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Original Article

Ethnobotanical and toxicology study of medicinal plants used for the treatment of diabetes in the High Atlas Central of Morocco

[Estudio etnobotánico y toxicológico de las plantas medicinales utilizadas para el tratamiento de la diabetes en el Alto Atlas Central de Marruecos]

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Abstract

Context: Diabetes mellitus is considered one of the scourges of the third millennium in the world for several years.

Aims: To evaluate, identify and preserve the experiences gained over the centuries. It is about therapeutic use of medicinal plants exploited for the treatment of diabetes, and to clarify its toxicities, in order to sensitize the population of the High Atlas Central (HAC) of Morocco not only on the risk but also the benefit of the use of phytotherapy.

Methods: The surveys ethnopharmacological were conducted 834 the interviewees, using semi-structured survey, by application of quantitative indices such as Consensus index (CI %), Use value (UVi), family UV (FUV), relative frequency of citation (RFC), plant part value (PPV), and informant consensus factor (ICF) to assess the exact value of medicinal plants (MP).

Results: We found that 144 medicinal plants in 121 genera and 52 plant families were traditionally used to treat diabetes, of which seven species were endemic to the study area, and 32 were being cited first ever to treating diabetes. In addition, we collected toxicological information on 99 antidiabetic plants, of which 41 species showed no toxic activity and 43 were toxic and sometimes lethal in high doses. The *Ranunculaceae* family showed the highest use value (FUV =0.139). Leaves were the most used plant parts (PPV =0.282) and infusion was the dominant method of preparation. The frequently used species were *Olea europaea* L. (UVi =0.172), *Salvia officinalis* L. (UVi =0.156) and *Euphorbia resinifera* Berg (UVi =0.150).

Conclusions: These results are a rich source of information. They contribute to the knowledge of the antidiabetic medicinal flora of our study area, and to the preservation of the local popular know-how of the word that tends to disappear. They may also represent a database that consists of purifying and identifying the characterization of active compounds of herbal extracts with antidiabetic activity.

Keywords: diabetes; High Atlas Central (Morocco); pharmacological; therapeutic use; toxicology.

Resumen

Contexto: La diabetes mellitus se considera uno de los flagelos del tercer milenio en el mundo desde hace varios años.

Objetivos: Evaluar, identificar y preservar las experiencias adquiridas a lo largo de los siglos. Se trata del uso terapéutico de las plantas medicinales explotadas para el tratamiento de la diabetes, y de aclarar sus toxicidades, a fin de sensibilizar a la población del Alto Atlas Central (HAC) de Marruecos no sólo sobre el riesgo sino también sobre el beneficio del uso de la fitoterapia.

Métodos: Las encuestas etnofarmacológicas se realizaron 834 a los entrevistados, utilizando una encuesta semiestructurada, mediante la aplicación de índices cuantitativos como el índice de consenso (CI %), el valor de uso (UVi), la familia UV (FUV), la frecuencia relativa de citación (RFC), el valor de la parte de la planta (PPV) y el factor de consenso de los informantes (ICF) para evaluar el valor exacto de las plantas medicinales (MP).

Resultados: Encontramos que 144 plantas medicinales en 121 géneros y 52 familias de plantas se usaban tradicionalmente para tratar la diabetes, de las cuales siete especies eran endémicas del área de estudio y 32 se citaban por primera vez para tratar la diabetes. Además, recopilamos información toxicológica sobre 99 plantas antidiabéticas, de las cuales 41 especies no mostraron actividad tóxica y 43 eran tóxicas y, a veces, letales en dosis altas. La familia *Ranunculaceae* mostró el valor de uso más alto (FUV = 0,139). Las hojas eran las partes de las plantas más utilizadas (VPP = 0,282) y la infusión el método de preparación predominante. Las especies más utilizadas fueron *Olea europaea* L. (UVi = 0,172), *Salvia officinalis* L. (UVi = 0,156) y *Euphorbia resinifera* Berg (UVi = 0,150).

Conclusiones: Estos resultados son una rica fuente de información. Contribuyen al conocimiento de la flora medicinal antidiabética de la zona de estudio, y a la preservación del saber popular local de la palabra que tiende a desaparecer. También pueden representar una base de datos para depurar e identificar la caracterización de compuestos activos de extractos de hierbas con actividad antidiabética.

Palabras Clave: Alto Atlas Central (Marruecos); diabetes; farmacológico; toxicología; uso terapéutico.

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INTRODUCTION

Diabetes mellitus is a condition characterized by chronic elevation of blood glucose concentration (hyperglycemia), which occurs when fasting plasma glucose is 1.26 g/L or >2g/L, regardless of the time of collection in the existence of clinical symptoms (Drouin et al., 1999).

This metabolic anomaly is due to inadequacy or poor insulin use by the body from hence the division of diabetes into two broad categories: insulin-dependent diabetes or diabetes type I (TD1) is characterized by insufficient insulin. Non-insulin-dependent diabetes or type II diabetes (TD2), results from poor use of insulin by the body. Also, there are other categories of diabetes namely gestational diabetes and more rarely genetic or acquired diabetes (WHO, 2015).

Diabetes is a major health problem worldwide. The epidemiological studies have shown that it affects all populations and all age groups equally. It expands rapidly, so there were 366 million diabetics in 2010 and 552 million are expected in 2030 (Whiting et al., 2011), which poses serious economic problems for developing countries. This explains why Morocco spends about 156 700 000 MAD each year to buy insulin and oral antidiabetic. It also spends about 15 million MAD to buy medico-technical and reactive equipment for the detection of the disease (WHO, 2015). Due to the expansion of this disease and high drug costs, it is frequent that the population of developing countries resort to traditional medication through therapeutic plants (Tabuti et al., 2003). Consists of these plants provide an accessible, affordable, lower cost medical potential (Okigbo and Omodamiro, 2007). It offers an inexhaustible resource that provides the common of the active pharmaceutical ingredients in Africa (Onsiyor et al., 2019). More than 80% of the population uses traditional medicine and medicinal plants to satisfy their needs in primary health (WHO, 2015). The valuation of natural resources is a priority that becomes increasingly important in many countries. Since its general assembly, the WHO encourages more research into leads including those using traditional herbal treatments (Palombo, 2006).

Ethnopharmacology and ethnobotany figure out people's knowledge, in relation to the use of plants to heal and fight against diseases, which makes it possible to identify antidiabetic remedies and to build up a database of medicinal plant (MP) to keep ancestral knowledge. Many plants from around the world have been studied for their antidiabetic effects. There is several ethnobotanical information has been collected in various parts of the world. Thus, over 1123 plant species, representing 183 families, are considered to have hypoglycemic and antidiabetic properties (Marles and Farnsworth, 1995; Ernst, 1997; Lamba et al., 2000).

The High Atlas Central (HAC) of Morocco by these reliefs, its topography and its geographical location, offers diverse vegetation, with the presence of a high rate of endemic species. This region is the origin of many sold in Morocco and abroad. However, data on therapeutic uses of MP and their toxicities are very rare (Belhaj et al., 2020), and no studies have proven the effectiveness of plants of this region in diabetes treatment. It is therefore important to keep a written record of all the phytotherapy practices because the transmission to future generations is based on oral tradition. Based on these data, we conducted surveys to identify the MP use locally by the population of the HAC, analyze the results regarding the relationship between these species and diabetic problems, to preserve the therapeutic knowledge of the population on this natural heritage and to value it for its rational use.

MATERIAL AND METHODS

Presentation of the study area

Due to its geographical position and climate, the HAC of Morocco offers a tremendous ecological and floristic diversity. Also, traditional phytotherapeutic knowledge is well represented in this region.

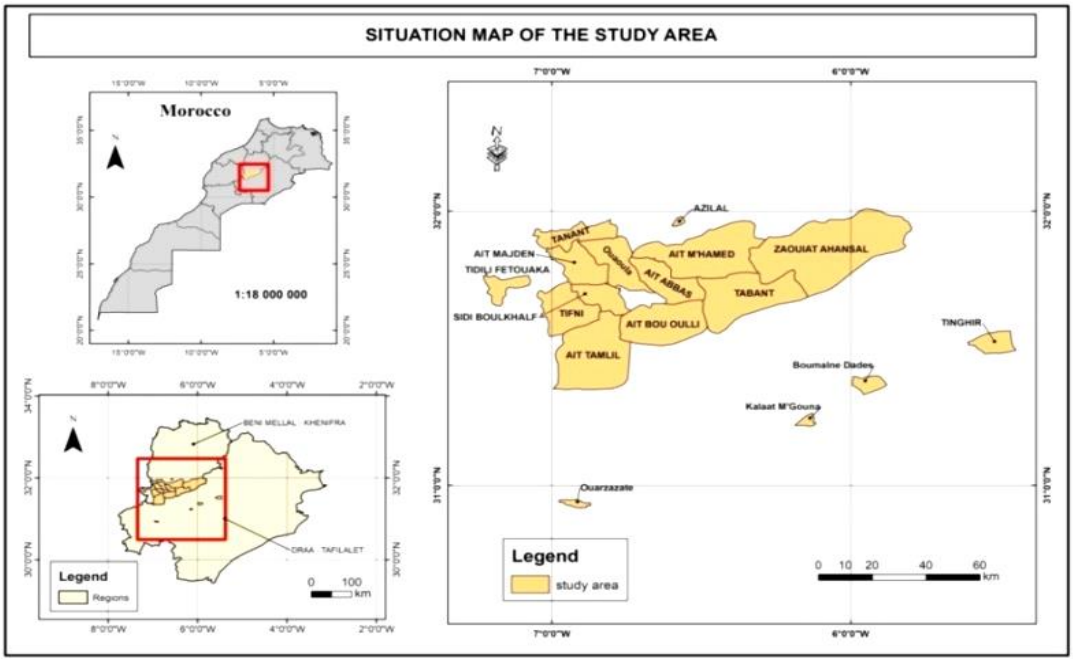

Figure 1. Map situation of the study area.
High Central Atlas (Realized by Belhaj according to the administrative division of 2015, Arcgis).

The study was conducted in the center of the atlas chain of Azilal North, Ouarzazate, and Tinghir South, in the High Central (Fig. 1).

The north side of the High Atlas Central (Fig. 1)

The municipalities of Aït abbas, Aït Bou Oulli, Tabant, Zaouiat Ahansal, Aït Majden, Tifni, Sidi-boulkhalef, Ouaoula, Aït M'hamed, Ait Tamlil, Tidli-Fetouaka, Tannant, Ouzoud, belonging to the city of Azilal, which is geographically located in the center of the Kingdom and belongs to the Beni Mellal-Khenifra economic region, which existed from the regional division of 2015 from the three former regions: Meknes-Tafilalet, Chaouia-Ouardigha and Tadla-Azilal (Official Bulletin, 2015). It occupies an area of about 1 million hectares, all mountainous, with the exception of a tiny part of the Tadla plain.

Administratively, the Beni Mellal-Khenifra region comprises five provinces: Azilal, Beni Mellal, Fquih Ben Salah, Khenifra and Khouribga, 135 communes including 16 municipalities and 119 rural Communes (HCP, 2018a). About 80% of the surface area of the Province is situated at an altitude of more than 1000 m and 60% above 1500 m (Tabuti et al., 2003).

The climate is generally Mediterranean and spreads over the four seasons. It characterizes by heavy rainfall during winter and spring and a very severe summer drought (Sauvage and Vindt, 1952).

Geologically, the area of the province extends over nearly one million hectares and covers a large part of the high limestone Atlas of the secondary age (Pique, 1994). Its population is 2 520 776 inhabitants, of which 1 282 037 are rural populations according to the national census of the population 2014 (HCP, 2018a), which explains the high illiteracy rate, which is 52%. The main plant formations in the area are as follows: The Holm oaks, which occupy an area of 205 000 ha or 57.59% of total forest area of the province followed by junipers with 18.15%, while maritime pine is only represented by 0.29% and secondary species by 10.46%, although planted forests occupy 9149 Ha or 2.61%.

The south side of the High Atlas Central (Fig. 1)

In the southern slope, this work was carried out in the provinces of Tinghir, Ouarzazate belonging to the Draa-Tafilalet region, which was established like the 11 other regions of the Kingdom, by the Decree of February 20st 2015, and published in Official Bulletin No. 6340 of March 5th, 2015 (Official Bulletin, 2015), encompasses an extension of 88 836 km:

- With a total area of 1 112 460 ha, the province of Ouarzazate edges to the northern by the province of Azilal and Marrakech, to the east by the province of Tinghir, to the south by the province of Tata and Zagora and to the west by the province of Taroudant. It belongs to the arid bioclimatic zone with a continental tendency, the soils of this zone are 75% clayey-silt soils, with little evolution of alluvial inputs at 20% and skeletal inputs at 5%.

The province's special crops occupy small areas, but still provide substantial income to producers. This includes saffron, which occupies 85 hectares with an average annual production of 215 kg (HCP, 2018b).

- With a total area of 908 960 ha, Tinghir province exists to the northern by the province of Azilal, to the east by the province of Errachidia, to the south and west by the province of Ouarzazate. It includes two circles, namely Tinghir, and Boumalne, tree municipalities (Tinghir, Kelaa M'gouna and Boumalne Dadés) and 17 rural commons. It belongs to the arid bioclimatic stage with a continental tendency.

The total population of Tinghir Province is 22 966 666, of which 168 084 or 73.19% are rural. The soils of the two sub-basins, Todgha and Dades-Mgoun, are in most cases alluvial, undeveloped, deep, silty-sandy and sandy. These soils are 75% iso humic, 20% alluvial and 5% skeletal. Special crops in the province occupy small areas, but still provide an important income to producers, particularly perfume roses, which have produced an average of 2743 tons over the past five years (HCP, 2018b).

Methodology

Data collection tools and procedures

In order to identify the medicinal plants used by the diabetic population in the study area (between 31 to 32 N latitude and 6 to 7 W longitude). The field surveys were conducted between May 2015 and August 2017. In the study area, the residents and sellers of medicinal plants (herbalist pharmacists and pharmacists) who were randomly selected to conduct interviews based on the local language, Amazigh or Arabic in different places (hospitals, pharmacies, houses, mosques and weekly markets) were properly informed of the purpose of this study. They regularly proceeded to accumulate and document the traditional therapeutic uses of plants against diabetic diseases.

By stratified random sampling (Martin, 2004), 623 informants aged from 19 to 94, from different socio-economic strata, were interviewed using 992 semi-structured and free questionnaire sheets (Appendix 1). Each interview took approximately one hour, in order to collect all the demographic information about the informants, such as gender, level of study and socio-economic level, as well as the local use of medicinal plants for the treatment of diabetes, including the vernacular name of each species, the parts used, the method of preparation, toxicological data, the type of plants, the effectiveness of plants according to the population surveys and the origin of the information (Appendix 1).

The surveys based on the method of semi-structured interviews (Bartholomew et al., 2000). Initially, identifying plant species was carried out during field trips for observation, sampling, recognition of spontaneous plants in the study area and photographing them, while the final determination of the taxonomic names of these plants in French and English was approved in collaboration with the laboratory of biodiversity and Natural Resources (LBNR) Faculty of sciences, Ibn Tofail University, Morocco, using the herbaria, directories and flora available such as: Moroccans medicinal and aromatic plants (Hmamouchi,

2001), Vascular flora of Morocco (Fennane and Ibn Tattou, 2005), The traditional Moroccan pharmacopoeia (Bellakhdar, 1997), Catalogs of vascular plants of northern Morocco, including identification keys (Valdés, 2002), volumes I and II, and finally, all the specimens of the plants recorded were kept in our laboratory (LBNR).

Data analysis

Various analytical tools can provide researchers with valuable means for assessing the exact value of different aspects of plant use data. Among these tools, the descriptive and quantitative statistical method for testing the hypothesis of comparing the means between the groups of the correspondents (ANOVA test and Student's t test, has a significant when ($p \leq 0.05$)), also used in this article the consensus index (CI%), the value of use (UVi), the UV family (FUV), the relative frequency of citation (RFC), the value of the plant part (PPV) and the consensus factor of informants (ICF). All analysis statistics were performed by the software SPSS Statistics (statistical software for Social sciences, version 21) and Excel 2010.

The use value (UVi)

Use value is a quantitative method that indicates the relative significance of locally known plant species, commonly used in quantitative ethnobotany, was determined by the formula [1] (Thomas et al., 2009).

$$UVi = \sum Uis / Ns \quad [1]$$

Where, Uis indicates the number per specific plant species mentioned by informant, and Ns to the number of interviewees who cited species.

The FUV identify the significance of plants families

FUV values show the importance of the plant's families. It was calculated by using formula [2] followed by Molares and Ladio (2009).

$$FUV = UVs / Ns \quad [2]$$

where UVs = UVis the total number of respondents reporting the family, and Ns = total number of species within each family.

Consensus index (CI %)

The percentage of informants with traditional indigenous knowledge of medicinal plant species used for disease control (in these study diabetic diseases) was determined according to a consensus index (CI %), which indicates the citation by % of informants [3]

$$CI = n / N \times 100 \quad [3]$$

where n is the number of respondents citing herbal species, whereas N is the number of all informants in the survey (Sreekeesoon and Mahomoodally, 2014).

The Plant Part Value (PPV)

PPV is the report on the total number of declared uses for any part of the plant. The total number of declarations for a given plant [4].

$$PPV (\%) = RU_{\text{plant part}} / RU \quad [4]$$

where RU is the total number of notified uses of any part of the plant and $RU_{\text{plant part}}$ is the number of uses cited for each plant part. The part that has the highest PPV is the one most used by respondents (Rahman et al., 2016).

The Informant Agreement Ratio (IAR)

The IAR was calculated to seek consensus among informants about a plant species used for the treatment of a particular disease. The applied formula [5] was used (Hoffman and Gallaher, 2007).

$$IARs = (NUC - NS) / (NUC - 1) \quad [5]$$

where NUC = number of use reports in each category, NS = number of species used in each category.

RESULTS AND DISCUSSION

Socio-demographic features of the informants in the High Atlas Central of Morocco

In total of 623 informants including 323 females and 309 males, (with a sex ratio female/male of 1.04) were interviewed though, in the HAC of Morocco (Table 1). Both sexes have a long history of using herbal medicines, however women more knowledge about the plant species and their medicinal uses than men (51.11% against 48.89%). The

test (the Student's T test) did not show any significant difference (p = 0.275). These results can be explained by the attachment of women to the traditional component, and the ease of transmission of information between them. In addition to, they take care and devote more of their time to household chores, and she cares about their treatment as well as their families particularly in rural areas. Similar results have been obtained in other studies in many regions of Africa such as in Morocco (Ziyyat et al., 1997; Eddouks et al., 2002; Tahraoui et al., 2007; Fouad and Lahcen, 2020), in Algeria (Blama and Mamine, 2013), in Côte d'Ivoire (Kouakou et al., 2020).

The family situation of the respondents was as the following: 54.74% were married, 25.21% were single, 11.88% were widows and 8.18% were divorced. These results can be explained by the fact that married people take care of their health as well as their children especially in the rural environment, and also to economize the material charges of the doctor and pharmacist. The difference between family's status was statistically significant (p = 0.000). Nabih (1992) and Chaachouay et al. (2019a) did in this regard ethnobotanical researches.

The data treatment shows that the most represented age group is the older people [70-94], with a frequency of 37.24%, followed by the age groups [50-70], and [30-50] with 27.93% and 21.83% respectively. The younger generations do not show much interest in the use of medicinal plants, so they remain in the last position with only 13%. The difference between age groups was significant (p = 0.000). These percentages illustrate that the experience accumulated and mastered with age is the main source of local information for the use of plants traditionally. However, we have seen a loss of information on the use of medicinal plants, especially among young people, who tend to no longer believe in this traditional medicine. This inherited knowledge is now in danger of disappearing, so it must be protected and rehabilitated. These results are consistent with the results of other authors in the Maghreb, for example: in Morocco (El Yahyaoui et al., 2015; Barkaoui et al., 2017) and Algeria (Derridj et al., 2009).

Taking into account the level of education, it reveals that the population surveyed is dominated by illiterates (40.29%), followed respectively by the people who have the secondary level (28.73%) the middle level (16.21%), then the university level (14.77%). The difference between the level of education and native knowledge was important (p = 0.000).

These results show that the more the education level increases, the more the use of medicinal plants decreases. These values are very close to data in several African countries, for example Morocco (Skalli et al., 2019), Algeria (Debbi and Guerrouche, 2019), Benin (Guinnin et al., 2015), which show that the use of plants remains the heritage especially of the poor people.

The results of our surveys show that the largest number of respondents (61.16%) had a low socio-economic level, while (22.15%) were unemployed, (13.16%) had an average level, and only (3.53%) had a slightly higher level. This is explained by the fact that most respondents are seasonal farmers (54%) or students (8%), while only (16%) are civil servants and (7%) are entrepreneurs. There is a significant difference between income/month and indigenous knowledge (p = 0.000). These values are in agreement with those reported in other regions of Morocco (Jouad et al., 2001; Chaachouay et al., 2019b).

Diversity of medicinal plant species in the study area

Among the 144 MP traditionally used against diabetes, 15 imported from other regions of the country, 49 were cultivated and 80 were spontaneous (of which seven were endemic to this study area). These species counted 121 genera divided into 52 families, of which the most represented were those of *Lamiaceae* and *Asteraceae*. Some of these plants had been reported in ethnobotanical surveys on diabetes treatment in Morocco (Eddouks et al., 2002; Laadim et al., 2017; Idm'hand et al., 2020).

Table 1. Demographic profile of informants interviewed.

Variables	Category	Total	Percentages (%)	P-values
Gender	Female	323	51.11	0.275
	Male	309	48.89	
Age groups (years)	19-30	81	13.00	0.000
	30-50	136	21.83	
	50-70	174	27.93	
	70-94	232	37.24	
Family situation	Married	341	54.74	0.000
	Single	157	25.21	
	Divorced	51	8.18	
	Widower	74	11.88	
Educational level	Illiterate	251	40.29	0.000
	Primary	179	28.73	
	Secondary	101	16.21	
	University	92	14.77	
Income/month	Unemployed	138	22.15	0.000
	350 - 1500 MAD	381	61.16	
	1500 - 5000 MAD	82	13.16	
	>5000 MAD	22	3.53	

These families were classified in alphabetical order, and for each inventoried plant were assigned: scientific names, local and English, therapeutic use, preparation, and origin, also the analytical tools that were used were FUV, UR, UV and CI (Table 2).

The comparison of our results with the ethnobotanical and ethnopharmacological studies carried out in search of medicinal plants used for the treatment of diabetes in Morocco; showed that 32 plant species were registered for the first time as antidiabetic drugs.

Frequency of botanical families the most used and their family use value (FUV)

The families with the greatest specific diversity based on the number of species and the FUV index were *Lamiaceae* (19 species, FUV= 0.060), *Asteraceae* (18 species, FUV = 0.035), *Fabaceae* (13 species, FUV = 0.059), *Apiaceae* (6 species, FUV = 0.054), *Cucurbitaceae* (5 species, FUV = 0.036), *Rutaceae* (5 species, FUV = 0.056), *Euphorbiaceae* (4 species, FUV = 0.064), *Myrtaceae* (4 species, FUV = 0.063), *Rosaceae* (2 species, FUV = 0.037), *Solanaceae* (2 species, FUV = 0.046), these families alone contained 57 species, almost 43.84% of all antidiabetic plants census. All other families represented by only one or two species. This high proportion of *Lamiaceae* and *Asteraceae* could be explained by their importance in the medicinal flora. They were part of the nine main families of the spontaneous flora of Morocco (Fennane et al., 1999), hence the existence of many spontaneous and endemic species of these families in the HAC of Morocco, this area characterized by an altitude gradient (plain, Piedmont and mountains) that offered a high availability of medicinal plants with a high rate of endemic species. The high representation of these families in traditional medicine had also been noted in many ethnobotanic surveys around the world, in Morocco (Bouayyadi et al., 2015), Pakistan (Rahman et al., 2016), and in Spain (Agelet and Vallès, 2001) (Fig. 2).

The use value UVi plant species

Analysis of the use value of medicinal plants in our study area showed that UVi ranged from 0.003 to 0.172 and their use ratios (Uis) from two to 109, the three species with the highest UVi are *Olea europaea* L. (UVi = 0.172), *Salvia officinalis* L. (UVi = 0.156), *Euphorbia resinifera* Berg (UVi = 0.150), these species were very popular, and had considerable local importance, which reflected their importance in the treatment of diabetic diseases, on the other hand, species with the lowest UVi values, such as *Sonchusoleraceus* L. (UVi = 0.003), *Pallenis spinosa* (L.) Cass. (UVi = 0.004), and *Fumaria officinalis* L. (UVi = 0.004), and which had low popularity, should not be abandoned, in order to preserve population knowledge and limit the risk of gradual disappearance of ancestral knowledge (Table 2).

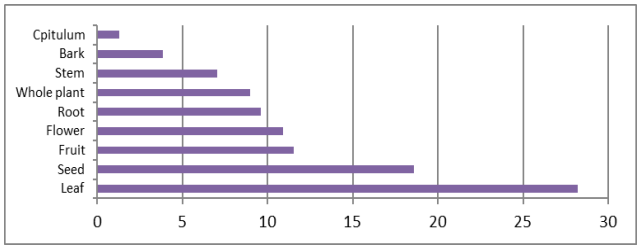

Figure 2. Percentage distribution of the parts used (PPV index).

The confirmation index CI%

The indices (CI%) of botanical taxa were mentioned in Table 2, in order to evaluate the agreements of the informants on the plants often used against diabetic diseases. The results revealed a high consensus around the use of the *Olea europaea* L. (CI% = 17.2%), and *Salvia officinalis* L. (CI% = 15.66%), which were considered to have a better healing potential in the HAC.

Parts of the medicinal plants used in the study area

In traditional medicine, each part of plant has therapeutic properties, which differed depending on the plant itself and the pathology treated. These plants could be used as whole or in part (leaf, fruit, seeds, stem, root), in order to determine the parts most usable to treat diabetic diseases. Based on the PPV index of partial value, showed a high frequency of use of leaf in our study area (PPV = 0.282), followed by seed (PPV = 0.185), and fruit (PPV = 0.115). The high rate of leaves used by the population of the region characterize by their ease and speed of harvesting (Bitsindou and Lejoly, 1996), and because the leaves are rich with a wide variety of active phytochemicals, which play an important role in therapeutic actions against diseases (Ahmad et al., 2009). These results were consistent with several similar studies established in several African countries: Morocco (Doukkali et al., 2015), Benin (Sangare et al., 2012) and Nigeria (Okafor and Ham, 1999), and differed with others conducted at the National by Haouari et al. (2018), which indicated that herbal recipes are mainly prepared from seeds, and at the international to Iran (Baharvand-Ahmadiet al., 2016) and Mali (Diarra et al., 2016), where the authors showed that fruits were the most used parts. These results were understandable because pathology and the geographical areas were different (Fig. 2).

Type of plants and harvesting techniques

Based on interviews conducted with the inhabitants of the HAC, a repertoire of 144 antidiabetic plants were constituted, most of these plants (55.55%) were spontaneous with eight endemic species, 34.03% were cultivated, and only 10.41% were imported from other regions of Morocco, which proved that the study area was endowed with a great wealth of MP, access to which was mainly directing collection (81%), and 100% manual, while the recipes prepared generally consisted of single plants (69.83%) or a combination of two or three plants (30.17%).

Methods of preparation

The results of our surveys showed seven methods of preparation used by the local population, whose infusion was the most requested (41.93%). These results were in disagreement with other works carried out in the Central Middle Atlas (Douira and Zidane, 2015) and north (Hachi et al., 2016) of Morocco, which showed that the decoction is the most requested mode. This significant difference was related to climatic, edaphic, biotic

and geological factors, as well as sociocultural factors and eating habits of each region of Morocco (Fig. 3).

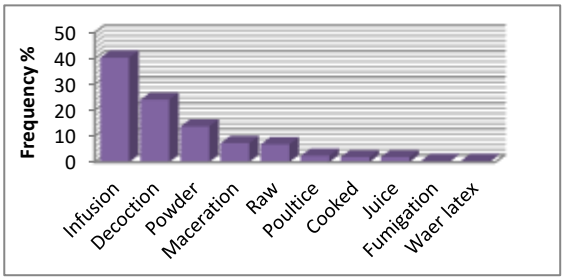

Figure 3. Percentage distribution of the methods of preparation.

Medicine administration methods

There were several methods of administration of plants, such as rinsing, massage, and oral, among others. In our study, the oral way was the most used means by the local population. This could be explained by the practice and simplicity of this mode, which facilitated the absorption of the active ingredients of medicinal plants, to easily transport them in the body, therefore the treatment of diabetic diseases. This predominance of oral administration had also been reported in (Didier et al., 2011; Yaseen et al., 2015), which confirmed the effectiveness and the importance of this method of administration worldwide.

Conditions of preparation

In our study area, herbal remedies were mostly prepared from fresh collected plants (49.6%), while 31.8% of the informants prepare their recipes from the dry parts of the plants, and 18.6% made their preparations medicinal from fresh or dry parts. Thus, drying, and conservation should be carried out protected from light, which allow the preservation of most of the active ingredients in plants. These results were consistent with similar work carried out in other African countries (Bousta et al., 2014; Kidane et al., 2018).

Dosage and duration of use of medicinal plants

The present study showed that the duration of treatment varied greatly among the categories of diabetic patients, ranging from three weeks to four years, so the majority of informants (62.12%) respected the doses, and only 37.88% of the cases toke their herbal remedies with non-specific doses, either in handful (21.02%) or in spoon (16.86%). Moreover, we noticed that even the exact frequency of doses was not correctly measured, usually a teaspoon (10 g), a spoon (20 g), a teacup (200 mL) or a cup (about 300 mL), however, this lack of exact dosing information among the respondents could lead to harmful effects, as there was often dose-dependent toxicity (Benkhnigue et al., 2010).

Values Informant Agreement Ratio (IAR)

In order to evaluate the agreement of the local population regarding the use of the species identified for specific use categories, we compared the number of times the informant mentioned the availability of plants in the study area to treat a specific disease with the number of plant species in each use category. The various human diseases had been defined in specific categories of use (Chaudhary et al., 2006). Recently, reported of agreement (IAR) analysis had been used as an important tool for processing ethnobotanic data (Uprety et al., 2010). It should be noted that the local people distinguish between the different types of diabetes. For example, TD1, which appeared mainly in children who become thin, the TD2 appears in most cases at maturity, while GTD was related to pregnancy which can disappear afterwards. According to Table 3, we were informed that the IAR values ranged from 0.94 to 0.97 per category of use, of which the most widespread plants and which were distinguished by their local importance were that TD1 with 95 species (IAR = 0.97), which may indicate a high degree of shared knowledge of this category in the HAC, then came the category of TD2 with 66 species (IAR = 0.96), and finally GDM with 18 species (IAR = 0.94).

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco.

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
	1. Amaryllidaceae											0.022
1		*Allium cepa* L. (LBNR5)	Lbassala/ Azalim	Onion	Whole plant	Raw, cooked, juice	Cultivated	TD1	7	0.011	1.10	
2		*Allium sativum* L. (LBNR6)	Touma/ Tishert	Garlic	Bulbs	Raw, cooked	Cultivated	TD1, TD2	21	0.033	3.32	
	2. Anacardiaceae											0.004
3		*Pistacia lentiscus* L. (LBNR8)	Drou/ Tidekht	Mastic-tree	Barks, leaves	Decoction, infusion	Spontaneous	TD1	3	0.004	0.47	
	3. Apiaceae											0.054
4		*Ammi visnaga* (L.) Lam. (LBNR11)	Bechnikha	Toothpick weed	Inflorescence, fruits	Decoction	Spontaneous	TD1	12	0.018	1.89	
5		*Carum carvi* L. (LBNR17)	Karwia	Caraway	Seeds	Infusion, powder	Cultivated	GDM	16	0.025	2.53	
6		*Coriandrum sativum* L. (LBNR18)	Kezbour	Coriander	Seeds	Infusion, raw	Cultivated	TD1, TD2	81	0.128	12.81	
7		*Foeniculum vulgare* Mill. (LBNR21)	Nafae	Fennel	Seeds	Decoction, infusion	Cultivated	TD1, TD2	37	0.058	5.85	
8		*Pimpinella anisum* L. (LBNR24)	Hbbat hlawa	Green anise	Seeds	Decoction	Cultivated	GDM	29	0.045	4.58	
9		*Ridolfia segetum* (L.) Moris (LBNR25)	Tebche	Ridolfia segetum	Seed	Powder	Spontaneous	TD1	34	0.053	5.37	
	4. Apocynaceae											0.108
10		*Caralluma europaea* (Guss.) N.E.Br. (LBNR28)	Darmouss	Caralluma europaea	Whole plant	Maceration	Spontaneous	TD1, TD2	73	0.115	11.55	
11		*Nerium oleander* L. (LBNR29)	Ddefla	Oleander	Leaves	Fumigation	Spontaneous	TD1	65	0.102	10.28	
	5. Arecaceae											0.016
12		*Chamaerops humilis* L. (LBNR31)	Ddoum	Dwarf fan palm	Roots	Cooked, powder	Spontaneous	TD2	12	0.018	1.89	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued…)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
13		*Phoenix dactylifera* L. (LBNR32)	Tmar	Date palm	Fruits	Decoction, raw	Cultivated	GDM	9	0.014	1.42	
	6. Aspargaceae											0.022
14		*Asparagus albus* L. (LBNR35)	Skkoum	Not found	Young sprouts	Raw	Spontaneous	TD1	14	0.022	2.21	
	7. Asteraceae											0.035
15		*Achillea odorata* L. (LBNR249)	El-qorte	Not found	Leaves	Infusion	Spontaneous	TD1	13	0.02	2.05	
16		*Achillea santolinoides* Lag. (LBNR39)	Chouihiya, El-qorte	Not found	Capitulum	Infusion	Spontaneous	TD2	5	0.007	0.79	
17		*Anthemis nobilis* L. (LBNR41)	Babounj, roumi	Camomilee	Flowers	Infusion	Spontaneous	TD1	6	0.009	0.94	
18		*Artemisia absinthium* L. (LBNR43)	Chiba	Wormwood	Whole plant	Poultice, decoction	Cultivated	TD1, TD2	23	0.036	3.63	
19		*Artemisia campestris* L. (LBNR44)	Chihi khorayss	Artemisia	Whole plant	Infusion	Spontaneous	TD2	19	0.03	3.00	
20		*Artemisia mesatlantica* Maire (LBNR45)	Chih elkhryassi	Artemisia	Whole plant	Decoction	Endemic	TD2	13	0.02	2.05	
21		*Artemisia herba-alba* Asso (LBNR46)	Chih/izri	White mugwort	Leaves, stems, roots	Decoction, infusion, powder	Spontaneous	TD1, TD2	77	0.121	12.18	
22		*Chrysanthemum coronarium* L. (LBNR52)	Hmessou	Crowndaisy	Flowers	Infusion	Spontaneous	TD1	29	0.045	4.58	
23		*Cladanthus arabicus* (L.) Cass. (LBNR53)	Tafsse	Not found	Flowers	Infusion	Spontaneous	TD1	17	0.026	2.68	
24		*Cynara cardunculus* L. (LBNR54)	Taggua	Artichoke	Roots, whole plant	Powder, infusion	Cultivated	TD1, TD2	24	0.037	3.79	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
25		*Cynara scolymus* L. (LBNR250)	El qoq	Artichoke	Fruits, leaves	Decoction	Cultivated	TD2	45	0.071	7.12	
26		*Dittrichia viscosa* (L.) Greuter (LBNR57)	Terhla	False yellowhead	Stems, leaves	Infusion	Spontaneous	TD1	33	0.052	5.22	
27		*Lactuca sativa* L. (LBNR251)	Lkhoss	Lettuce	Leaves	Infusion, raw	Cultivated	TD2	15	0.023	2.37	
28		*Matricaria chamomilla* L. (LBNR61)	Lbabounj	Common chamomile	Capitulums	Infusion	Spontaneous	GDM	12	0.018	1.89	
29		*Pallenis spinosa* (L.) Cass. (LBNR63)	Nouged	Spiny starwort	Whole plant	Decoction, infusion	Spontaneous	TD1	3	0.004	0.47	
30		*Scolymus hispanicus* L. (LBNR65)	Garnina	Golden thistle	Roots, flowers	Decoction, infusion	Spontaneous	TD2	4	0.006	0.63	
31		*Sonchus oleraceus* (L.) L. (LBNR66)	Tifaf	Sow thistle	Leaves	Decoction	Spontaneous	TD2	2	0.003	0.31	
32		*Tanacetum vulgare* L. (LBNR252)	Lbalssam	Common tansy	Leaves	Infusion	Spontaneous	TD1	65	0.102	10.28	
	8. Berberidaceae											0.025
33		*Berberis hispanica* Boiss. & Reut. (LBNR67)	Oud Aghriss	Barberry	Bark	Decoction	Spontaneous	TD2	16	0.025	2.53	
	9. Brassicaceae											0.053
34		*Anastatica hierochuntica* L. (LBNR253)	Chajrat kaff mryem	Not found	Stems, leaves	Infusion	Spontaneous	GDM	29	0.045	4.58	
35		*Brassica oleracea* L. (LBNR70)	Mkwrr	Cabbage	Fresh leaf	Poultice, raw	Cultivated	GDM	31	0.049	4.90	
36		*Brassica rapa* L. (LBNR71)	Left	Turnip	Roots, leaves	Cooked, infusion	Cultivated	TD1	44	0.069	6.96	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
37		*Eruca vesicaria* (L.) Cavi. (LBNR253)	Al girjir	Rocket	Seeds, whole plant	Powder, juice	Spontaneous	TD1	26	0.041	4.11	
38		*Lepidium sativum* L. (LBNR75)	Hab rchad	Garden cress	Seeds	Powder, maceration	Cultivated	TD1, TD2	38	0.06	6.01	
39		*Raphanus sativus* L. (LBNR77)	Lefjel	Radish	Seeds, roots	Decoction, raw	Cultivated	TD2	57	0.09	9.01	
	10. Burseraceae											0.126
40		*Boswellia carterii* Birdw. (LBNR79)	Salabane	Carteri	Fruits	Decoction, infusion	Imported	TD1, TD2	79	0.125	12.50	
	11. Capparaceae											0.097
41		*Capparis spinosa* L. (LBNR82)	Lkabbar	Caper	Fruits, leaves	Decoction, infusion	Spontaneous	TD1	61	0.096	9.65	
	12. Cistaceae											0.047
42		*Cistus ladanifer* L. (LBNR88)	Touzalt	Cista	Leaves	Decoction	Spontaneous	TD1	27	0.042	4.27	
43		*Cistus laurifolius* L. (LBNR89)	Agullid	Cista	Seeds, flowers	Powder	Spontaneous	TD1	33	0.052	5.22	
	13. Cucurbitaceae											0.036
44		*Bryonia dioica* Jacq. (LBNR91)	Terbouna	Red bryony	Stems, fruits	Decoction	Spontaneous	TD2	24	0.037	3.79	
45		*Citrullus colocynthis* (L.) Schrad. (LBNR254)	Tafrzizt	Not found	Fruits, seeds	Infusion, powder	Spontaneous	TD1	14	0.022	2.21	
43		*Citrullus vulgaris* Schard. (LBNR92)	Dellah	Watermelon	Leaves	Infusion, maceration	Cultivated	TD1, TD2	12	0.018	1.89	
47		*Cucumis sativus* L. (LBNR94)	Lkhyar	Cucumber	Seeds	Powder	Cultivated	TD2	18	0.028	2.84	
48		*Cucurbita maxima* Duchesne (LBNR95)	Lgraa hamra	Red zucchini	Seeds	Powder, decoction	Cultivated	TD1	48	0.075	7.59	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
	14. Cupressaceae											0.087
49		*Juniperus oxycedrus* L. (LBNR98)	L arâar chrini	Prickly juniper	Leaves	Maceration	Imported	TD1, TD2	77	0.121	12.18	
50		*Juniperus phoenicea* L. (LBNR99)	L arâar, El-horr	Aerial parts	Leaves	Maceration, infusion	Imported	TD1	33	0.052	5.22	
	15. Cyperaceae											0.017
51		*Cyperus longus* L. (LBNR255)	Arouk, esaad	Not found	Roots	Maceration	Imported	TD1	11	0.017	1.74	
	16. Equisetaceae											0.006
52		*Equisetum ramosissimum* Desf (LBNR102)	Dayl laawd	Not found	Stems	Decoction	Spontaneous	TD1	4	0.006	0.63	
	17. Euphorbiaceae											0.06
53		*Euphorbia echinus* Hook.f. & Coss. (LBNR103)	Tikiwt	Euphorbia echinus	Stems, leaves	Powder, maceration, infusion	Spontaneous	TD2	49	0.077	7.75	
54		*Euphorbia peplis* L. (LBNR256)	Hlliba	Not found	Whole plant	Infusion	Spontaneous	GDM	3	0.004	0.47	
55		*Euphorbia resinifera* O.Berg (LBNR106)	Zeggoum	Gum Euphorbium	Flowers, latex	Infusion, latex water	Endemic	TD1, TD2	95	0.150	15.03	
56		*Mercurialis annua* L. (LBNR105)	Harryga lmalsa	Mercury	Whole plant	Decoction, infusion	Spontaneous	TD1	16	0.025	2.53	
	18. Ericaceae											0.014
57		*Arbutus unedo* L. (LBNR107)	Barnnou	Arbutus	Leaves, roots	Infusion	Spontaneous	TD1	9	0.014	1.42	
	19. Fabaceae											0.059
58		*Acacia gummifera* Willd. (LBNR108)	Telh	Not found	Roots	Decoction	Endemic	TD2	17	0.026	2.68	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
59		*Anagyris foetida* L. (LBNR109)	Foul gnawa	Mediterranean stinkbush	Leaves	Infusion	Cultivated	TD2	14	0.022	2.21	
60		*Cassia absus* L. (LBNR110)	El habba sawdae	Not found	Seeds	Powder	Imported	TD1	53	0.083	8.38	
61		*Ceratonia siliqua* L. (LBNR111)	Lkharoub	Carob tree	Leaves, seeds	Infusion, powder	Imported	TD1, TD2	61	0.097	9.65	
62		*Cicer arietinum* L. (LBNR112)	Lhomms	Chickpea	Seeds	Powder, infusion	Cultivated	TD1	12	0.018	1.89	
63		*Glycine max* (L.) Merr. (LBNR113)	Soja	Chinese peas	Seeds	Infusion, raw	Cultivated	TD1	21	0.033	3.32	
64		*Glycyrrhiza glabra* L. (LBNR114)	Aarq ssuss	Licorice	Roots	Infusion	Imported	TD1	44	0.069	6.96	
65		*Lupinus albus* L. (LBNR115)	Foul gnaawa	Lupinus	Seeds	Powder, infusion	Spontaneous	TD1, TD2	79	0.125	1.25	
66		*Lupinus luteus* L. (LBNR116)	Ssemkala	Not found	Seeds	Decoction	Spontaneous	TD2	6	0.009	0.94	
67		*Medicago sativa* L. (LBNR117)	Fessa	Alfalfa	Leaves, seeds	Infusion, maceration	Cultivated	TD1	32	0.05	5.06	
68		*Phaseolus vulgaris* (LBNR119)	Loibiyya	Green beans	Fruits	Powder, raw	Cultivated	TD1	58	0.091	9.17	
69		*Retama monosperma* (L.) Boiss. (LBNR120)	Rtam	Retama	Roots, leaves	Decoction, infusion	Spontaneous	TD2	8	0.012	1.26	
70		*Trigonella foenum-graecum* L. (LBNR122)	Halba	Fenugreek	Seeds	Powder, infusion	Spontaneous	TD1, TD2	91	0.143	14.39	
	20. Fagaceae											0.025
71		*Quercus rotundifolia* Lam. (LBNR124)	Chêne kermès	El-qermez	Leaves	Decoction	Imported	TD1	16	0.025	2.53	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
	21. Fumariaceae											0.004
72		*Fumaria officinalis* L. (LBNR125)	Hachichat, essabian	Fumitory	Roots, leaves	Decoction, infusion	Spontaneous	TD1	3	0.004	0.47	
	22. Gentianaceae											0.038
73		*Centaurium spicatum* (L.) Fritsch (LBNR126)	Gosset l-hayya	Spiked centaury	Stems, flowers	Infusion	Cultivated	TD1	24	0.037	3.79	
	23. Geraniaceae											0.019
74		*Pelargonium roseum* Willd. (LBNR127)	Laattercha	Rose-scented	Leaves	Infusion	Cultivated	TD1	12	0.018	1.89	
	24. Iridaceae											0.022
75		*Crocus sativus* L. (LBNR128)	Zaʿfarān lhour	Crocus sativus	Stigmas	Infusion	Cultivated	GDM	14	0.022	2.21	
	25. Juglandaceae											0.027
76		*Juglans regia* L. (LBNR129)	Lgargaa/ Swak	*Common walnut*	Barks, leaves	Decoction, infusion	Cultivated	TD1, TD2	17	0.026	2.68	
	26. Lamiaceae											0.060
77		*Ajuga iva* (L.) Schreb. (LBNR130)	Timarna	Southern Bugle.	Whole plant	Decoction	Spontaneous	GDM	6	0.009	0.94	
78		*Ballota hirsuta* Benth. (LBNR131)	Merrouwt	Horehound	Leafy stems	Decoction, infusion	Spontaneous	TD1	19	0.030	3.00	
79		*Calamintha officinalis* Moench (LBNR132)	Manta	Woodland calamint	Whole plant	Decoction, infusion	Spontaneous	TD1	8	0.012	1.26	
80		*Lavandula dentata* L. (LBNR135)	Lkhzama	Fringed lavender	Whole plant	Poultice, infusion	Spontaneous	TD2	12	0.018	1.89	
81		*Lavandula maroccana* Murb. (LBNR136)	Iguiz	Not found	Flowers, leaves	Decoction, infusion	Endemic	TD1	33	0.052	5.22	
82		*Lavandula multifida* L. (LBNR137)	Lhlhal	Lavender harvests	Inflorescence	Decoction, infusion	Spontaneous	TD1, TD2	44	0.069	6.96	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
83		*Lavandula stoechas* L. (LBNR138)	Meriwt, Ifzi	Horehound	Flowers, leaves	Decoction	Spontaneous	GDM	7	0.011	1.10	
84		*Melissa officinalis* L. (LBNR140)	Naanaa trunj	Lemon balm	Leaves	Infusion	Spontaneous	TD1	37	0.058	5.85	
85		*Mentha spicata* L. (LBNR256)	Mentha	Apple mint	Leaves	Infusion, decoction	Spontaneous	TD1	13	0.020	2.05	
86		*Mentha suaveolens* Ehrh. (LBNR142)	Timijja	Apple mint	Whole plant	Infusion	Spontaneous	TD1	48	0.075	7.59	
87		*Ocimum basilicum* L. (LBNR143)	Lhbaq	Basil	Whole plant	Infusion	Cultivated	GDM	5	0.007	0.79	
88		*Origanum compactum* Benth. (LBNR144)	Zaater	Oregano	Leaves	Infusion, powder	Spontaneous	TD2	21	0.033	3.32	
89		*Rosmarinus officinalis* L. (LBNR146)	Azir	Common Rosemary	Leaves	Decoction, infusion	Imported	TD1, TD2	86	0.136	13.60	
90		*Salvia officinalis* L. (LBNR147)	Salmiya	Garden sage	Leaves	Decoction, maceration	Cultivated	TD1, TD2	99	0.156	15.66	
91		*Teucrium polium* L. (LBNR149)	Jiida	Shrubby germander	Whole plant	Decoction, powder	Spontaneous	TD1, TD2	43	0.068	6.80	
92		*Thymus broussonetii* Boiss. (LBNR150)	Azoukenni	Not found	Leaves, flowers	Infusion, maceration	Endemic	TD1	85	0.134	13.44	
93		*Thymus maroccanus* Ball. (LBNR151)	Tazoukennit	Not found	Leaves, flowers	Maceration, infusion	Endemic	TD1, TD2	71	0.112	11.23	
94		*Thymus satureioides* Coss. & Ball. (LBNR152)	Tazoukennit	Not found	Leaves Flowers	Maceration, infusion	Endemic	TD1, TD2	69	0.109	10.91	
95		*Thymus vulgaris* L. (LBNR153)	Zaitra	Thyme	Leaves	Infusion	Spontaneous	TD2	59	0.093	9.33	
	27. Lauraceae											0.071
96		*Cinnamomum cassia* (L.) J.Presl (LBNR155)	El Qarfa	Cinnamon	Barks	Decoction, infusion	Imported	TD1	57	0.090	9.01	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
97		*Laurus nobilis* L. (LBNR156)	Ourak moussa	Laurel	Leaves	Decoction, infusion	Spontaneous	TD2	32	0.05	5.06	
	28. Linaceae											0.133
98		*Linum usitatissimum* L. (LBNR157)	Zeriaa ketane	Flax	Seeds	Decoction, infusion	Cultivated	TD1, TD2	83	0.131	13.13	
	29. Lythraceae											0.120
99		*Punica granatum* L. (LBNR159)	Rommane	Grenadier	Pericarp barks	Powder	Cultivated	TD2	75	0.118	11.86	
	30. Malvaceae											0.031
100		*Hibiscus esculentus* L. (LBNR161)	Lmlokhiyya	Okra	Flowers	Infusion	Cultivated	TD1	22	0.034	3.48	
101		*Hibiscus sabdariffa* L. (LBNR162)	Karkadil	Red tea	Flowers, leaves	Infusion	Spontaneous	TD1	17	0.026	2.68	
	31. Moraceae											0.064
102		*Ficus carica* L. (LBNR164)	Karmouss	Fig	Leaves	Maceration, infusion	Spontaneous, cultivated	TD1, TD2	69	0.109	10.91	
103		*Ficus dottata* Gasp. (LBNR257)	Karmouss		Fruits	Decoction	Spontaneous	GDM	13	0.02	2.05	
	32. Myrtaceae											0.063
104		*Eucalyptus globulus* Labill. (LBNR165)	Kalitouss	Eucalyptus	Barks	Decoction, infusion	Imported	TD1	53	0.083	8.38	
105		*Eugenia caryophyllata* Thunb. (LBNR166)	Qronfel	Clove	Cloves	Maceration, infusion	Cultivated	TD1	25	0.039	3.95	
106		*Myrtus communis* L. (LBNR167)	Rayhane	Common Myrtle	Leaves	Infusion	Imported	TD2	32	0.05	5.06	
107		*Jasminum fruticans* L. (LBNR168)	Yasmin	Jasmine	Leaves, flowers	Maceration, infusion	Spontaneous	TD1, TD2	49	0.077	7.75	
	33. Nitrariaceae											0.024
108		*Peganum harmala* L. (LBNR169)	Lharmal	Harmal	Seeds	Infusion, powder	Spontaneous	TD2	15	0.023	2.37	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
	34. Oleaceae											0.106
109		*Olea europaea* L. (LBNR172)	Zaytoun	Olive	Fruits, leaves	Raw, decoction, other	Spontaneous Cultivated	TD1, TD2	109	0.172	17.24	
110		*Olea oleaster* Hoffm. & Link. (LBNR173)	Zabbouj	Not found	Leaves, flowers	Infusion, decoction	Spontaneous	TD1	24	0.037	3.79	
	35. Pedaliaceae											0.017
111		*Sesamum indicum* L. (LBNR177)	Zenjlane	Sesame	Seeds	Powder	Imported	GDM	11	0.017	1.74	
	36. Plantaginaceae											0.070
112		*Globularia alypum* L. (LBNR180)	Taslgha	Not found	Flowers	Decoction, infusion	Spontaneous	TD1	44	0.069	6.96	
	37. Poaceae											0.071
113		*Avena sativa* L. (LBNR184)	Khourtal	Oat	Seeds	Infusion, powder, decoction	Cultivated	TD1, TD2	76	0.120	12.02	
114		*Avena sterilis* L. (LBNR185)	Askoune	Not found	Seeds	Decoction, powder	Cultivated	TD1	35	0.055	5.53	
115		*Catapodium tuberculosum* Moris (LBNR258)	Zwan	Not found	Seeds	Decoction	Spontaneous	TD1	24	0.037	3.79	
116		*Hordeum vulgare* L. (LBNR187)	Cheir	Barly	Seeds, whole plant	Decoction	Cultivated	TD1, TD2	63	0.099	9.96	
117		*Lolium perenne* L. (LBNR188)	Zouane	Perennial ryegrass	Seeds	Decoction, infusion	Cultivated	GDM	44	0.069	6.96	
118		*Panicum miliaceum* L. (LBNR189)	Tafsout	Millet	Seeds	Decoction	Spontaneous	TD2	28	0.044	4.43	
119		*Phalaris canariensis* L. (LBNR191)	Zwan abiyad	Not found	Seeds	Powder, infusion	Spontaneous	TD2	21	0.033	3.32	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
120		*Triticum durum* Desf. (LBNR193)	Lkamh	Wheat	Seeds	Infusion	Cultivated	TD1, TD2	66	0.104	10.44	
	38. Portulacaceae											0.062
121		*Portulaca oleraceae* L. (LBNR198)	Rejla	Green purslane	Whole plant	Cooked	Spontaneous	TD1	39	0.061	6.17	
	39. Ranunculaceae											0.139
122		*Nigella sativa* L. (LBNR203)	Sanouje	Black seed	Seeds	Powder, infusion	Cultivated	TD1, TD2	87	0.137	13.76	
	40. Rhamnaceae											0.073
123		*Ziziphus lotus* (L.) Lam. (LBNR206)	Ssedra, Azougar	Wild jujube	Leaves, roots, fruits	Infusion, decoction, powder	Spontaneous	TD2	46	0.072	7.27	
	41. Rosaceae											0.037
124		*Prunus amygdalus* Batsch. (LBNR209)	Loz lharr	Bitter almond tree	Leaves	Decoction	Spontaneous	TD2	38	0.060	6.01	
125		*Prunus armeniaca* L. (LBNR210)	Lmchmach	Apricot tree	Seeds	Powder	Cultivated	TD1	24	0.037	3.79	
126		*Rubus ulmifolius* Schott. (LBNR217)	Laallik, tabgha	Not found	Fruits, leaves	Infusion	Spontaneous	GDM	9	0.014	1.42	
	42. Rutaceae											0.056
127		*Citrus aurantium* L. (LBNR220)	Larange	Orange flower	Flowers, fruits	Poultice, juice, infusion	Imported	TD1, TD2	86	0.136	13.6	
128		*Citrus medica* L. (LBNR259)	El hamed lbldi	Citron	Flowers	Infusion	Cultivated	TD1	31	0.049	4.90	
129		*Citrus paradisi* Macfad. (LBNR260)	Pamplemouss	Grapefruit	Fruits	Juice	Cultivated	TD2	18	0.028	2.84	
130		*Ruta graveolens* L. (LBNR224)	L-Fijel	Common rue	Roots	Decoction, infusion	Spontaneous	TD1	14	0.022	2.21	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
131		*Ruta montana* (L.) L. (LBNR225)	Awermi	Not found	Leaves stems	Decoction	Spontaneous	TD1, TD2	27	0.042	4.27	
	43. Solanaceae											0.046
132		*Capsicum annuum* L. (LBNR227)	Felfla	Pepper	Fruits	Raw	Cultivated	TD2	14	0.022	2.21	
133		*Solanum lycopersicum* L. (LBNR232)	Maticha	Tomato	Fruits	Raw	Cultivated	TD1, TD2	33	0.052	5.22	
134		*Withania frutescens* (L.) Pauquy (LBNR235)	Tirnet	Not found	Leaves	Infusion	Cultivated	TD1	41	0.064	6.48	
	44. Taxaceae											0.049
135		*Taxus baccata* L. (LBNR236)	Igen	Yew	Roots	Decoction	Spontaneous	TD1	31	0.049	4.90	
	45. Theaceae											0.035
136		*Camellia thea* Link. (LBNR261)	Atay	Green tea	Leaves	Decoction, infusion	Imported	TD1	22	0.034	3.48	
	46. Thymelaeacea											0.054
137		*Thymelaea hirsuta* (L.) Endl. (LBNR238)	Lmetnan	Not found	Leaves, stems	Infusion, powder	Spontaneous	TD1, TD2	51	0.080	8.06	
138		*Thymelaea virgata* (Desf.) Endl. (LBNR239)	Metnan	Not found	Leafed stems	Decoction	Endemic	TD1	17	0.026	2.68	
	47. Urticaceae											0.062
139		*Urtica urens* L. (LBNR241)	Tikzint	Stinging Nettle	Leaves	Powder	Spontaneous	TD1	39	0.061	6.17	
	48. Verbenaceae											0.020
140		*Aloysia citriodora* Palau. (LBNR242)	Lwizza	Lemon verbena	Leaves	Infusion	Cultivated	GDM	13	0.020	2.05	

Table 2. Medicinal plants used treatment of diabetes in the High Atlas Central of Morocco (continued...)

No.	Families	Scientific name (voucher number)	Local name	English name	Parts used	Preparation	Origin	MU	Uis	UVi	CI	FUV
	49. Vitaceae											0.036
141		*Vitis vinifera* L. (LBNR243)	Al-ainab	Grapes	Young leaves	Decoction	Spontaneous, cultivated	TD2	23	0.036	3.63	
	50. Xanthorrhoeaceae											0.030
142		*Asphodelus microcarpus* Salzm. & Viv. (LBNR245)	Blaluz	Not found	Tubers	Decoction, raw	Spontaneous	GDM	19	0.03	3.00	
	51. Zingiberaceae											0.044
143		*Zingiber officinale* Rosc (LBNR247)	Skinjbir	Ginger	Roots	Maceration, powder, infusion	Cultivated	TD1	28	0.044	4.43	
	52. Zygophyllaceae											0.155
144		*Zygophyllum gaetulum* Emb. & Maire (LBNR248)	Aaggaya	Not found	Leaves	Infusion	Spontaneous	TD1, TD2	97	0.153	15.34	

MU: Medicinal use; Uis: Number of different uses mentioned by each informant; UVi: Use value; CI.: Confirmation index; FUV: Family use value; TD1: Type 1 diabetes; TD2: Type 2 diabetes; GDM: Gestational diabetes mellitus.

Table 3. Informant agreement ratio for the treatment of diabetes by category.

Categories	List of plant species used and number of citations	NS	NUC	IAR
Type 1 diabetes	*Allium cepa* L. (7), *Allium sativum* L. (17), *Pistacia lentiscus* L. (3), *Ammi visnaga* (L.) Lam. (12), *Coriandrum sativum L.* (48), *Foeniculum vulgare* Mill. (26), *Ridolfia segetum* Moris (34), *Caralluma europaea* (Guss.) N.E.Br. (34), *Nerium oleander* L. (65), *Asparagus albus* L. (14), *Achillea odorata* L. (13), *Anthemis nobilis* L. (6), *Artemisia absinthium* L. (14), *Artemisia herba alba* Asso. (54), *Chrysanthemum coronarium* L. (29), *Cladanthus arabicus* (L.) Cass. (17), *Cynara cardunculus* L. (18), *Dittrichia viscosa* (L.) Greuter. (33), *Pallenis spinosa* (L.) Cass. (3), *Tanacetum vulgare* L. (65), *Brassica rapa* L. (44), *Eruca vesicaria* (L) Cavi. (26), *Lepidium sativum* L. (13), *Boswellia carterii* Birdw. (52), *Capparis spinosa* L. *(61), Cistus Ladanifer* L. (5), *Cistus laurifolius* L. (33), *Citrullus colocynthis* (L.) Schrad. (14), *Citrullus vulgaris* Schard (5), *Cucurbita maxima* Duchesne (48), *Juniperus oxycedrus* L. (48), *Juniperus Phoenicea* L. (33), *Cyperus longus* L. (11), *Equisetum ramosissimum* Desf (4), *Euphorbia resinifera* Berg (57), *Mercurialis annua* L. (16), *Arbutus unedo* L. (9), *Cassia absus* L. (53), *Ceratonia siliqua* L. (23), *Cicer arietinum* L. (12), *Glycine max* (L.) Merr(21), *Glycyrrhiza glabra* L. (44), *Lupinus albus* L. (48), *Medicago sativa* L. (32), *Phaseolus vulgaris* L. (58), *Trigonella foenum-graecum* L. (55), *Quercus coccifera* L. (16), *Fumaria officinalis* L. (3), *Centaurium spicatum* (L.) Fritsch (24), *Pelargonium roseum* Willd. (12), *Juglans regia* L. (5), *Ballota hirsuta* Benth. (19), *Calamintha officinalis* Moench (8), *Lavandula maroccana* Murb. (33), *Lavandula stoechas* L. (21), *Melissa officinalis* L. (37), *Mentha spicata* L. (13), *Mentha suaveolens* Ehrh. (48), *Rosmarinus officinalis* L. (35), *Salvia officinalis* L. (59), *Teucrium polium* L. (19), *Thymus broussonetii* Boiss. (85), *Thymus maroccanus* Ball. (38), *Thymus satureioides* L. (22), *Cinnamomum cassia* Blum (57), *Linum usitatissimum* L. (55), *Hibiscus esculentus* L. *(22), Hibiscus sabdariffa* L. (17), *Ficus carica* L. (41), *Eucalyptus globulus* Labill (53), *Eugenia caryophyllata* Thunb (25), *Jasminum fruticans* L. (32), *Olea europaea* L. (65), *Olea oleasis* Hoffm. & Link. (54), *Globularia alypum* L. (44), *Avena sativa* L. (18), *Avena sterilis* L. *(35), Catapodium tuberculosum* Moris (24), *Hordeum vulgare* L. (36), *Triticum durum* Desf (41), *Portulaca oleraceae* L. (39), *Nigella sativa* L. (32), *Prunus armeniaca* L. (24), *Citrus aurantium* L. (63), *Citrus medica* L. (31), *Ruta graveolens* L. (14), *Ruta montana* (L.) L. (16), *Solanum lycopersicum* L. (15), *Withania frutescens* (L.) Pauquy (41), *Taxus baccata* L. (31), *Camellia thea* Link. (22), *Thymeleae hirsuta* (L.) Endl (22), *Thymelea virgata* Mill (17), *Urtica urens* L. (39), *Zingiber officinale* Rosc (28), *Zygophyllum gaetulum* Emberger & Maire (40).	95	2853	0.96
Type 2 diabetes	*Allium sativum* L. (3), *Coriandrum sativum* L. (33), *Foeniculum vulgare* Mill. (11), *Caralluma europaea* (Guss.) N.E.Br. (39), *Chamaerops humilis* L. (12), *Achillea santolinoides* Lag. (5), *Artemisia absinthium* L. (9), *Artemisia campestris* L. (12), *Artemisia mesatlantica* Maire (13), *Artemisia herba alba* Asso. (23), *Cynara cardunculus* L. (6), *Cynara scolymus* L. (45), *Lactuca sativa* L. (15), *Scolymus hispanicus* L. (4), *Sonchus oleraceus* L. (2), *Berberis hispanica* Boiss &Reut (16), *Lepidium sativum* L. (25), *Raphanus sativus* L. (57), *Boswellia carterii* Birdw. (27), *Bryonia dioica* Jacq. (24), *Citrullus vulgaris* Schard (7), *Cucumis sativus* L. (18), *Juniperus oxycedrus* L. (29), *Euphorbia echinus* Hook.f. & Coss. (49), *Euphorbia resinifera* Berg (38), *Acacia gummifera* Willd (17), *Anagyris foetida* L. (14), *Ceratonia siliqua* L. (38), *Lupinus albus* L. (31), *Lupinus luteus* L. (6), *Retama monosperma* (L.) Boiss (8), *Trigonella foenum-graecum* L. (36), *Juglans regia* L. (12), *Lavandula dentata* L. (12), *Lavandula stoechas* L. *(23), Origanum compactum* Benth (21), *Rosmarinus officinalis* L. (51), *Salvia officinalis* L. (40), *Teucrium polium* L. (19), *Thymus maroccanus* Ball. (33), *Thymus satureioides* L. (47), *Thymus vulgaris* L. (48), *Laurus nobilis* L. (32), *Linum usitatissimum* L. (28), *Punica granatum* L. (75), *Ficus carica* L. (28), *Myrtus communi* L. *(32), Jasminum fruticans* L. *(17), Peganum harmala* L. *(15), Olea europaea* L. *(44), Avena sativa* L. (58), *Hordeum vulgare* L. (27), *Panicum miliaceum* L. (28), *Phalaris canariensis* L. (21), *Triticum durum* Desf. (25), *Nigella sativa* L. (55), *Ziziphus lotus* (L.) Lam. (46), *Prunus amygdalus* Batsh. (38), *Citrus aurantium* L. (23), *Citrus paradisi* Macfad. (18), *Ruta montana* (L.) L. (11), *Capsicum annuum* L. (14), *Solanum lycopersicum* L. (18), *Thymeleae hirsuta* (L.) Endl (29), *Vitis vinifera* (23), *Zygophyllum gaetulum* Emberger & Maire (31).	66	1648	0.96
Gestational diabetes mellitus	*Carum carvi* L. (16), *Pimpinella anisum* L. (29), *Phoenix dactylifera* L. (9), *cynara cardunculus* L. (6), *Matricaria chamomilla* L. (12), *Anastatica hierochuntica* L. (16), *Brassica oleracea* L. (31), *Euphorbia peplis* L. (3), *Crocus sativus* L. (14), *Ajuga iva* (L.) Schreb. (6), *Marrubium vulgare* L. (7), *Ocimum basilicum* L. (5), *Ficus dottata* Gasp. (13), *Sesamum indicum* L. (11), *Lolium perenne* L. (44), *Rubus ulmifolius* Schott. (9), *Asphodelus microcarpus* Salzm & Viv. (19), *Aloysia citriodora* Palau (13).	18	263	0.94

NS: Number of species used in each category; NUC: Number of use reports in each category; IAR: Values informant agreement ratio.

Table 4. The toxicity of the plants inventoried in the High Atlas Central.

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Amaryllidaceae	*Allium cepa* L. (LBNR5)	-	No study	-	(Jouad et al., 2001; Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al. 2015; Douira and Zidane 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	13
	Allium sativum L. (LBNR6)	Bulb	No toxic activities. Cardiovascular toxicity (in case of high dose)	(Lawal et al., 2016)	(Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Idm'hand et al., 2020)	9
Anacardiaceae	*Pistacia lentiscus* L. (LBNR8)	Fatty oil	Dermal toxicity, harmful for pregnancy	(Jouad et al. 2002)	(Benkhnigue et al., 2010; Bousta et al., 2014; Hachi et al., 2016; Idm'hand et al., 2020)	4
Apiaceae	*Ammi visnaga* (L.) Lam. (LBNR11)	The aqueous extract of plant	No acute toxicity	(Djerrou et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Laadim et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	9
	Carum carvi L. (LBNR17)	The aqueous extract of plant	No toxic activities	(Lahlou et al., 2007)	(Eddouks et al., 2002; Barkaoui et al., 2017; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	5
	Coriandrum sativum L. (LBNR18)	Seeds	No toxic activities, neurological toxicity, in case of high dose	(Hammiche et al., 2013)	(Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Laadim et al., 2017; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	7
	Foeniculum vulgare Mill. (LBNR21)	Essential oil	Neurological toxicity (in case of high dose)	(Bellakhdar, 1997)	(Jouad et al., 2001; Benkhnigue et al., 2010; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	7
	Pimpinella anisum L. (LBNR24)	Essential oil and seeds	No toxic activities	(Ajebli et al., 2017)	(Benkhnigue et al., 2010; Alami et al., 2015; Barkaoui et al. 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Idm'hand et al., 2020)	7
	Ridolfia segetum Moris (LBNR25)	Essential oil	No toxic activities	(Miranda et al., 2019)	(Benkhnigue et al., 2010; Chaachouay et al., 2019a; Idm'hand et al., 2020)	3
Apocynaceae	*Caralluma europaea* (Guss.) N.E.Br. (LBNR28)	The aqueous extract of plant	Cardiovascular toxicity, renal intoxication	(Issiki et al., 2017)	(Benkhnigue et al., 2010; Laadim et al., 2017; Idm'hand et al., 2020)	3
	Nerium oleander L. (LBNR29)	Leaves	Dermal toxicity, digestive toxicity, cardiovascular toxicity	(Mazumder et al., 1994; Ajebli et al., 2017)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	10

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Arecaceae	*Chamaerops humilis* L. (LBNR31)	All parts of plant	No toxic activities	(Hasnaoui et al., 2011)	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3
	Phoenix dactylifera L. (LBNR32)	-	Not identified	-	(Eddouks et al., 2002; Benkhnigue et al., 2010; Laadim et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	5
Aspargaceae	*Asparagus albus* L. (LBNR35)	-	Not identified	-	(Hachi et al., 2016; Idm'hand et al., 2020)	2
Asteraceae	*Achillea odorata* L. (LBNR249)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Achillea santolinoides Lag. (LBNR39)	-	Not identified	-	No data	0
	Anthemis nobilis L. (LBNR41)	-	Not identified	-	No data	0
	Artemisia absinthium L. (LBNR43)	Aerial parts	Harmful for pregnancy, cardiovascular toxicity, neurological toxicity	(Bonet et al., 1999; Zekkour, 2008; Hammiche et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Douira and Zidane, 2015; Laadim et al., 2017; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	9
	Artemisia campestris L. (LBNR44)	Aerial parts	Dermal toxicity	(Zekkour, 2008)	No data	0
	Artemisia, mesatlantica Maire (LBNR45)	Aerial parts	Adverse effects on fertility and reproduction, neurological toxicity	(Marrif et al., 1995)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane 2015; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	12
	Artemisia herba alba Asso. (LBNR46)	Aerial parts	No toxic activities	(Ghazi et al., 2016)	(Benkhnigue et al., 2010; Idm'hand et al., 2020	2
	Chrysanthemum coronarium L. (LBNR52)	Aerial parts	No toxic activities	(Boutaghane, 2013)	No data	0
	Cladanthus arabicus (L.) Cass. (LBNR53)	-	Not identified	-	(Benkhnigue et al., 2010)	1

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
	Cynara cardunculus L. (LBNR54)	Flowers	No toxic activities	(Zikiou, 2013)	(Jouad et al., 2001; Benkhnigue et al., 2010; Alami et al., 2015; Laadim et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	6
	Cynara scolymus L. (LBNR250)	Fruit	Abortive	(Bellakhdar, 1997)	No data	0
	Dittrichia viscosa (L.) Greuter (LBNR57)	Leaves and flowers	No acute toxicity or sub-chronic toxicity	(Célia et al., 2017)	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3
	Lactuca sativa L. (LBNR251)	Aerial parts	Dermal toxicity	(Zekkour, 2008)	(Jouad et al., 2001; Benkhnigue et al., 2010; Laadim et al., 2017; Idm'hand et al., 2020)	4
	Matricaria chamomilla L. (LBNR61)	Leaves and flowers	No toxic activities	(Singh et al., 2011)	(Benkhnigue et al., 2010; Douira and Zidane, 2015; Mrabti et al., 2019; Idm'hand et al., 2020)	4
	Pallenis spinosa (L.) Cass. (LBNR63)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Scolymus hispanicus L. (LBNR65)	-	Not identified	-	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3
	Sonchus oleraceus L. (LBNR66)	Aerial parts	No toxicity even at high doses	(Amira and Lamia, 2018)	(Idm'hand et al., 2020)	1
	Tanacetum vulgare L. (LBNR252)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Berberidaceae	*Berberis hispanica* Boiss & Reut (LBNR67)	Root bark	No toxic activities	(El Ouarti et al., 2011)	No data	0
Brassicaceae	*Anastatica hierochuntica* L. (LBNR253)	Root	No toxic activities	(Shah et al., 2014)	(Benkhnigue et al., 2010; Chaachouay et al., 2019a; Idm'hand et al., 2020)	3
	Brassica oleracea L. (LBNR70)	Leaf	No toxic activities	(Gonçalves et al., 2012)	(Benkhnigue et al., 2010; Hachi et al., 2016; Laadim et al., 2017; Chaachouay et al., 2019a; Idm'hand et al., 2020)	5
	Brassica rapa L. (LBNR71)	-	Not identified	-	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
	Eruca vesicaria (L) Cavi. (LBNR253)	Seed oil	Renal toxicity, reproductive toxicity	(El-Gayar et al., 2016; Grami et al., 2020)	No data	0
	Lepidium sativum L. (LBNR75)	Seeds	No toxic activities	(Doke and Guha, 2014)	(Benkhnigue et al., 2010; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Idm'hand et al., 2020)	5
	Raphanus sativus L. (LBNR77)	-	Not identified	-	(Benkhnigue et al., 2010; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Idm'hand et al., 2020)	5
Burseraceae	*Boswellia carterii* Birdw. (LBNR79)	-	Not identified	-	No data	0
Capparaceae	*Capparis spinosa* L. (LBNR82)	Leaf and fruit	No toxic activities	(Benzidane, 2018)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Fouad and Lahcen 2020; Idm'hand et al., 2020)	9
Cistaceae	*Cistus ladanifer*L. (LBNR88)	-	Not identified	-	(Benkhnigue et al., 2010; Barkaoui et al., 2017)	2
	Cistus laurifolius L. (LBNR89)	Leaf	No toxic activities	(Küpeli and Yesilada, 2007)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Cucurbitaceae	*Bryonia dioica* Jacq. (LBNR91)	All parts of the plant	Digestive toxicity, neurological toxicity	(Zekkour, 2008)	No data	0
	Citrullus colocynthis (L.) Schrad. (LBNR254)	Fruit and seeds	Digestive toxicity, cardiovascular toxicity, neurological toxicity, dermal toxicity	(Zekkour, 2008; Benariba, 2013; Hammiche et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Hachi et al., 2016; Laadim et al., 2017; Chaachouay et al., 2019a; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	11
	Citrullus vulgaris Schard. (LBNR92)	Ethanolic extract from seeds	Digestive toxicity, dermal toxicity	(Ahn et al., 2011)	No data	0
	Cucumis sativus L. (LBNR94)	-	Not identified	-	(Benkhnigue et al., 2010; Barkaoui et al., 2017; Laadim et al., 2017; Hachi et al., 2016; Mrabti et al., 2019; Idm'hand et al., 2020)	6
	Cucurbita maxima Duchesne (LBNR95)	Seeds	No toxic activities	(Orech et al., 2005)	No data	0

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Cupressaceae	*Juniperus oxycedrus* L. (LBNR98)	Leaf oil	Cardiovascular toxicity, neurological toxicity, hepatic toxicity	(Houmman et al., 2019)	No data	0
	Juniperus phoenicea (LBNR99)	Leaf	Harmful for pregnancy	(Najem et al., 2020)	(Benkhnigue et al., 2010; Hachi et al., 2016; Chaachouay et al., 2019a; Idm'hand et al., 2020)	4
Cyperaceae	*Cyperus longus* L. (LBNR255)	All plant parts	Digestive toxicity	(Najem et al. 2020)	No data	0
Equisetaceae	*Equisetum ramosissimum* Desf (LBNR102)	Roots	Harmful for pregnancy	(Alebous et al., 2016)	No data	0
Euphorbiaceae	*Euphorbia echinus* Hook.f. & Coss. (LBNR103)	-	Not identified	-	(Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Barkaoui et al., 2017; Idm'hand et al., 2020)	5
	Euphorbia peplis L. (LBNR256)	-	Not identified	-	(Chaachouay et al., 2019a)	1
	Euphorbia resinifera Berg (LBNR106)	Latex	Dermal toxicity, digestive toxicity	(Zekkour, 2008; Najem et al., 2020)	(Tahraoui et al., 2007; Hachi et al., 2016; Mrabti et al., 2019; Idm'hand et al., 2020)	4
	Mercurialis annua L. (LBNR105)	Aerial parts	Digestive toxicity	(Benkhnigue et al., 2010)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Ericaceae	*Arbutus unedo* L. (LBNR107)	Roots	No toxic activities	(Pabuçcuoğlu et al., 2003)	No data	0
Fabaceae	*Acacia gummifera* Willd (LBNR108)	-	Not identified	-	No data	0
	Anagyris foetida L. (LBNR109)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Cassia absus L. (LBNR110)	Seeds	Oral toxicity, reproductive toxicity	(Jothy et al., 2011; Hamedi et al., 2015)	No data	0
	Ceratonia siliqua L. (LBNR111)	-	Not identified	-	(Benkhnigue et al., 2010; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Idm'hand et al., 2020)	6

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
	Cicer arietinum L. (LBNR112)	-	Not identified	-	(Mrabti et al., 2019; Idm'hand et al., 2020)	2
	Glycine max (L.) Merr. (LBNR113)	-	Not identified	-	(Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	5
	Glycyrrhiza glabra L. (LBNR114)		Cardiovascular toxicity (high doses), harmful for pregnancy	(Cael, 2009)	(Skalli et al., 2019)	1
	Lupinus albus L. (LBNR115)	Seeds	No toxic activities	(Bellakhdar, 1997)	(Jouad et al., 2001; Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Mrabti et al., 2019; Idm'hand et al., 2020)	6
	Lupinus luteus L. (LBNR116)	Seeds	Anticholinergic toxicity	(Thambiraj et al., 2018)	(Benkhnigue et al., 2010)	1
	Medicago sativa L. (LBNR117)	-	Not identified	-	(Benkhnigue et al., 2010; Hachi et al., 2016; Laadim et al., 2017; Mrabti et al., 2019; Idm'hand et al., 2020)	5
	Phaseolus vulgaris (LBNR119)	-	Not identified	-	(Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Hachi et al., 2016; Chaachouay et al., 2019a; Idm'hand et al., 2020)	6
	Retama monosperma (L.) Boiss (LBNR120)	Aerial parts	Abortifacient	(Bellakhdar 1997)	No data	0
	Trigonella foenum-graecum L. (LBNR122)	Seeds	Toxic effects on reproductive and in pregnant women	(Yadav and Baquer, 2014)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	14
Fagaceae	*Quercus rotundifolia* Lam. (LBNR124)	Leaf	No toxic activities	(Al-Qura'n S, 2005)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Fumariaceae	*Fumaria officinalis* L. (LBNR125)	All plant parts	No toxic activities	(Goetz et al., 2009)	(Chaachouay et al., 2019a)	1
Gentianaceae	*Centaurium spicatum* (L.) Fritsch (LBNR126)	-	Not identified	-	No data	0
Geraniaceae	*Pelargonium roseum* Willd. (LBNR127)	-	Not identified	-	No data	0

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Iridaceae	*Crocus sativus* L. (LBNR128)	Flowers	Harmful for pregnancy	(Hammiche et al., 2013)	(Idm'hand et al., 2020)	1
Juglandaceae	*Juglans regia* L. (LBNR129)	Walnut	Dermal toxicity	(Panth et al., 2016)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	5
Lamiaceae	*Ajuga iva* (L.) Schreb. (LBNR130)	All plant parts	No toxic activities	(El Hilaly et al., 2004)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Idm'hand et al., 2020)	11
	Ballota hirsuta Benth. (LBNR131)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Calamintha officinalis Moench (LBNR132)	Aerial parts	No toxic activities	(Verma et al., 2011)	No data	0
	Lavandula dentata L. (LBNR135)	All plant parts	No toxic activities	(Aly et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al.,2010; Douira and Zidane, 2015; Barkaoui et al., 2017; Idm'hand et al., 2020)	7
	Lavandula maroccana Murb. (LBNR136)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Lavandula multifida L. (LBNR137)	Aerial parts	No toxic activities	(Yassine et al., 2016)	(Benkhnigue et al., 2010; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Idm'hand et al., 2020)	5
	Lavandula stoechas L. (LBNR138)	Aerial parts	A very low toxicity	(Bensalah, 2014)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Idm'hand et al., 2020)	12
	Melissa officinalis L. (LBNR140)	Aerial parts	No toxic activities	(Skotti et al., 2014)	No data	0
	Mentha spicata L. (LBNR 256)	Aerial parts	No toxic activities	(Caro et al., 2018)	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3
	Mentha suaveolens Ehrh. (LBNR142)	Leaf	No toxic activities	(Moreno et al., 2002)	No data	0

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
	Ocimum basilicum L. (LBNR143)	-	Not identified	-	(Benkhnigue et al., 2010; Hachi et al., 2016)	2
	Origanum compactum Benth (LBNR144)	-	Not identified	-	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Idm'hand et al., 2020)	7
	Rosmarinus officinalis L. (LBNR146)	All plant parts	Harmful for pregnancy	(Hammiche et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al. 2017; Laadim et al., 2017; Chaachouay et al., 2019a; Skalli et al., 2019; Idm'hand et al., 2020)	12
	Salvia officinalis L. (LBNR147)	Sage oil	Tonic-clonic seizures	(Halicioglu et al., 2011)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Chaachouay et al., 2019a; Mrabti et al. 2019)	11
	Teucrium polium L. (LBNR149)	All plant parts, flowering tops	Liver toxicity (high doses), no toxic activities	(Zekkour, 2008; Krache, 2018; Meguellati et al., 2019)	(Barkaoui et al., 2017; Idm'hand et al., 2020)	2
	Thymus broussonetii Boiss. (LBNR150)	Essential oils of plant	Neurological toxicity, digestive toxicity	(Elhabazi et al., 2012)	(Skalli et al., 2019; Idm'hand et al., 2020)	2
	Thymus maroccanus Ball. (LBNR151)	All plant parts	Low toxicity	(Elhabazi et al., 2008)	No data	0
	Thymus satureioides Coss. &Ball. (LBNR152)	All plant parts	Low toxicity	(Elhabazi et al., 2008)	(Tahraoui et al., 2007; Benkhnigue et al., 2010; Barkaoui et al., 2017; Idm'hand et al., 2020)	4
	Thymus vulgaris L. (LBNR153)	Flower and leaves, essential oils	No toxic activities, neurologic, dermatologic toxicity	(Basch et al., 2004)	(Benkhnigue et al., 2010; Hachi et al., 2016; Barkaoui et al., 2017; Idm'hand et al., 2020)	4
Lauraceae	*Cinnamomum cassia* Blum (LBNR155)	-	Not identified	-	(Tahraoui et al., 2007; Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Idm'hand et al., 2020)	5
	Laurus nobilis L. (LBNR156)	Essential oils	No toxic activities	(Labiad et al., 2019)	(Benkhnigue et al., 2010; Laadim et al., 2017; Idm'hand et al., 2020)	3

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Linaceae	*Linum usitatissimum* L. (LBNR157)	Essential oils	No toxic activities	(Gorriti et al., 2010)	(Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Barkaoui et al., 2017; Chaachouay et al., 2019a; Skalli et al., 2019; Idm'hand et al., 2020)	7
Lythraceae	*Punica granatum* L. (LBNR159)	Whole fruit, extracts, peel extract	No toxic activities	(Vidal et al., 2003; Jahromi et al., 2015)	(Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Barkaoui et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	6
Malvaceae	*Hibiscus esculentus* L. (LBNR161)	Fruit	No toxic activities	(Alqasoumi, 2012)	No data	0
	Hibiscus sabdariffa L. (LBNR162)	Rosellecalyx	No toxic activities	(Beltrán-Debón et al., 2010; Sireeratawong et al., 2013)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Moraceae	*Ficus carica* L. (LBNR164)	Leaf	No toxic activities	(Labiad et al., 2019)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Barkaoui et al., 2017; Chaachouay et al., 2019a; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	10
	Ficus dottata Gasp. (LBNR257)	-	Not identified	-	(Chaachouay et al., 2019a)	1
Myrtaceae	*Eucalyptus globulus* Labill. (LBNR165)	Leaf	Neurological toxicity	(Hammiche et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Mrabti et al., 2019)	7
	Eugenia caryophyllata Thunb (LBNR166)	Extract from plant	No toxic activities	(Lee et al., 2000)	No data	0
	Myrtus communis L. (LBNR167)	Leaf	Neurological toxicity	(Uehleke and Brinkschulte-Freitas, 1979)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Douira and Zidane, 2015; Hachi et al., 2016; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	8
	Jasminum fruticans L. (LBNR168)	-	Not identified	-	No data	0
Nitrariaceae	*Peganum harmala* L. (LBNR169)	Seeds	Neurological toxicity digestive toxicity, hepatic toxicity, abortive	(Lamchouri et al., 2000; Mahmoudian et al., 2002)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Laadim et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	8
Oleaceae	*Olea europaea* L. (LBNR172)	Leaf	No toxic activities	(Fehri et al., 1994)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Alami et al., 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	11

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
	Olea oleaster Hoffm. & Link. (LBNR173)	-	Not identified	-	No data	0
Pedaliacece	*Sesamum indicum* L. (LBNR177)	Leaf	No toxic activities	(Okwuosa et al., 2011)	(Jouad et al. 2001; Eddouks et al. 2002; Douira and Zidane 2015; Barkaoui et al. 2017; Mrabti et al. 2019; Fouad and Lahcen 2020; Idm'hand et al. 2020)	6
Plantaginaceae	*Globularia alypum* L. (LBNR180)	Aerial parts	Intoxicated digestive toxicity (with long-term employment)	(Hammiche et al., 2013)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Hachi et al., 2016; Idm'hand et al., 2020)	7
Poaceae	*Avena sativa* L. (LBNR184)	-	Not identified	-	(Benkhnigue et al., 2010; Hachi et al., 2016; Idm'hand et al., 2020)	3
	Avena sterilis L. (LBNR185)	-	Not identified	-	(Idm'hand et al., 2020)	1
	Catapodium tuberculosum Moris (LBNR258)	-	Not identified	-	(Benkhnigue et al., 2010)	1
	Hordeum vulgare L. (LBNR187)	-	Not identified	-	(Idm'hand et al., 2020)	1
	Lolium perenne L. (LBNR188)	Aerial parts	Neurotoxic (high doses)	(Zekkour, 2008)	(Idm'hand et al., 2020)	1
	Panicum miliaceum L. (LBNR189)	-	Not identified	-	(Idm'hand et al., 2020)	1
	Phalaris canariensis L. (LBNR191)	-	Not identified	-	(Benkhnigue et al., 2010; Bousta et al., 2014; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Mrabti et al., 2019; Idm'hand et al., 2020)	7
	Triticum durum Desf. (LBNR193)	-	Not identified	-	No data	0
Portulacaceae	*Portulaca oleraceae* L. (LBNR198)	-	Not identified	-	(Benkhnigue et al., 2010; Laadim et al., 2017; Chaachouay et al., 2019a; Mrabti et al., 2019; Idm'hand et al., 2020)	5
Ranunculaceae	*Nigella sativa* L. (LBNR203)	Seed	Harmful for pregnancy, digestive toxicity	(Zekkour, 2008)	(Jouad et al., 2001; Eddouks et al., 2002; Tahraoui et al., 2007; Benkhnigue et al., 2010; Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	14

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Rhamnaceae	*Ziziphus lotus* (L.) Lam. (LBNR206)	Seed oil	No toxic activities	El Hachimi et al., 2017)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Barkaoui et al., 2017; Mrabti et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	8
Rosaceae	*Prunus amygdalus* Batsh. (LBNR209)	Seed	Respiratory metabolic toxicity	(Hammiche et al., 2013)	No data	0
	Prunus armeniaca L. (LBNR210)	Seed	Respiratory metabolic toxicity	(Hammiche et al. 2013)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Rubus ulmifolius Schott. (LBNR217)	Aerial parts	No toxic activities	(Ali et al., 2017)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Barkaoui et al., 2017; Mrabti et al., 2019; Skalli et al., 2019; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	10
Rutaceae	*Citrus aurantium* L. (LBNR220)	Fruit	Dermaltoxicity, cardiovascular toxicity	(Calapai et al., 1999)	(Benkhnigue et al., 2010; Bousta et al., 2014; Douira and Zidane, 2015; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	5
	Citrus medica L. (LBNR259)	Fruit	Dermaltoxicity	(Goetz, 2014)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Citrus paradisi Macfad. (LBNR260)	Fruit	Hepato-toxicity (in higher doses)	(Enye, 2012)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Ruta graveolens L. (LBNR224)	Leaves	Antifertility, cardiovascular toxicity, hepato-toxicity	(Seak and Lin, 2007; Hammiche et al., 2013)	(Benkhnigue et al., 2010)	1
	Ruta montana (L.) L. (LBNR225)	Aerial parts	Dermal toxicity	(Zekkour, 2008)	(Eddouks et al., 2002; Benkhnigue et al., 2010; Alami et al., 2015; Douira and Zidane, 2015; Hachi et al., 2016; Fouad and Lahcen, 2020)	6
Solanaceae	*Capsicum annuum* L. (LBNR227)	Fruit	Dermal toxicity	(Zekkour, 2008)	(Benkhnigue et al., 2010; Douira and Zidane, 2015; Idm'hand et al., 2020)	3
	Solanum lycopersicum L. (LBNR232)	-	Not identified	-	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
	Withania frutescens (L.) Pauquy (LBNR235)	-	Not identified	-	No data	0
Taxaceae	*Taxus baccata* L. (LBNR236)	Aerial parts, stem and leaves	Cardiovascular toxicity, hepato-toxicity	(Chang et al., 2001; Zekkour, 2008)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Theaceae	*Camellia thea* Link. (LBNR261)	Leaves	Hepato-toxicity	(Zekkour, 2008)	(Benkhnigue et al., 2010; Alami et al., 2015; Barkaoui et al., 2017; Laadim et al., 2017; Mrabti et al., 2019; Idm'hand et al., 2020)	6

Table 4. The toxicity of the plants inventoried in the High Atlas Central (continued…)

Families	Scientific name	Data on intoxication activity			Ethnobotanic studies	No. citation
		Toxic part	Type of toxicity	Reference		
Thymelaeacea	*Thymelaea hirsuta* (L.) Endl (LBNR238)	Aerial parts	Dermal toxicity, digestive toxicity	(Zekkour, 2008; Benkhnigue et al., 2010)	(Eddouks et al., 2002; Benkhnigue et al., 2010; Idm'hand et al., 2020)	3
	Thymelea virgata Mill. (LBNR239)	-	Not identified	-	No data	0
Urticaceae	*Urtica urens* L. (LBNR241)	Leaves	Dermal toxicity	(Zekkour, 2008)	No data	0
Verbenaceae	*Aloysia citriodora* Palau. (LBNR242)	-	Not identified	-	(Bousta et al., 2014; Alami et al., 2015; Douira and Zidane, 2015; Idm'hand et al., 2020)	4
Vitaceae	*Vitis vinifera* L. (LBNR243)	-	Not identified	-	(Benkhnigue et al., 2010; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	3
Xanthorrhoeaceae	*Asphodelus microcarpus* Salzm & Viv. (LBNR245)	Aerial part, steam flower, leaves and root	No toxic activities	(Mayouf et al., 2019)	(Benkhnigue et al., 2010; Idm'hand et al., 2020)	2
Zingiberaceae	*Zingiber officinale* Rosc (LBNR247)	-	Not identified	-	(Alami et al., 2015; Douira and Zidane, 2015; Skalli et al., 2019; Idm'hand et al., 2020)	4
Zygophyllaceae	*Zygophyllum gaetulum* Emberger & Maire (LBNR248)	Leaves	Prevent sexual maturity both in males and females	(Abbassi et al., 2003)	(Jouad et al., 2001; Eddouks et al., 2002; Benkhnigue et al., 2010; Douira and Zidane, 2015; Hachi et al., 2016; Barkaoui et al., 2017; Fouad and Lahcen, 2020; Idm'hand et al., 2020)	8

The low quantity of MP used to treat gestational diabetes could be explained by the fact that this diabetes occurs only during pregnancy, and that pregnant women were very sensitive to all risks resulting from the use of certain plants that can be toxic (Table 3).

Traditional knowledge acquisition modes

According to the surveys carried out in the study area, we found that the relationship between the local population and the flora surrounding them was intimate. The informants had expertise on the virtues and use of plants in traditional medicine. This ancestral knowledge transmitted heritable from ascendants (wise men) to descendants (young people). In our survey, it was found that 39.81% of respondents based their choice of proper medicinal plants on the experience of their ancestry, while 32.14% consulted herbalists, and 24.2% through revelations because of the presence of many medicinal plants in their environment. Our findings in relation to the modes of acquisition of traditional knowledge were in agreement with that of Mrabti et al. (2019).

The reasons for choosing this herbal medicine

We looked for the reasons that led to the use of medicinal plants in our diabetic population. We found that the majority of people chose traditional treatment because it was affordable (in 54% of cases), effective and accessible compared to modern medicine (in 46% of cases). According to studies conducted in this field, surveys achieved in southeastern Morocco, among 20 herbalists and 700 patients suffering from diabetes, hypertension and heart disease, from the region of Tafilalat, had shown that phytotherapy is preferred by the local population because it was cheaper (58%), more effective (40%) and better than modern medicine (63%) (Eddouks et al., 2002).

Also in Africa, a study carried out in Guinea by Baldé et al. (2006) showed that among the diabetic population studied, 33% of the patients used phytotherapy for multiple and sometimes associated reasons: belief in the efficacy of plants in 74% of cases, better accessibility to this treatment for 70% of patients, lower cost in 48% of cases. The popular of the users of phytotherapy were satisfied (85%).

The medicinal plants most used by the local population

Of the 144 species listed, the most widely used medicinal plants were: *Olea europaea*, *Salvia officinalis* and *Euphorbia resinifera*.

The use rates of these plants were higher than for any other plant, indicating that they were the best known in the treatment of diabetes and would probably be among the most effective.

The use of *Olea europaea* and *Salvia officinalis* was confirmed by other research conducted in Morocco: in the north (Chaachouay et al., 2019a), the centre (Mrabti et al., 2019), and the south of the country (Katiri et al., 2017), so it was important to carry out a phytochemical, toxicological and pharmacological study of these medicinal plants with antidiabetic potential.

The most cited plants that have been the subject of scientific studies on their antihyperglycemic effects

The hypoglycemic effect of some of these listed plants had been the subject of several studies, including *Salvia officinalis*, which was widely used in our study, and whose effectiveness had been demonstrated by several studies. According to Foster-Powell et al. (2002), the administration of 500 mg/day of sage leaf extract for three months significantly lowers blood glucose. Indeed, the administration of sage extract significantly lowered blood glucose in diabetic mice in case of moderate hyperglycemia (Brennan et al., 1996).

Jaouhari et al. (1999; 2000), demonstrated the hypoglycemic effect of *Zygophyllum gaetulum*. So, *Lupinus albus* was also present with high frequency in our study, according to González-Santiago et al. (2017), these grains reduced hepatic glucose production and leading to a reduction in the glycemic index. A study conducted this year by Bouzghaya et al. (2020), showed that *Linum usitatissimum* seed was effective in controlling lipid peroxidation and antioxidant enzymes in the liver and kidneys,

which were responsible for diabetes-related complications due to hyperglycaemia. The aqueous extracted of the leaves of *Origanum vulgare* had a strong and powerful anti-hyperglycemic activity in rats (Gonzalez et al., 1992; Lemhadri et al., 2004). Several researchers had shown that *Nigella sativa* has a high hypoglycaemic capacity (Fararh et al., 2004; Ahmad et al., 2013). *Olea europae* was the most widely used plant in our study; according to Jemai et al. (2009), administration of an olive leaf extract significantly decreased blood glucose levels. This antidiabetic effect can be explained by their antioxidant activity by reducing the oxidative stress that accompanies diabetes and its complications. In addition, these extracts also improved insulin secretion (Gerich, 1998). *Trigonella foenum-graecum* is the fourth plant used by the HAC population. Several studies had demonstrated the hypoglycemic effects of fenugreek (Kumar et al., 2012; Swaroop et al., 2014), moreover, the results of the study of Sharma et al. (1990) had concluded that fenugreek grains were useful in the control of glycemia. Recent study, published in 2017, concluded that *Rosmarinus officinalis* is effective in the traditional treatment of diabetes mellitus (Hamidpour et al., 2017). *Citrus aurantium* ranked 6th in order of frequency. Suntar et al. (2018) had examined the antidiabetic effect of this plant. Two isolated studies had shown that extracts of *Coriandrum sativum* can lower blood sugar levels in diabetic rats (Gray and Flatt, 1999; Aissaoui et al., 2011).

Data on the toxicity of the plants inventoried in the High Atlas Central

Among the antidiabetic plants inventoried, we found that the local populations were able to identify certain species recognized by their toxic powers, such as *Euphorbia resinifera, Nerium oleander, Citrullus colocynthis, Nigella sativa and Zygophyllum gaetulum*. They insisted on the use of these plants with caution and in small doses, and that these plants are forbidden to pregnant women in order to avoid any complications.

According to the research carried out in several databases, we had collected toxicological information on 99 antidiabetic plants identified. The results of this study revealed that 41 species did not have any toxic activates, three plants had a very low toxicity, while five species were toxic, but have a high dose and a long duration of use, and seven species were dangerous for pregnant women, and can lead to abortion.

It also showed that 43 species used for their antidiabetic activities by the local population are toxic. Some of them such as *Nerium oleander, Peganum harmala* and *Euphorbia resinifera* can be lethal at high doses. So, the risks of using these toxic plants must be carefully evaluated, while the rest of the species, that is to say 45 antidiabetic plants, have not yet been identified for their toxic activities in any scientific research (Table 4).

The new antidiabetic species

Among the 144 species identified in this study, and in comparison, with the results of various ethnobotanical and ethnopharmacological studies conducted in different regions of Morocco, 32 species were described for the first time as antidiabetic plants, and were not previously reported in published literature (Table 4).

CONCLUSIONS

The present work has enabled us to carry out a first study in the HAC of Morocco. It concerns about diabetic problems and the scientific evaluation of the toxicity of the medicinal plants used against this disease. This ethnobotanical survey has enabled us to invent and identify 144 species belonging to 52 families, 32 are quoted for the first time and have never been mentioned in the literature, and 43 species have been found to be toxic even at low doses. But the majority of users of these plants do not pay enough attention to the consequent risks of their use.

These results are a very rich source of information. They contribute to the knowledge of the antidiabetic medicinal flora of our study area, and to the preservation of local popular know-how the word that tending to disappear. They can also represent a database which consists in purifying and identifying the characterization of the active compounds of medicinal plant extracts with antidia-

betic activity. In this way, it makes it possible to elucidate the mechanism of action of these plants, by carrying out an in-depth phytochemical study, particularly of the most popular species such as *Thymus broussonetii* Boiss and *Euphorbia resinifera* Berg, then to confirm their uses through scientific research and clinical trials on their toxicities, in order to evaluate their effectiveness, safety and thus the standardization of their use.

CONFLICT OF INTEREST

The authors declare no conflicts of interests.

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AUTHOR CONTRIBUTION:

Contribution	Belhaj S	Chaachouay N	Zidane L
Concepts or ideas	x		x
Design	x		x
Definition of intellectual content	x	x	x
Literature search	x	x	x
Experimental studies	x		x
Data acquisition	x		x
Data analysis	x		x
Statistical analysis	x		x
Manuscript preparation	x	x	x
Manuscript editing	x		x
Manuscript review	x	x	x

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Appendix 1. Survey carried out on the study area.

Date.....
Region: ..... Municipality: .....
Commune..... Other: .....

➢ **Information about the interviewed**

Age: Age: {19-30}□ {30 - 50}□ {50 - 70}□ {70-94}□
Sex: Male □ Female □
Level of study: Illiterate□ Primary□ Secondary□ University□
Family situation: Single□ Married□ Divorced□ Widower□
Gender: Male□ Female□
Locality: City□ Village□ Town□ Douar□
Profession: .....
Income / month (MAD): Unemployed□ {350 - 1500 }□ {1500 - 5000}□ {≥ 5000}□

✓ When you feel sick, you address:

- To traditional medicine□, why? Effective□ Less expensive□ Ineffective medicine□
- In modern medicine□, Why? Effective□ More accurate□ Toxicity of plants□
- If it's both, what is the first: Modern medicine□ Traditional medicine□

➢ **Plant material:**

▪ Vernacular name: ..... ▪ Scientific name: ..... ▪ English name: .....
▪ Use of the plant: Therapeutic□ Cosmetic□ Other□
▪ Harvesting technique: Manual□ Mechanical□
▪ Single plant□ Possible association (of plants)□:.....
▪State of the plant: Fresh□ Dried □
▪ Used part: ▪ Flowers□ Fruits□ Seed□ Bark□ Root□ Bulb□ Top flower□ Leaves□ Stem□ Overhead□ Whole plant□
Other combinations□: .....
▪Form of employment: Tisane□ Powder□ Cream□ Essential oils□ Syrup□ Another form of use:
▪ Method of preparation: Infusion□ Decoction□ Poultice□ Maceration□ Fumigation□ Raw□ Cooked□ Other□: .....
▪Method of administration: Oral□ Massage□ Rinsing□ Brushing□ Gargle□ Other□: .....

➢ **Use**:

▪ What types of Diabetes do you have? TD1□ TD2□ GDM□
- You know the toxic antidiabetic plants? Yes□ No□
- What are these plants?.....

▪Diagnosis By: Himself□ The experience of their ancestry□ The herbalist□
▪Results: Healing□ Improvement□ Ineffective□ Toxicity: .....
▪Side effects: Side effect: .....Toxicity: ..... Precaution of use: .....