrated by the central nervous system through endocrine, neurological, immunological, and behavioral mechanisms [7]. Fevers can be arbitrarily classified into acute, subacute, and chronic fevers based on their duration. Acute fevers (lasting < 7 days) are characteristic of infectious diseases such as malaria and viral infections, while subacute fevers (usually lasting less than two weeks) can be seen in typhoid fever. Chronic or persistent fevers (lasting > 2 weeks) are typical of chronic bacterial infections such as tuberculosis, viral infections such as HIV, cancers, and connective tissue diseases [8]. Equivalent rectal temperatures of ≥38 °C (100.4 °F) or axillary temperatures of ≥37.5 °C (99.5 °F) in both adults and children are indicative of fever [9], following to the World Health Organization (WHO) [10], the Infectious Disease Society of America [11], and the Society of Critical Care Medicine [12] recommendations, and represents one of the most common symptoms of disease in Morocco [13].

Medicinal plants remain a significant source of healthcare treatments in many regions of Morocco and an important source of chemical compounds with several affordable and easily accessible benefits. Following the recommendation of the WHO, approximately 80% of people rely on traditional medicine to treat their diseases [14,15]. Moroccan flora is made up of nearly 4200 species and subspecies belonging to almost all of the major known botanical families (130 families and 940 genera are represented) and about 1500 introduced species, with 1118 species used in care [14,16]. The current study area is Casablanca, a remarkable sector of Morocco's western province with a large unexplored ethnobotanical and floristic biodiversity. As a result, Casablanca is regarded as a haven for herbalists of various cultures. Therefore, the use of medicinal plants and the procedures used in their preparation have been passed down from generation to generation, either verbally or in writing, and herbalists collect this information from different generations and prescribe it to people suffering from fever.

Although very few surveys have been conducted in Casablanca to present sound science on plants used in traditional medicine systems [17,18]. There are only a few plant species with anti-febrile properties mentioned in the literature [19]. Some of these plants have a strong reputation in traditional medicine around the world, while others are still being studied scientifically. Accordingly, this study aimed to document the ethnobotanical knowledge focusing on ethnomedicine in Casablanca province. For the first time, we inventoried all medicinal plant species applied in Casablanca according to local ethnomedicinal knowledge in the treatment of febrile illnesses, collecting herbalists' knowledge about the utilization of medicinal platforms to alleviate the causes of fever. The traditional therapeutics were documented and analyzed using seven quantitative indices: The Fidelity Level (FL), Use Value (UV), Frequency of Citation (FC), Relative Frequency of Citation (RFC), and Informant Consensus Factor (ICF).

2. Material and Methods

2.1. Study Zone

Casablanca, Morocco's economic capital is located in Morocco's center-west (33°32′00″ N 7°35′00″ W), facing the Atlantic Ocean and is one of the major agricultural centers throughout the year. The climate is warm, wet in the winter, humid, and temperate in the summer [20,21]. There is high humidity and a light winter frost.

Grand Casablanca is considered to be the most significant region in Morocco, covering an area of 1115 km^2. The most populous, 18.8% of the country's total population, has 3,615,903 residents, with (1,833,648) women slightly outnumbering men (1,782,255), drawing many migrants from different parts of Morocco, resulting in significant socioeconomic and cultural heterogeneity [20]. The Grand Casablanca region's natural forests stand out for their high vegetative variability, which makes them excellent locations for plant accumulation [22]. Hence, the choice of Casablanca as the city to establish this study

is reasonable. The Casablanca districts in which the survey was established are represented in Figure 1.

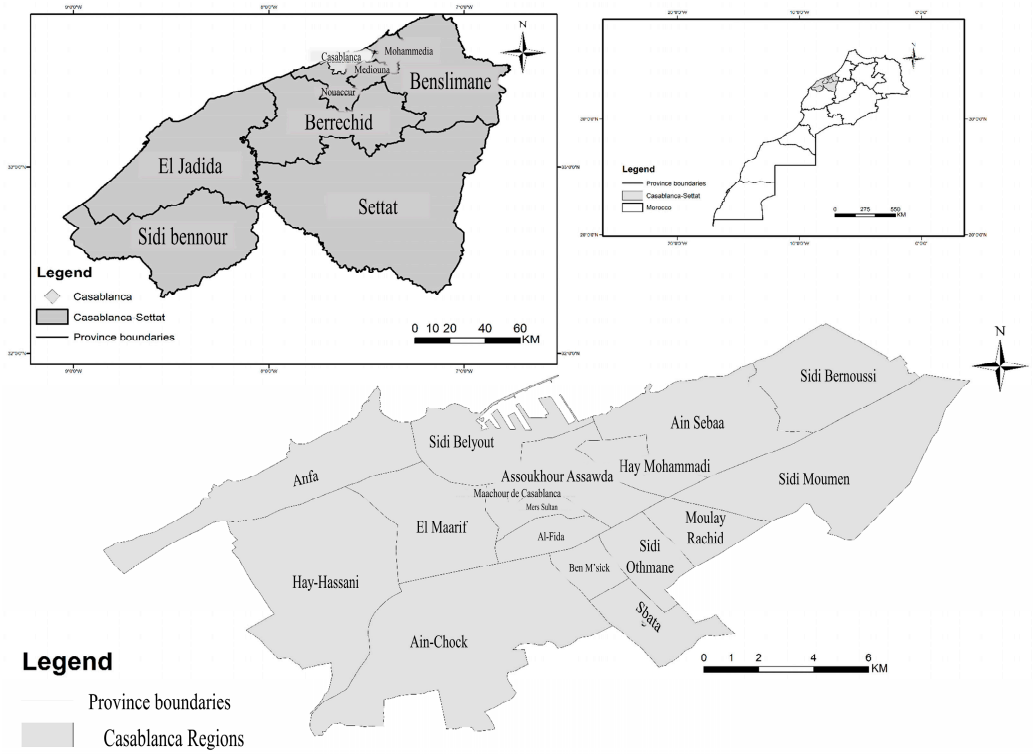

Figure 1. Location of different research locations in Casablanca, Morocco.

2.2. Data Gathering

An ethnobotanical study was accomplished between May and October 2021. Before collecting ethnobotanical data, informants were fully informed of the research's aims and the accuracy of the data they would offer to get their permission to participate in the research. Furthermore, the participants were assured of their anonymity in this study.

According to the sample size calculation (Supplementary File S1), using the formula given by Lwanga and Lemeshow [23], the required number of herbalists was 86. A total of 130 traditional herbalists in Casablanca were assessed for eligibility criteria, as represented in (Supplementary File S2). Elderly traditional herbalists, informants who were not herbalists, druggists, or traditional healers, as well as those who were not native to the study area or who had not lived there for ten years or more, were all excluded from the survey. A total of 105 traditional herbalists distributed in the different districts represented in Figure 1 in the province of Casablanca were interviewed directly through semi-structured interviews (Supplementary File S3) using the Moroccan language (Arabic: Darija).

This interview has been separated into two parts: the first concerns descriptive statistics (e.g., sex, source of information, educational level, and age). The second section includes questions about plant species' vernacular names, plant parts used, mode of preparation, diseases treated by the plants listed by the informants, and method of administration. In ethnobotany, collecting voucher herbarium specimens is a mandatory practice [24]. As a result, samples of the listed plants were collected during several field trips to different areas of the study zone. Using the standard method, each plant specimen collected was numbered, dried, and preserved [25]. Each specimen has been placed at the herbarium of the University of Agricultural Sciences and Veterinary Medicine (USAMV) Cluj-Napoca in Romania, identified by a botanist under the numbers "3305-3326", and checked according to published literature and Plants of the World Online [26].

2.3. Data Analysis

The findings of the ethnobotanical investigation were evaluated using Use Value (UV), Relative Frequency of Citation (RFC), Informant Consensus (ICF), and Fidelity Level (FL) [27–30]. The graphs represented in this study were designed using GraphPad 8.0.2, Excel with XLSTAT software, and Origin Pro.

2.3.1. Use Value (UV)

According to [31], the *UV* was calculated using the following formula:

$$\boldsymbol{UV} = \frac{\sum \boldsymbol{UR}}{\boldsymbol{Ni}} \quad (1)$$

where *UR* is the number of uses mentioned for a particular species, and N_i is the total number of respondents. A plant that secures a high *UV* score that indicates there are many useful reports for that plant, while a low score indicates fewer useful reports cited by the informants.

2.3.2. Frequency of Citation (FC)

The *FC* was determined as follows [32]:

$$\boldsymbol{FC} = \boldsymbol{UR}/\boldsymbol{N_c} \times \mathbf{100} \quad (2)$$

where *UR* is the Number of times a particular species was mentioned, and N_c is the total number of times that all species were mentioned.

2.3.3. Relative Frequency of Citation (RFC)

The *RFC* represents each species' level of use in the study zone [33] assessed using the following formula:

$$\boldsymbol{RFC} = \boldsymbol{FC}/\boldsymbol{N_i} \quad (3)$$

where *FC* is the frequency of citations, and N_i is the total number of survey participants.

2.3.4. Fidelity Level

The *FL* is the proportion of herbalists, who indicated the use of particular plant species to treat a particular illness [34], evaluated using this formula:

$$\boldsymbol{FL}(\%) = \boldsymbol{N_a}/\boldsymbol{N_i} \times \mathbf{100} \quad (4)$$

where N_a is the number of herbalists who noted using a plant to treat the same main disease, and N_i is the sum of herbalists who suggested the plant as a treatment for any significant disease.

2.3.5. Informant Consensus Factor

The *ICF* indicates the level of agreement among herbalists on the reported medicinal plants used to cure a specific disease [35], established using this formula:

$$\boldsymbol{ICF} = \boldsymbol{N_{ur}} - \boldsymbol{N_t}/\boldsymbol{N_{ur}} - \mathbf{1} \quad (5)$$

where N_{ur} is the number of each category that has been mentioned, and N_t is the number of plants mentioned to manage the disease.

2.4. Bibliographic Review

A study of the literature on the most frequently cited plants and their pharmacological activities was undertaken using the electronic databases listed below: PubMed: http://www.ncbi.nlm.nih.gov/pubmed (accessed on 7 December 2022), Google Scholar: http://www.scholar.google.com/ (accessed on 7 December 2022), Science Direct: http://www.

sciencedirect.com/ (accessed on 7 December 2022), and Scopus: http://www.scopus.com/ (accessed on 7 December 2022).

3. Results

3.1. Socio-Demographic Data

One hundred five traditional herbalists in various areas of Casablanca, including 19 females and 86 males, were interviewed, with a female/male ratio of 0.22. As illustrated in Table 1, most herbalists were males, 81.9%, compared to 18.1% females. The high percentage of male herbalists can be attributed to males' dominance in this domain in the study zone.

Table 1. Socio-demographic variables of herbalists (n = 105) in Casablanca, Morocco.

Factors	Classes	Frequency	Percentage (%)
Gender	Female	19	18.1
	Male	86	81.9
Age	≤30	17	16.2
	31–40	18	17.1
	41–50	36	34.3
	≥51	34	32.4
Educational status	Illiterate	29	27.6
	Primary	44	41.9
	Secondary	28	26.7
	University	4	3.8
Source of Knowledge	Hereditary	73	70
	Herbalists	32	30

The majority of herbalists, 34.3%, had ages ranging between 41 and 50 years, followed by herbalists 32.4% who were older than 51 years, then herbalists 17.1% who were between 31 and 40 years, and finally, 16.2% who were less than 30 years, which shows that elders are the main traditional knowledgeable (Table 1).

Regarding the level of education (Table 1), most herbalists, 41.9%, had been in primary school, 27.6% were illiterate and required knowledge from their ancestors, and 26.7% of the herbalists had been in secondary school. Nevertheless, less than 3.8% of herbalists had a university-level education in this domain. In this study, we can notice the dominance of moderately studied populations, which can be attributed to the legacy of ethnobotanical knowledge passed on to new generations. However, this transfer should not result in the loss of information on medicinal plants. A total of 70% of the herbalists reported acquiring the information through the experiences of their ancestors, and 30% reported information acquired from herbalists. No one has mentioned that this information may be acquired from other sources such as medicine, pharmacists, the media, or by reading books about traditional Arab medicine (Table 1).

The distribution of herbalist shops in the Casablanca districts gives an important diversity of information (Figure 2). Among the 105 herbalists interviewed, 25 localized their shops in El Fida (24%), and 15 in Hay Mohammedi (14%).

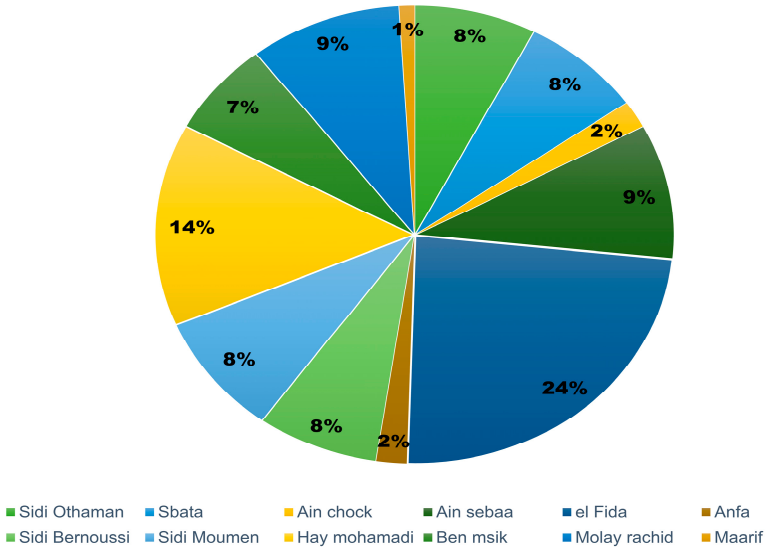

Figure 2. Distribution of traditional herbalists interviewed in Casablanca, Morocco.

The results of the hierarchical clustering analysis HCA is shown in the form of a polar heat map with a dendrogram (Figure 3) and indicate the level of reports for each species based on the study sites, in which the intensity of reports of each species in a particular site along a color gradient determines the color of a cell in the polar.

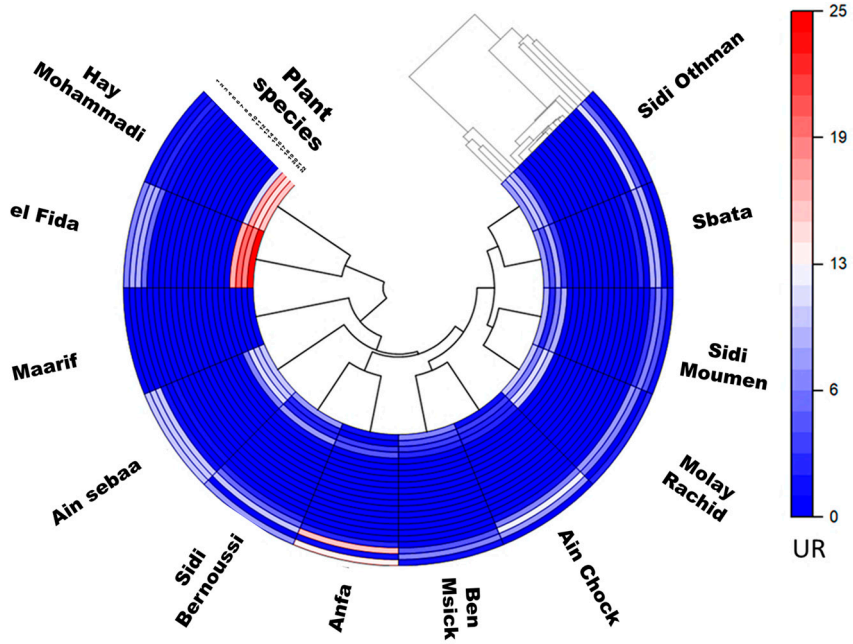

Figure 3. Polar Heatmap with dendrogram indicating the distance between study areas and medicinal plant species mentioned using the number of citations (UR) in each district. *Species; 1: *L. dentata*, 2: *M. spicata*, 3: *E. globulus*, 4: *C. nepata*, 5: *M. communis*, 6: *M. pulegium*, 7: *S. officinalis*, 8: *O. grosii*, 9: *L. siceraria*, 10: *T. broussonetii*, 11: *O. europaea*, 12: *Z. lotus*, 13: *O. basilicum*, 14: *M. suaveolens*, 15: *S. rosmarinus*, 16: *A. absinthium*, 17: *A. herba-alba*, 18: *C. sativum*, 19: *P. rhoeas*, 20: *C. limon*, 21: *J. turbinata*, 22: *D. ambrosioides*.

The findings revealed two significant groups of districts, the first of which includes Hay El Mohammadi and El Fida and is represented by a higher level of UR, while the other regions are part of the second group, which includes species that are less commonly re-

ported. This indicates a correlation between the two districts (El Fida and Hay Mohammadi) in terms of plant reports and herbalist knowledge.

The two districts of Hay El Mohammadi and El Fida are the most populated and have a higher number of plants cited. The results show that the herbalists belonging to these two districts have more knowledge and a wealth of plant species information used to manage febrile illnesses.

The most cited species in these 2 districts are *Coriandrum sativum*, *Papaver rhoeas*, *Citrus* × *limon*, *Tetraclinis articulata*, and *Dysphania ambrosioides*.

3.2. Quantitative Analysis

From this survey, we concluded that 22 medicinal species of plants from 11 botanical families were suggested by herbalists to cure four categories of febrile illnesses at the study sites. These plants are listed in Table 2, in which we provide the informative evidence (scientific names, the method of preparation, the part used, the local name, and the quantitative values FC, RFC, and UV).

Table 2. Plants suggested by herbalists to treat febrile illnesses in Casablanca, Morocco.

N°	Scientific Names of Families and Species (Voucher Number)	Local Name	Parts Used	Traditional Dosages	Method of Preparation	Method Administration	UR	UV	FC	RFC
1	Amaranthaceae *Dysphania ambrosioides* (L.) Mosyakin & Clemants (CLA30324)	*M'khinza*	Leaves	Spoon Spoon Handful	Infusion Juice Poultice	Internal use External use	105	1	15.88	0.15
2	Apiaceae *Coriandrum sativum* L. (CLA30321)	*Kasbour*	Leaves	Handful	Juice	Internal use	4	0.038	0.60	0.005
3	Asteraceae *Artemisia herba-alba* (CLA30310)	*Chih*	Leaves	Spoon	Decoction	External use	1	0.009	0.1	0.001
4	*Artemisia absinthium* L. (CLA30323)	*Chiba*	Aerial parts	Spoon	Infusion	Internal use	1	0.009	0.1	0.001
5	Cupressaceae *Tetraclinis articulata* (Vahl) Mast. (CLA30320)	*El-Aarar*	Leaves Bark	Spoon Handful	Decoction Poultice	Internal use External use	80	0.76	12.10	0.11
6	Cucurbitaceae *Lagenaria siceraria* (Molina) Standl. (CLA30314)	*Slawi*	Fruit	1 unit 1 unit	Juice Poultice	Internal use External use	3	0.028	0.004	0.004
				Lamiaceae						
7	*Clinopodium nepeta* (L.) Kuntze (CLA30307)	*Manta*	Leaves	Handful	Infusion	Internal use	59	0.56	8.92	0.085
8	*Mentha spicata* L. (CLA30305)	*Naanaa*	Whole plant	Handful	Infusion	Internal use	49	0.46	7.41	0.07
9	*Lavandula dentata* L. (CLA30311)	Khzama	Leaves	Spoon	Infusion	Internal use	51	0.48	7.71	0.073
10	*Mentha pulegium* L. (CLA30322)	*Flio*	Whole plant	Spoon	Infusion	Internal use	10	0.09	1.51	0.01
11	*Salvia officinalis subsp. officinalis* (CLA30309)	*Salmiya*	Leaves	Handful	Infusion	External use	1	0.009	0.151	0.001
12	*Mentha suaveolens* Ehrh. (CLA30312)	*Timija*	Leaves	Spoon	Infusion	External use	1	0.009	0.151	0.001
13	*Origanum grosii* Pau & Font Quer (CLA30317)	*Zàater*	Leaves	Handful Handful	Infusion Decoction	Internal use External use	3	0.02	0.45	0.004
14	*Salvia rosmarinus* Spenn. (CLA30306)	*Azir*	Leaves and stems	Glass Glass	Infusion Decoction	Internal use External use	4	0.038	0.6	0.005
15	*Thymus broussonetii* Boiss. (CLA30318)	*Ziitra*	Leaves	Glass	Infusion	Internal use	2	0.019	0.3	0.0028
16	*Ocimum basilicum* L. (CLA30325)	*hbaq*	Leaves and stems	Spoon Spoon	Decoction Infusion	Internal use	1	0.0095	0.151	0.001

Table 2. *Cont.*

N°	Scientific Names of Families and Species (Voucher Number)	Local Name	Parts Used	Traditional Dosages	Method of Preparation	Method Administration	UR	UV	FC	RFC
				Myrtaceae						
17	*Eucalyptus globulus* Labill. (CLA30319)	*Kalitouse*	Leaves/Bark	Handful Handful	Infusion Decoction	Internal use External use	94	0.89	14.22	0.135
18	*Myrtus communis* L. (CLA30308)	*Rihan*	Leaves	Handful	Decoction	Internal use	2	0.10	1.66	0.015
19	Oleaceae *Olea europaea* L. (CLA30316)	*Zitoun*	Leaves/Bark	Glass	Infusion	Internal use External use	11	0.019	0.30	0.002
20	Papaveraceae *Papaver rhoeas* L. (CLA30315)	*Belâaman*	Leaves	Handful Handful	Infusion Decoction	Internal use External use	81	0.77	12.25	0.11
21	Rhamnaceae *Ziziphus lotus* (L.) Lam (CLA30326)	*Sedra*	Leaves/Root -bark	Handful	Infusion	Internal use External use	1	0.009	0.151	0.001
22	Rutaceae *Citrus* × *limon* (L.) Osbeck (CLA30313)	*Limon*	Fruit	5 units	Juice	Internal use	97	0.92	14.67	0.139

3.3. Relative Frequency of Citation and Use Value

In the study area, the use value (UV) of plants recommended for the treatment of fever varies between 0.009 and 1; the most important UV are those obtained by *D. ambrosioides* L. (UV = 1), followed by *C. limon* (L.) Osbeck (UV = 0.92), *E. globulus* L. (UV = 0.89), *P. rhoeas* (UV = 0.77), and *T. articulata* (Vahl) Mast (UV = 0.76). The lowest value, (UV = 0.009), is obtained for *Z. lotus* (L.), *O. basilicum* L., *M. suaveolens* Ehrh., *S. officinalis*, *A. absinthium*, and *A. herba alba*.

The RFC value ranges from 0 to 1. When it nears 0, it demonstrates that none of the respondents referred to this plant as useful, and when it nears 1, it indicates that this plant was considered useful by almost all respondents. The results show that values ranged from 0.15 to 0.001 (Table 2). The least-mentioned use values were presented by six plant species (RFC = 0.001 for each). The results of this investigation revealed that *D. ambrosioides* L. had the most significant relative frequency of citation (RFC = 0.15), followed by *C. limon* (RFC = 0.139) (Figure 3). This indicates that they are very well known by traditional herbalists due to their therapeutic virtues and their wide distribution in the study area.

3.4. Fidelity Level

The FL% is a crucial indicator of which plant of a given species is more powerful against some of the diseases listed [34]. In this research, the FL values varied from 28.57% to 100%. According to the study, one species, *D. ambrosioides* L., was found to have a 100% FL for all types of fever (Table 3). An FL of 100% indicates that the informants mentioned this plant to treat this disease. This information means that Casablanca informants tend to rely on these specific plants to treat febrile illnesses. Thus, nine plant species are highly cited for many fever illnesses.

Table 3. Fidelity level and disease categories treated by plants in Casablanca, Morocco.

Diseases	Plant Species	FL%	Nur	Nt	ICF
Unspecified Fever	*D. ambrosioides* L.	100	45	14	0.70
	C. limon (L.) Osbeck	95.23			
	E. globulus Labill.	89.52			
	P. rhoeas L.	77.14			
	T. articulata	76.19			
	M. pulegium L.	57.14			
	L. dentata L.	48.57			
Enteric Fever	*D. ambrosioides* L.	100	40	12	0.72
	C. limon (L.) Osbeck	100			
	S. rosmarinus	85.71			
	P. rhoeas L.	69.52			
	M. pulegium L.	56.19			
Influenza	*D. ambrosioides* L.	100	20	8	0.63
	C. limon (L.) Osbeck	90.47			
	S. rosmarinus	88.57			
	M. spicata L.	84.76			
	L. dentata L.	34.28			
Spotted Fever	*D. ambrosioides* L.	100	12	6	0.54
	C. nepeta	59.04			
	E. globulus Labill.	50.47			
	C. limon (L.) Osbeck	28.57			
	P. rhoeas L.	38.09			

3.5. Informant Consensus Factor

The ICF is used to evaluate herbalists' level of agreement regarding the reported plants used to treat a particular illness (Table 3). ICF values were between 0.5 and 0.72. Enteric fever (ICF = 0.72), unspecified fever (ICF = 0.70), and influenza (ICF = 0.63) were the categories where the informants agreed the most.

Principal component analysis (PCA) showed two top principal components (eigenvalue ≥ 1), accounting for 98.82% of the total variation of the parameters studied. To facilitate the selection of species based on the ethnobotanical parameters studied, a biplot was created using two first principal components (F1 and F2), taking into consideration the most cited disease (Enteric fever). F1 explained 76.41% of the total variation and was significantly influenced by the UR, UV, FC, and RFC. While F2 accounted for 22.41% of the total variation, it was significantly influenced by the ICF and FL indices. The projection of the species in two-dimensional space by the F1 and F2 loading factors could be differentiated into four main clusters.

D. ambrosioides L. and *C. limon* were associated positively with FC, FL, RFC, and ICF, while *S. officinalis* and *M. pulegium* were associated positively with the ICF index (Figure 4).

These results indicated the frequent use of *D. ambrosioides* L. and *C. limon* to treat enteric fever according to herbalists' knowledge, demonstrating the relative medicinal importance of these two species in the present local area.

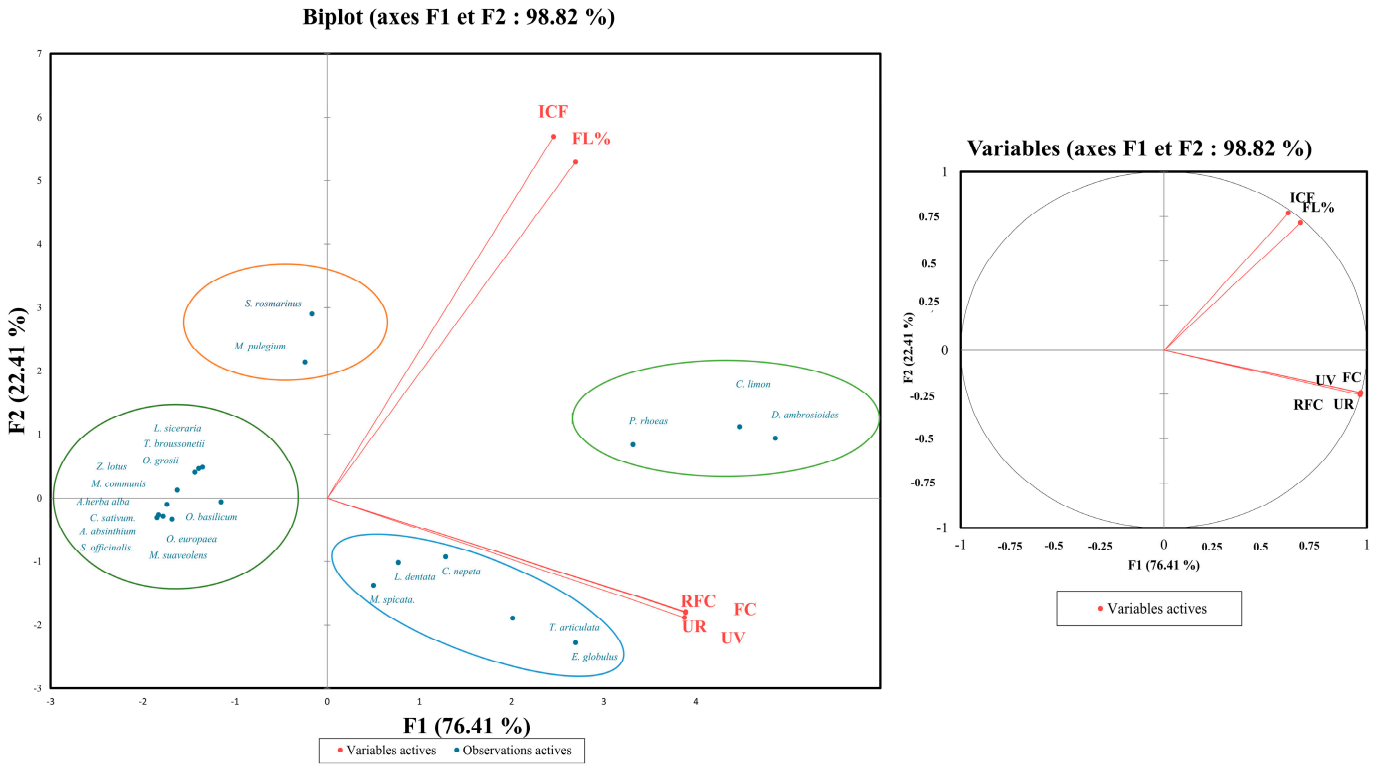

Figure 4. Principal components analysis (PCA) for an ethnobotanical index of the reported species in Casablanca, Morocco.

3.6. Method of Administration and Preparation

Many preparation techniques, such as decoction, juice, infusion, and poultice, are used to aid in the prescription of the plant's active ingredients. Table 2 shows the knowledge of the preparation of plants cited in the study zone. According to the findings, the majority of treatments were prepared using infusion (33.33%), followed by poultice (26.67%), decoction (20%), and juice (13.33%), with other preparations (cooked, maceration, and inhalation) accounting for only 6.67%.

3.7. Medicinal Uses of Combined Plants

In this research, the participants defined the use of eight plants from the inventory with a wide range of indications as recipe medicines; three combinations have been reported, and the most often mentioned herbs for reducing fever are reported in Table 4.

Table 4. Preparation method of medicinal plant combinations in Casablanca, Morocco.

N°	Form	Preparation Method
C1	Juice	Some leaves of *D. ambrosioides* (Handful) were made in juice with 1 cup of *C. limon* (250 mL).
C2	Juice	Leaves of *D. ambrosioides* (Spoon), *M. communis* (Spoon), *T. articulata* (Spoon), *Z. lotus* (Spoon), and *M. suaveolens* (Spoon), mixed with one tablespoon of honey.
C3	Poultice	Leaves of *D. ambrosioides* (Handful), *M. spicata* (Handful), and *L. dentata* (Handful) mixed with 1/2 cup of vinegar (125 mL).

Figure 5 displays the findings of combinations of medicinal plants using several indices (UR, RFC, and FL%), with combination 1, which comprises *D. ambrosioides* and *C. limon*, stated as being more popular than other combinations. According to herbalists, all

reported combinations are used to treat enteric fever. However, we can see a difference in the FL values of each combination, with C1 showing a higher FL = 85.71%, followed by C2 and C3 with FL values of 57.65%, and 56.14%, respectively.

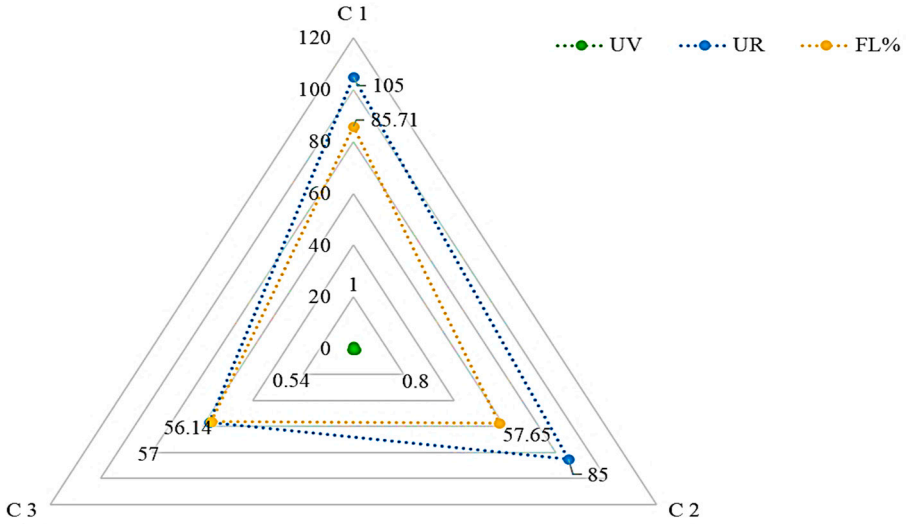

Figure 5. Quantitative values of combined medicinal plants used to treat enteric fever in Casablanca, Morocco.

4. Discussion

The survey conducted in Casablanca regions revealed that information on plants used to counter febrile illnesses varies from one respondent to another. Additionally, research's documentation of traditional knowledge has been skewed toward men [35]. Indeed, men predominate in medicinal plant sales, consistent with the findings of other research conducted in other Moroccan areas surveyed [17–36]; on the other hand, women dominate the practice and use of medicinal plants in their daily lives, and they are experts in the properties of plants. Several studies have found that the attention of male specialists in ethnobotanical research has disregarded the abundance of plant knowledge held by females [37]. More women herbalists must be included in this profession to take advantage of their knowledge. Herbalists' ages ranged between 30 and 61 years, most of them between 41 and 50 (34.3%) (Table 1). This survey shows that the elderly are the main repositories of folk knowledge. However, it seriously threatens indigenous knowledge because of the aging of older generations. This finding is comparable to those reported by [38,39]. According to data analysis, the vast majority of herbalists had a primary level education with a percentage of 41.9%. The predominance of the population that was poorly educated indicated the verbal transfer of knowledge from one generation to another and a continuous transition from the illiterate generation to the next, which is more educated. This is similar to the reported results by Zougagh et al., 2019 [17]. However, this transfer should not be conducted with the loss of information on medicinal plants, which indicates the need to sensitize the most educated people to this profession. Indeed, herbalists with a sufficiently high academic level can have a positive influence on the development of the practice of phytotherapy in the study zone because they can document the information by themselves on each plant and become aware of the degree of seriousness of each reported toxic principle. They can also ensure the written transcription of their knowledge and thus avoid its erosion or bad transmission when only orality is possible. The inhabitants of Casablanca utilize a few sources of knowledge about the usage of plants, with the experience of ancestry being the most crucial resource, with a rate of 70%, which shows the oral transmission of folk knowledge from the older generation to the next generation after a long experience. It also demonstrated that ethnomedical knowledge is primarily focused on older family members. However, it has recently become more complicated to transfer knowledge from older generations to young people attributed to the distrust of some people, particularly among

youth, who do not believe in traditional medicine, leading to a loss of knowledge about medicinal plants [40–43]. The herbalists are distributed mostly in two districts El Fida and Hay Mohammadi, which are the most diversified and populated in Casablanca. The local population of these districts uses the most medicinal and aromatic plants in the treatment of different diseases. This richness is also reflected in the broad culture of phytotherapy and phytopharmacology among the selected herbalists and traditional healers.

The herbalists reported the employment of 22 species, cultivated or spontaneous in the research zone, for developing different anti-febrile illness treatments. Calculating the species' RFC allows for establishing a link between each species and the uses assigned to it. The findings demonstrated that (*D. ambrosioides*, *C. limon*, *T. articulata*, *C. nepeta*, and *M. spicata*) have a higher value than others (*S. officinalis*, *M. suaveolens*, *A. absinthium*, *O. basilicum*, and *Z. lotus*), and that could be attributed to plant availability and easy cultivation [17]. The high usage rates show that they are well-known among the herbalists surveyed as anti-fever herbal remedies. These species belong to 11 families. The abundance of bioactive elements in these families could explain this predominance [44,45] (Supplementary File S4). On the one hand, the present study showed that two species have a fidelity level equal to 100% in nearly all categories of fevers, which reflects their effectiveness in the treatment of various febrile illnesses when only four species have recorded a fidelity level lower than 50%. For its part, the spectrum of action in relation to fever varies from one type to another; some have effects on a wide range of diseases, while others have a limited spectrum directed only against a class of febrile diseases. This is the case, for example, of *T. articulata* and *C. nepeta*, with restricted actions against nonspecific fever, and spotted fever, respectively. On the other hand, with regard to the informants' agreement ratio (ICF), a high value of ICF reflects the respondents' agreement to recommend certain plants for the treatment of specific diseases. Therefore, plants with high ICF values are effective in treating certain types of febrile diseases and are a potential source for the discovery of new active molecules that will form the basis for further research. Enteric fever is the category with the highest agreement, indicating that this disorder is common in Casablanca, where spotted fever had the lowest ICF. The choice of one plant part or the other depends on its content in active principles, the method of preparation, the disease treated, and the ethnomedicinal experience acquired by each herbalist. Indeed, in the study area, the leaves represent the most used part, and even literature research has confirmed that this part is the most recommended in the treatment of a range of diseases [46], due to the abundance of secondary metabolites, their availability from herbalists, and the simplicity of leaf remedy preparations [47]. Indeed, as regards the mode of preparation and administration of the recipes, they constitute parameters conditioning the effectiveness, safety, or toxicity of a plant [48]. Since some preparation methods allow the extraction of higher concentrations of active principles than others. Thus, to treat febrile illnesses, the respondents resort primarily to infusion, its use is justified by the fact that this method of preparation allows the accumulation of the most active compounds and reduces the toxic effects of some molecules [48]. Finally, the remedies used to treat febrile illnesses are most often administered orally, the most preferred route by patients [49].

This study presents some relevant combinations used to treat enteric fever. Other studies report that plants are more active when combined [50]. It is well known that using a combination of different herbs rather than just one to treat a disease has become more efficacious [51]. The concept of synergy, which emphasizes that the plants' combination may lead to better therapeutic efficacy, is best shown by using two or more plants [50,52]. This result should be critical in other research to study the synergy between these plants and should be subject to further study. The exhortation to use one plant or another by herbalists in Casablanca for febrile illnesses is based primarily on their accumulated experiences rather than scientific proof. Hence, sixteen plants were mentioned for the first time in this survey to treat fever in Morocco. Other medicinal plants were already reported to be used for fever by other international studies: *Dysphania ambrosioides* L. [53,54], *Citrus* × *limon* (L.) Osbeck [54], *Mentha spicata* L. [55], *Ocimum basilicum* L. [55], *Coriandrum sativum* L. [56],

and *Eucalyptus globulus* Labill. This finding is an important contribution to the indigenous knowledge of medicinal plant use in Morocco.

It is interesting to note that the majority of the identified plants have been investigated (in vitro and/or in vivo) for anti-fever activities. This gives additional credence to the use of these plants in fever treatment. As the pathogenesis of fever involves bacterial attacks or inflammatory responses, antibacterial and anti-inflammatory therapies may have potential value in its treatment. Our study has shown that the most commonly cited medicinal plants by herbalists (31%) used for fever have these anti-inflammatory, antipyretic, and antibacterial properties;

Dysphania ambrosioides L., aqueous leaf extract shows antipyretic, antimicrobial activities tested in vivo with a concentration of 800 mg kg^{-1} for 3 h [57,58]. While dichloromethane leaf extract and essential oils (α-pinene, borneol, globulol, α-terpineol, and 1,8 cineole) of *Eucalyptus globulus* Labill. show in vivo antipyretic effects at a concentration of 250 mg kg^{-1}, anti-inflammatory, and analgesic effects at 100 mg kg^{-1} [59,60]. As well, *Olea europaea* L. leaves ethanolic extract (caffeic acid, luteolin 7-*O*-glucoside, and apigenin 7-*O*-glucoside) shows an antipyretic effect in vivo at a concentration of 200 mg kg^{-1} for 120 min [61,62]. Furthermore, *Citrus* × *limon* (L.) Osbeck., methanolic fruit extract (gallic acid, caffeic acid, syringic acid, and *p*-Coumaric acid) shows an antimicrobial effect in vitro with zones of inhibition ranging from 4 to 29 mm [63]. *Myrtus communis* L., aerial parts essential oil (α-Pinene, limonene, 1,8-cineole, linalool, linalyl acetate, and α-terpineol) shows anti-microbial activity in vitro with zones of inhibition ranging from 8 to 29 mm and an anti-inflammatory effect in vivo at 2 mL kg^{-1} [64,65]. Likewise, *Tetraclinis articulata* L., an aqueous leaf extract (quercetin and catechin) shows an anti-inflammatory effect in vitro [66]. Other studies show that the methanolic leaves extract of *Ziziphus lotus* L. has an anti-inflammatory effect in vivo at 200 mg kg^{-1} [67]. While *Mentha suaveolens* Ehrh., fresh aerial parts essential oil (carvone, limonene, and dihydrocarveol acetate) show anti-inflammatory activity in vivo at 100 mg kg^{-1} [67]. The methanolic extract of *Mentha spicata* L., aerial parts (carvone, and limonene) show anti-inflammatory activity in vivo at 250 mg kg^{-1} [68]. Whereas the methanolic extract of *Lavandula dentata* L., aerial parts (hydroxybenzoic acids and hydroxycinnamic acids) show anti-inflammatory activity in vivo at 10 mg kg^{-1} [69].

In addition, the chemical composition of these plants is a determining factor in herbal therapy. Therefore, many abiotic and biotic factors can act to increase or decrease both yield and chemical composition.

Plants are physically attacked by many biological agents like fungi, viruses, bacteria, and nematodes, which cause stress in plants known as biotic stress. Due to the nature of plants, they cannot move to protect themselves or use the immune system, but they show resistance against these pathogens through the production of secondary metabolites. The production of some secondary metabolites may also be enhanced by some environmental factors involved in the plant's defense system for survival. During growth and development, plants interact with the surrounding environment, where they encounter different abiotic components like water, light, temperature, soil, and chemicals [70]. In previous studies, it has been proven that the chemical composition of essential oils can change dramatically from region to region and from one country to another. This is related to the geographical location, as well as the climatic conditions of the place of harvest and the nature of the soil in which this plant grows [71]. Variations in the chemical composition of a plant that was obtained at different seasons of the year have also been reported [72]. The production of chemical compounds by different parts is related to the anatomical, physiological, and transcriptomic characteristics of plants. Plants are stressed due to high or low salinity, resulting in a change in the content of secondary metabolites [73]. Light is essential for plants to photosynthesize and grow, which affects the accumulation and properties of secondary metabolites. Chemical stress is simulated when the essential nutrients for the growth and biosynthesis of plant secondary metabolites are not at an adequate concentration. Different chemicals, such as minerals, heavy metals, fertilizers, gases, toxins, pesticides, growth regulators, and elicitors, may induce chemical stress in plants [73].

Some of the main bioactive compounds of the most cited plant are represented in Figure 6.

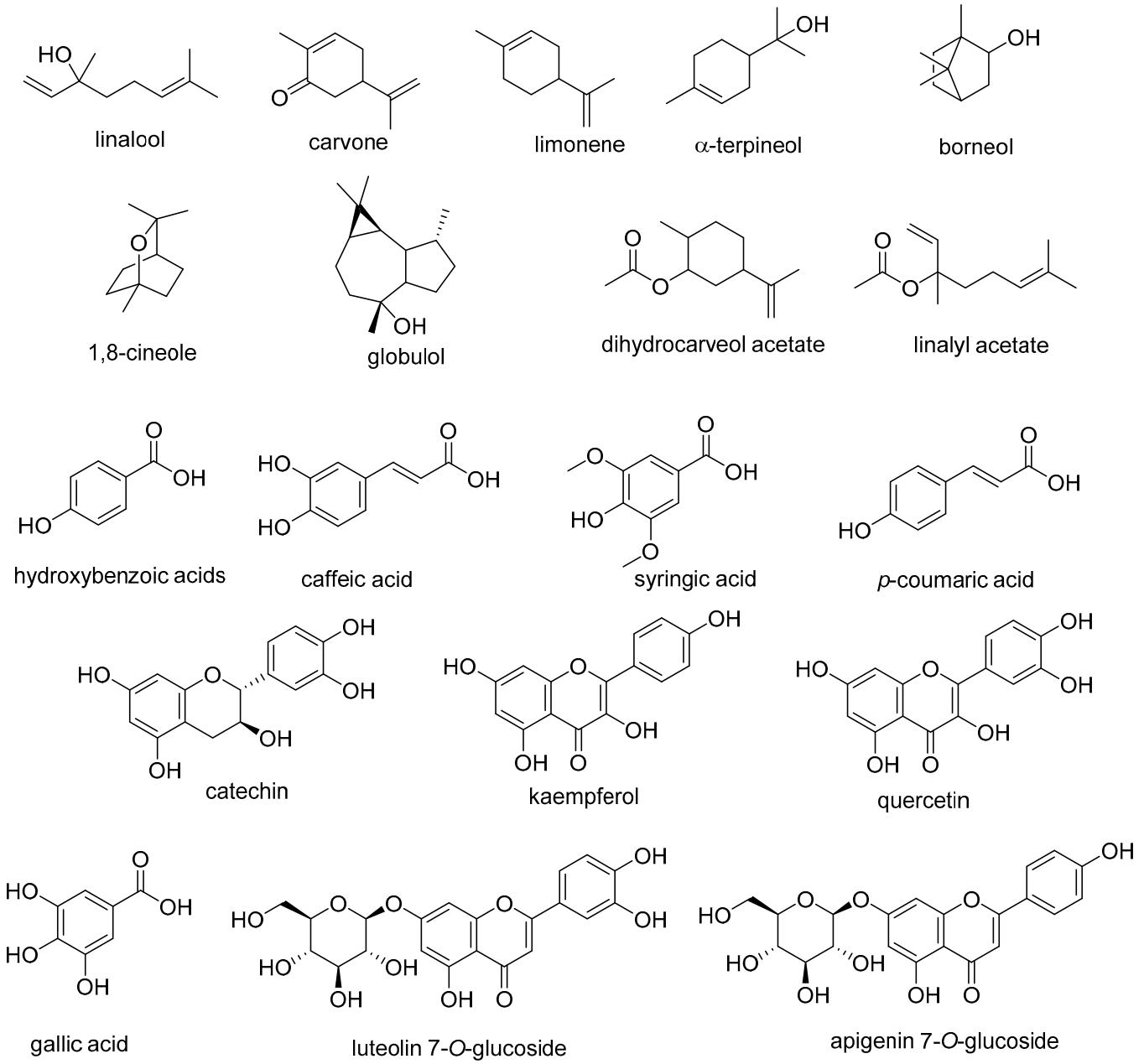

Figure 6. Chemical structures of some major bioactive compounds in the most cited plant.

4.1. Limitations of the Study

This study was carried out in one part of Morocco (Casablanca) and may not reflect traditional uses in other Moroccan regions. The survey was carried out for six months (from May to October 2021), and we were unable to identify the plants that followed in other seasons. This study is based solely on interviews with traditional herbalists. A wider range of participants would increase the completeness of the results.

4.2. Conclusions and Recommendations for Future Research

This study provides the first report on plants used to manage fever in Casablanca, Morocco. While the people living in this city are still attached to folk medicine to treat febrile illnesses, this research is being conducted in Casablanca. We have tried to uncover

information about the plants used and the preparation methods. The results illustrate the promising effects of some plants in managing this disease, especially when they are combined. As a result, medicinal plants with high RFC levels should be evaluated for biochemical and pharmacological assessment to determine bioactive constituents that may provide therapeutic options with fewer harmful side effects and lower bacterial resistance.

Similarly, low RFC plants should be evaluated to ensure that historical ethnomedicinal information is passed down to upcoming generations. More research on the effect of all herbs reported in this study on fever and the mechanism of synergy between them should be encouraged to value the combinations cited. Once the beneficial effects of these herbs have been demonstrated to be effective (in vivo, including human studies), it is possible to produce medicines helpful in treating febrile illnesses.

Natural products, which have evolved over many years, have unique chemical structures, giving them diversity in their biological effects and medication-like properties. It is well known that research using natural products has made a significant contribution to drug development. Many products have become important resources for developing new lead compounds (e.g., antihypertensives and anticancer drugs). Natural products will undergo continual use toward meeting the need to develop effective drugs; very likely, they will play an important function in the discovery of medications for managing certain human and animal diseases.

Indeed, herbalists must be encouraged to work 'hand in hand' with healthcare workers in the diagnosis and treatment of diseases, where there is a need for better knowledge of febrile illnesses for proper management. Also, this study could provide another opportunity for encouraging the passing down of historical ethnomedicinal information to upcoming generations.

Furthermore, as previously stated, most traditional cures are centered on symptoms that, from the standpoint of modern institutional medicine, may have very different causes and would be treated in very different ways. Another challenge is that traditional medical practice is perceived as dualistic, natural, and preternatural, which does not correspond well with the scientific monistic approach [74]. Ethnobotanical research, on the other hand, remains a valuable source of information. Although ethnobotanical indices cannot identify plant substances for drug discovery, they can provide information about the cultural value and importance of plants, as well as conservation issues.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15070879/s1. File S1: Sample size Calculation; File S2: Eligibility Criteria; File S3: Questionnaire; File S4: Traditional uses of the documented plants in Morocco. References are placed in [75–89].

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Abbreviations

FL: Fidelity Level; FIV: Family Importance Value; ICF: Informant Consensus Factor; PPV: Plant Part Value; RFC: Relative Frequency of Citation; WHO: World Health Organization.

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