Biodiversity of poisonous medicinal plants solicited in the traditional phytotherapy of the central Middle Atlas - Morocco

Mariame Najem, Amine Daoudi, El Houssine Bouiamrine, Jamal Ibijbijen, Laila Nassiri

Databases and Inventories

Abstract

Background: The central Middle Atlas is a region renowned for its wealth of medicinal plants and ancestral knowledge of its local population in traditional pharmacopoeia. Thus, the main aim of this study is the valorization of poisonous medicinal plants and to provide an overview on the state of plant biodiversity of toxic medicinal plants, recommended by the actors of traditional medicine in this region

Methods: The survey carried out involving actors of traditional medicine in the central Middle Atlas made it possible to establish a list of toxic medicinal plants recommended by these actors. A field survey was then conducted in order to identify the plants inventoried in the different sites of the study area, for taxonomic confirmation and /or determination.

Results: Ethnobotanical survey allowed us to identify 123 medicinal plants used. Of these, 83 are declared toxic. The floristic prospection of these 83 toxic medicinal plants revealed that the majority of these plants are spontaneous herbaceous, with a rate of endemism of 8.34%. In addition, these plants are grouped into 74 genera and distributed over 36 families, of which the most represented are Lamiaceae (15.66%) and Asteraceae (14.46%). Also, the study revealed that *Anacyclus pyrethrum* L., *Aristolochia paucinervis* Pomel and *Urtica urens* L. are the most toxic plants used therapeutically. Moreover, the results show that for some plants, the most toxic parts are the most recommended by practitioners of traditional medicine in the study area, generally with internal use. Thus, the risks of poisoning are indisputable and accentuated by the recorded cases of confusion.

Conclusion: The Middle Atlas is a region known for its flora biodiversity and especially for poisonous medicinal plants. The uncontrolled use of these plants can lead to sequelae and possibly serious intoxications.

Keywords: Floristic prospecting, toxic medicinal plants, Central Middle Atlas, phytotherapy.

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Résumé

Contexte: Au Maroc, la région du Moyen Atlas central est réputée pour sa richesse en plantes médicinales et les connaissances ancestrales de sa population locale en matière de pharmacopée traditionnelle. Aussi, l'objectif principal de la présente étude est de valoriser parmi ces plantes médicinales utilisées par les acteurs de la médecine traditionnelle

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de cette région, celles déclarées toxiques et de fournir un aperçu sur leur biodiversité.

Méthodes: L'enquête conduite auprès d'acteurs de la médecine traditionnelle au Moyen Atlas central a permis d'établir une liste des plantes médicinales toxiques recommandées par eux. Ensuite, une prospection a été menée sur le terrain, afin d'identifier sur les différents sites de la zone d'étude, les plantes inventoriées, pour une confirmation et / ou une détermination taxonomique.

Résultats: L'enquête ethnobotanique nous a permis d'identifier 123 plantes médicinales utilisées, parmi lesquelles, 83 ont été déclarées toxiques. L'investigation floristique menée sur ces 83 plantes a révélé que la majorité sont des herbacées spontanées, avec un taux d'endémisme de 8,34%. Ces plantes relèvent de 74 genres et 36 familles, dont les plus représentées sont les Lamiaceae (15,66%) et les Asteraceae (14,46%). Par ailleurs l'étude a révélé que d'une part, *Anacyclus pyrethrum* L., *Aristolochia paucinervis* Pomel et *Urtica urens* L. sont les plantes toxiques les plus utilisées en thérapeutique; d'autre part, pour certaines de ces plantes, les parties les plus toxiques sont les plus recommandées par les praticiens de la médecine traditionnelle dans la zone d'étude, et généralement en usage interne. Les risques d'empoisonnement sont donc incontestables, d'autant plus qu'ils sont accentués par des cas de confusion entre espèces.

Conclusion: Le Moyen Atlas est une région connue pour sa biodiversité floristique qui recèle de nombreuses plantes médicinales toxiques. L'utilisation incontrôlée de ces plantes peut entraîner des séquelles dues à d'éventuelles intoxications graves.

Mots-clés: Prospection floristique, Plantes Médicinales Toxiques, Moyen Atlas central, Phytothérapie.

Background

The Middle Atlas is a mountain range that extends over 450 km and covers a total area of 27550 km^2 (El Jihad 2016). Due to its location and the physical characteristics of its environment, the Middle Atlas area offers the greatest wealth of renewable natural resources: aquatic, edaphic, floristic, faunistic and forest.

The flora of the Middle Atlas is very rich, and it includes a large number of endemic species, rare or very remarkable (Benabid 2002). The vegetation is very diverse. The phytocenoses are luxuriant, that due to the precipitations which are either in the form of rains or snow according to the altitude (Benbrahim *et al*. 2004) and offer the most important forest potentialities of Morocco. All types of Moroccan natural ecosystems are grouped in the Middle Atlas except those of the arid and Saharan zones (Benabid 2002).

This floristic heritage, the severity of the climatic conditions, the geographical isolation, the rudimentary sanitary infrastructure are all factors which have anchored the culture of the return to nature in the care of the affections of the local population (Nassiri *et al.* 2016).

Thus, for the purpose of studying biodiversity and valuing toxic medicinal plants, recommended by the actors of traditional medicine, in the Moroccan central Middle Atlas, a floristic prospection was conducted based on a catalog of poisonous plants carefully drawn up (Najem *et al.* 2018 a).

Material and methods

The study area

Given the large size of the Middle Atlas ecoregion, the study area chosen to conduct this survey includes the Meknes prefecture; the province of El hajeb; Azrou, Ifrane and Timahdite communes belonging to the province of Ifrane and the Khenifra and M'rirt communes of the Khenifra province (Fig. 1).

Inventory

Using questionnaire cards, a field campaign spread over 7 months was conducted in the central Middle Atlas, with the different actors of traditional medicine: traditional healers, herbalists and druggists. Using the "*Free listing*" technique, respondents are asked to answer closed and semi-closed questions considered more efficient for data collection. Each respondent delivered an average of 18 plants; this made it possible to complete 1042 questionnaire forms.

Statistical analysis

The data collected on the raw cards were analyzed by the statistical processing software SPSS Statistics 20 and Excel 2010 to highlight information related to the toxic medicinal plants used.

Prospecting outings and systematic determination

At the traditional medicine practitioners, it was impossible to make or verify the systematics of several species, because they were available mostly

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in the form of powder. For all this, and in order to avoid the possible intoxications inherent in the confusion of species, a survey on the ground was conducted once the list of plants declared toxic was established, in order to identify the plants inventoried in the different sites of the study area, for taxonomic confirmation and /or determination. Each toxic medicinal plant was carefully sampled, numbered for identification in the laboratory based on the practical flora of Morocco. (Fennane *et al*. 1999, Fennane *et al*. 2007, Fennane *et al*. 2014).

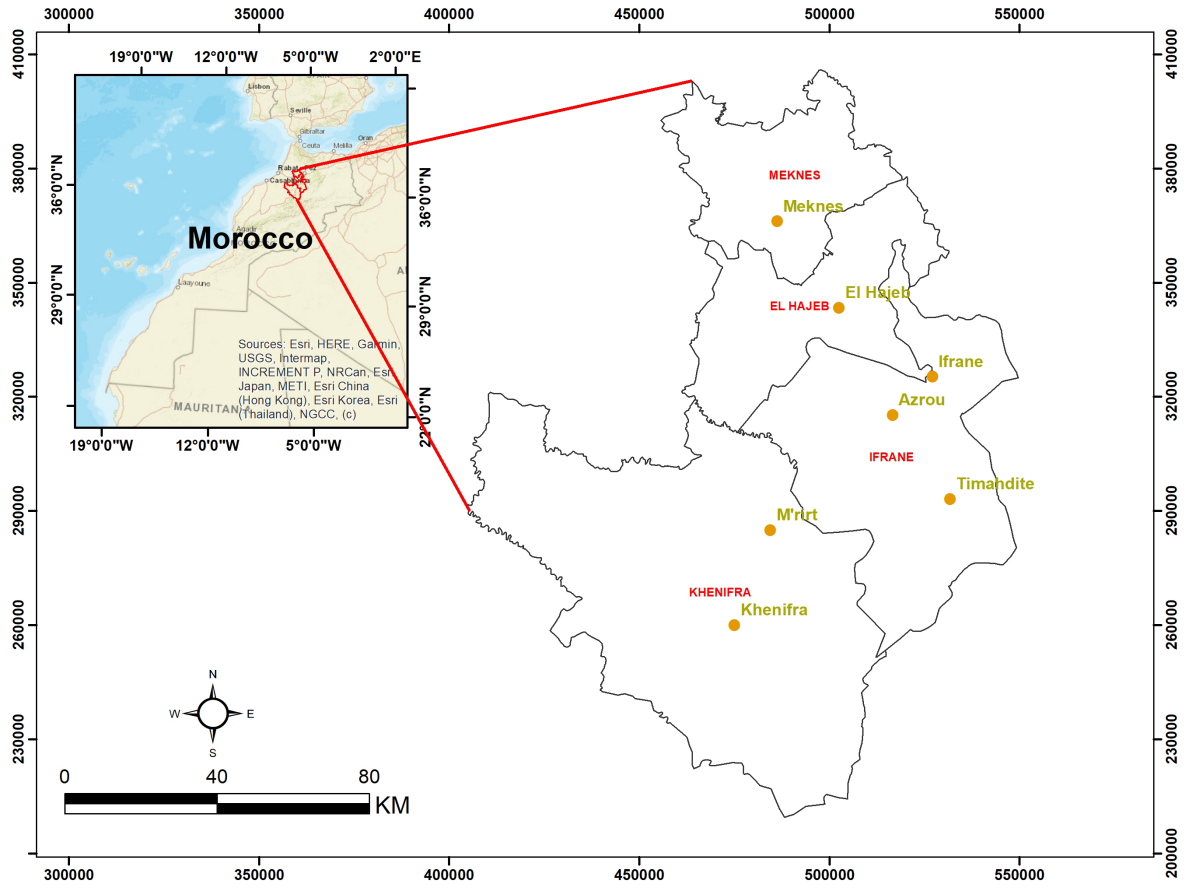

Fig.1. Study area

Results and discussion

Profile of traditional medicine actors investigated

The actors of traditional medicine surveyed (druggists, herbalists and traditional healers) are all from the study area. They are experienced in the practice of herbal medicine or the sale of medicinal plants. Therefore, they are able to provide correct and original information on the use of plants, since medicinal plants are an integral part of their daily basis. As they perform herbal medication for many years and passed from a father to a son.

Age class and gender

The knowledge of the actors of traditional medicine, related to the toxicity of medicinal plants of the central Middle Atlas, is widespread among all age groups. The average age is 34, the minimum 18 and the maximum 70. As shown in Fig. 2, the dominance of people aged between 20 and 40 years (48.62%), however, people whose age is greater than 60 years is only represented by16.36%.

Indeed, rejuvenation of the actors of traditional medicine is quite visible, demonstrating the persistence of natural and traditional treatments, as access to conventional care is difficult due to the variety of geographical and socio-economic and cultural level of the population of the central Middle Atlas; in addition to the poor state of hygiene and sanitation and inadequate health infrastructure in rural municipalities. Also, this rejuvenation of the domain is a sign of the durability of the transmission of knowledge from one generation to another; contrary to information obtained in other studies (Anyinam 1995, Mehdioui & Kahouadji 2007,

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Benkhnigue *et al*. 2011). Nevertheless, knowledge of the uses of medicinal plants and their properties, especially their toxicity, is generally acquired after a long accumulated experience (Anyinam 1995).
In the absence of proper transmission, the traditional therapeutic knowledge finds diluted and the poisoning risk is inevitable.

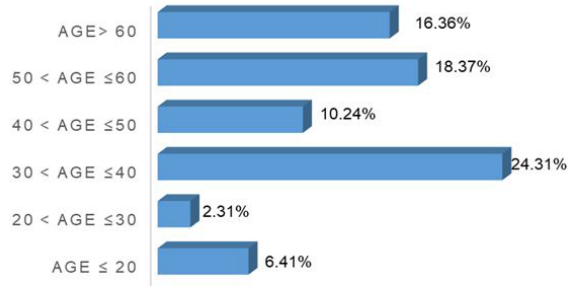

Fig. 2. Distribution of respondents by age

As for gender, men dominate the sector 87.40%, while women hold only 12.60% (Fig.3). The field of herbal medicine and the sale of medicinal plants is generally restricted to men in the study area. However, other ethnobotanical work done in the province of Essaouira (Mehdioui & Kahouadji 2007), in the region of Mechra Bel Ksiri (Benkhnigue *et al*. 2011) and at the prefecture of Agadir-Ida-Outanane (El Hafian *et al*. 2014) have shown that women are more demanding traditional herbal knowledge than men. However, in recent years, the participation of women in the field of sales has been noticed through the creation of associations or even pharmacies specialized in medicinal plants (Bammou *et al*. 2015).

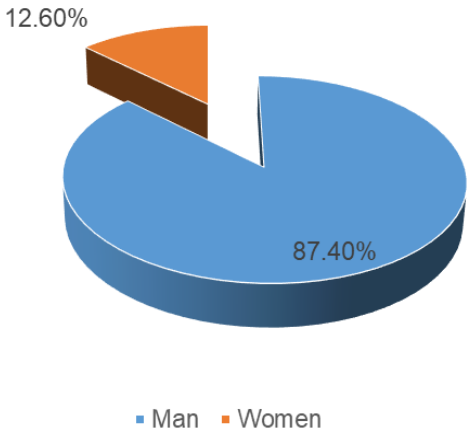

Fig. 3. Distribution of respondents by gender

Occupation and level of education
In the central Middle Atlas, the majority of the sellers of plants are druggists (42%), the herbalists and the traditional healers come then with a percentage of 37% and 21% respectively (Fig.4).

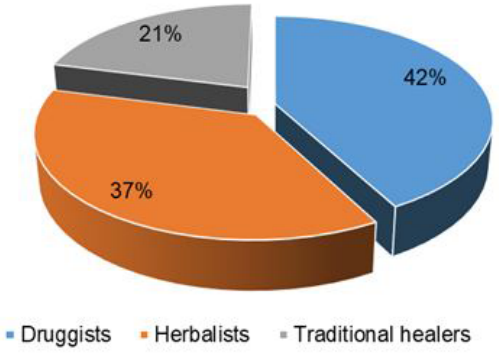

Fig. 4. Actors in traditional medicine

Regarding the level of education, actors of traditional medicine that have a secondary level of education dominate with a percentage of 42% (Fig. 5). However, those with a primary level of education have a significant percentage (28%) and illiterates occupy 18% of respondents. This rate of illiteracy can be a real obstacle to the development of the practice of phytotherapy (Bammou *et al*. 2015), following the difficulties encountered by these people to understand precisely transmitted instructions and flourish in the evolution of herbal medicine. Thus, the anarchic and not mastered use of medicinal plants may present a risk of intoxication and a serious health problem. Therefore, efforts must be made to provide continuous education to the actors of this sector. However, the portion of practitioners with a university level (12%), will probably change this domain, including to avoid complications related to the toxicity of some herbs and possible side effects (Bammou *et al*. 2015).

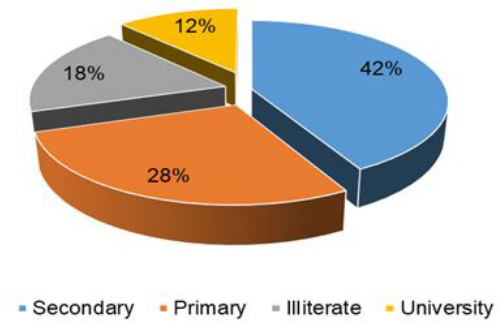

Fig. 5. Education levels of actors in traditional medicine.

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Source of knowledge of the plants

The knowledge of the uses of medicinal plants and their properties is generally acquired after a long experience, accumulated and transmitted from one generation to another (Mehdioui & Kahouadji 2007). Thus, 54% of the traditional medicine actors surveyed refer to the experiences of their parents and 20% to the experiences of the other actors more skilled in the field (Fig. 6). So herbal medicine in the central Middle Atlas is a heritage based on ancestral knowledge passed down from one generation to the next, and when an old actor of traditional medicine dies, it is like a library that burns and unfortunately, a great knowledge will be lost. However, the recommendation of medicinal plants, mainly based on oral transmission represents a real health risk. Our ancestor, although they have over time discovered the virtues of plants, do not control their phytochemical and pharmaco-toxicological properties (Najem et *al*. 2018 b).

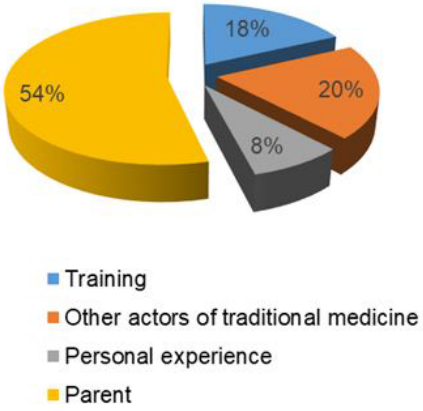

Fig. 6. Source of knowledge about medicinal plants.

In addition, 8% of respondents attend voluntarily continuous training either nationally through the Union of Herbalists of Morocco, or internationally. This is a positive point that indicates that traditional healers maintain their knowledge of medicinal plants (Doukkali *et al*. 2015) and with the experience accumulated with age we could evolve this field and one day Morocco will have a traditional medicine in the image of other models such traditional Chinese medicine.

Toxic medicinal plants enumerated

A total of 123 medicinal plants were identified used by traditional medicine practitioners in the study area; of these, 83 are declared toxic (67.48%), at least once by their users. (Fig.7). The frequency of citing the toxicity differs from one plant to another. Thus, 26% of the plants are declared toxic by all of their users, 33% of the plants have a frequency of citation of toxicity greater than or equal to 50%, however, plants with a toxicity frequency of less than 50% are represented by 41% (Fig. 8, Tab.1).

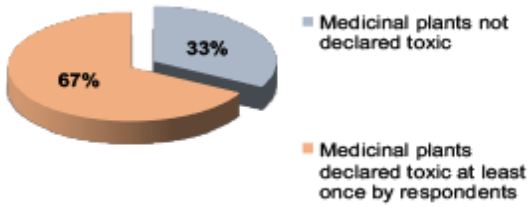

Fig. 7. Frequency of medicinal plants declared toxic.

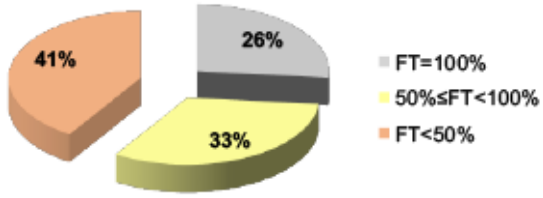

Fig. 8. Distribution of toxic plants according to the frequency of the declaration of toxicity (FT) by the users.

The use of this high number of plants declared toxic by the actors of traditional medicine in the study area is a double-edged weapon, because it reflects the control and the valorization of these actors of almost all the flora of the region and increases the risks of intoxications.

Families

The toxic plants used in traditional medicine of the central Middle Atlas are divided into 36 families. The most represented families are: Lamiaceae (13 species), Asteraceae (12 species), Apiaceae (9 plants), Brassicaceae (4 species), Solanaceae and Fabaceae (or legumes) holding each 3 species. The other 30 remaining families are each represented by only two or one plant (Fig. 9, Table 1). Lamiaceae and Asteraceae are important botanical families (Table 2), they include respectively 202 and 550 species growing in Morocco (Doukkali *et al.* 2015, Fennane 2012). Thus, in addition to being the most used families in herbal medicine in the Middle Atlas region they are also the most represented in the Mediterranean countries (Benítez *et al.* 2010, Savo *et al.* 2011). These families are also the richest in spontaneous plants (Nassiri *et al*. 2016), and contain the largest number of poisonous plants (Najem *et al.* 2018 a).

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Table1. Toxic medicinal plants used by the actors of traditional medicine in the central Middle Atlas

Family / Latin names	Local names	Herbarium specimen number	Extend of the plant population	Period of collection	State of plants	Used parts	Administration mode	Frequency of use (%)	FT(%)
Acanthaceae									
Acanthus mollis L.	Sebana	2682/IS/N°38	Fresh forests and shady rocks in the study area	Summer and early autumn	Fresh	Leaf	Internal: oral External: bandaging	15.52	33.33
Amaranthaceae									
*Chenopodium ambrosioides*L.	Mkhinza	247/IS/N°36	Very cultivated in the study area	Spring and summer	Fresh/dry	Leaf, Fruit	Internal: oral External: bandaging	41.38	75
Anacardiaceae									
Pistacia atlantica Dsf.	Lebtem	1810/IS/N°38	Khenifra region	Spring and summer	Fresh/dry	Leaf, Fruit, Stem, Flowers, Resin	Internal: oral External: bandaging, rinsing, massage	37.93	45.45
Pistacia lentiscus L.	Drou	1809/IS/N°38	Meknes region (in association with the Oleaster)	Late spring and early summer	Fresh/dry	Leaf, Fruit, Resin	Internal: oral	24.14	42.86
Apiaceae									
Ammi majus L.	Aatrilal	2025/IS/N°38	Very abundant in the study area	Autumn	Dry	Fruit	Internal: oral	18.97	36.36
Ammi visnaga (L.) Lam	Bachnikha / khala	2024/IS/N°38	Very abundant in the study area	Summer and autumn	Fresh/dry	Fruit, Flowers	Internal: oral Others	36.21	47.62
Anethum graveolens L.	Chibt	2041/IS/N°38	Little cultivated in the study area	Autumn	Dry	Fruit	Internal: oral	1.72	100
Angelica archangelica L.	Hachichat malaeka	23/PTM	Cultivated in some places in the study area	Autumn	Dry	Fruit, Root	Internal: oral	8.62	80
Carum carvi L.	Kerwiya	30/PTM	Cultivated in Meknes and El Hajeb	Autumn	Dry	Leaf, Fruit	Internal: oral	29.31	17
Coriandrum sativum L.	Kesbour	1955/IS/N°38	Cultivated throughout the study area	All year	Fresh/dry	Leaf, Flowers, Seeds	Internal: oral External: rinsing	5.17	33
Ferula communis L.	Boubal, lkellikha	2044/IS/N°38	Spontaneous in the study area	Late spring and early summer	Fresh/dry	Flowers, Resin	Internal: oral External: bandaging	15.52	100

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Foeniculum vulgare P. Mill.	Besbas	1991/IS/N°38	Cultivated in Meknes	Summer	Fresh/dry	Leaf, Root, Seeds	Internal: oral External: bandaging	8.62	40
Pimpinella anisum L.	Habat hlawa	46/PTM	Little cultivated in the study area	Autumn	Dry	Fruit	Internal: oral External: bandaging	15.52	55
Apocynaceae									
Nerium Oleander L.	Defla	2079/IS/N°38	Abundant near watercourse	From spring to autumn	Dry	Leaf, Root, Flowers	Internal: oral External: bandaging	24.14	100
Aristolochiaceae									
Aristolochia paucinervis Pomel	Bereztam	81/IS/N°36	Fields, ermes, matorrals, plains, low and medium mountains of the study area	Summer	Dry	Leaf, Fruit, Root	Internal: oral External :bandaging, massage Others	55.17	100
Asteraceae									
Achillea millefolium L.	Khala	61/PTM	spontaneous in areas of low afforestation, on the roadside	End of spring and summer	Fresh/dry	Flowers	Internal: oral External: bandaging	10.34	33
Atractylis cancellata L.	Nejma	2870/IS/N°40	Degraded forests, ermes, uncultivated fields, plains, low and medium mountains	Spring and autumn	Dry	Leaf, Stem	External: bandaging	6.90	25
Anacyclus pyrethrum L.	Akirkarha	3145/IS/N°40	Timahdite Region	Spring	Fresh/dry	Leaf, Root, Flowers	Internal: oral External: bandaging, massage Others	81.03	59
Anthemis nobilis L.	Babounj roumi	3139/IS/N°40	Ermes, lawn, low and medium mountains of the study area	Summer and autumn	Dry	Fruit, Flowers	Internal: oral	10.34	50
Artemisia arborescens L.	Chiba	3213/IS/N°40	Cultivated in the study area!*	Summer and autumn	Dry	Leaf, Flowers	Internal: oral	5.17	33.33
Artemisia herba-alba Asso.	Chih abiad	3207/IS/N°40	Plain of Moulouya	Summer	Fresh/dry	Leaf, Stem	Internal: oral External: bandaging	8.62	80
Atractylis gummifera L.	Dad	2828/IS/N°40	Abundant in the study area	Spring and autumn	Dry	Leaf, Root, Flowers	Internal: oral External: bandaging	22.41	100
Chrysanthemum parthenium Bern.	Uqhuwan	3197/IS/N°40	Cultivated and spontaneous in fields, rubble and hedgerows	End of spring and summer	Fresh/dry	Leaf, Flowers	Internal: oral	8.62	20
Echhinops spinosus L.	Chouk lahmar	2824/IS/N°40	Region of Azrou and Ifrane	Summer	Dry	Root	Internal: oral	22.41	100

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Launaea arborescens (Batt.) Maire	Intrim	3323/IS/N°40	Steppes, arid rock, overgrazed areas, plains and low mountains	All year	Dry	Leaf, Root, Resin	Internal: oral External: bandaging	6.90	75
Santolina rosmarinifolia L.	Ouzouaza	3125/IS/N°40	Matorrals of low and medium mountains	End of spring and summer	Dry	Leaf, Root, Stem, Flowers	Internal: oral	10.34	33.33
Senecio sp.	Achbat salma	770/IS/N°40	Cosmopolitan species	Spring	Dry	Leaf, Fruit, Root, Stem, Flowers	Internal: oral	10.34	100
Berberidaceae									
Berberis vulgaris L.	Adoudrih, ârgîs	48/IS/N°36	Timahdite region	Spring	Dry	Leaf, Fruit, Root	Internal: oral External: rinsing	8.62	80
Boraginaceae									
Borrago officinalis L.	Bouchanaf	2187/IS/N°38	Very abundant (Ruderal plant)	Spring and summer	Dry	Leaf, Root, Seeds, Flowers	Internal: oral External: bandaging	17.24	20
Heliotropium europaeum L.	Khaniza ratba	2170/IS/N°38	Crops and fallows, plains, low and medium mountains	End of spring and summer	Dry	Leaf, Root, Stem, Flowers	Internal: oral	8.62	100
Brassicaceae									
Brassica napus L.	Left fajli	824/IS/N°36	Cultivated in the study area	Spring and summer	Fresh/dry	Leaf, Root, Seeds	Internal: oral	6.90	25
Brassica nigra (L.) W.D.J.koch	Khardal aswad	817/IS/N°36	Very abundant in cultivated fields	Autumn	Fresh/dry	Leaf, Seeds	Internal: oral	12.07	42.86
Diplotaxis sp.	Charyat	202/IS/N°36	Messicole plant	Autumn	Dry	Leaf, Seeds	External: bandaging	5.17	100
Lepidium sativum L.	Hab erchad	905/IS/N°36	cultivated and often subspontaneous around dwellings	Autumn	Dry	Seeds	Internal: oral	10.34	100
Buxaceae									
Buxus sempervirens L.	Bakss	1711/IS/N°38	Region of Azrou and Ifrane	All year	Dry	Leaf	Internal: oral	5.17	66.67
Caprifoliaceae									
Sambucus nigra L.	Sembouqa	2746/IS/N°40	Low mountains of the study area	Summer	Dry	Leaf, Fruit Flowers	Internal: oral	6.90	50
Caryophyllaceae									
Corrigiola telephiifolia Pour.	serghina	348/IS/N°36	Region of Azrou and Timahdite	Summer	Fresh/dry	Root, Stem	External: bandaging, rinsing,	51.72	13.33
Saponaria vaccaria L.	Hamrat erras	559/IS/N°38	Cosmopolitan species	Autumn	Dry	Root	Internal: oral	6.90	75

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							External: bandaging		
Cistaceae									
Cistus ladaniferus L.	Touzal	704/IS/N°36	Low mountains of the study area	Spring	Dry	Leaf, Flowers	Internal: oral	15.52	22.22
Cyperaceae									
Cyperus longus L.	Arouk esaad	3702/IS/N°40	Water's edge, wet places, plains, low and medium mountains	Summer	Dry	Root	Internal: oral External: bandaging	13.79	100
Ericaceae									
Arbutus unedo L.	Bakhanou	1062/IS/N°36	Common in the study area	Autumn and early winter	Fresh/dry	Leaf, Fruit Root	Internal: oral	3.45	50
Euphorbiaceae									
Euphorbia helioscopia L.	Halib assou	1744/IS/N°38	Cosmopolitan species	Summer	Fresh/dry	Leaf, Tg, Flowers	Internal: oral	12.07	100
Euphorbia resinifera Berg.	Louban maghribi	1727/IS/N°38	Khenifra region	Spring	Dry	Resin	External: bandaging, rinsing,	6.90	100
Fabaceae									
Astragalus gummifera Labill.	Ktira	229/PTM	Some specimens cultivated in the study area	Spring	Fresh/dry	Resin	Internal: oral External: bandaging	6.90	25
Astragalus lusitanicus Lam.	Fouila	1315/IS/N°38	Common in the study area	Spring	Fresh/dry	Root	External: bandaging, massage	15.52	33.33
Trigonella foenum graecum L.	Halba	1553/IS/N°38	Very cultivated in the study area	Summer	Dry	Seeds	Internal: oral	12.07	71.43
Lamiaceae									
Ajuga iva (L.) Schreb.	Chandgoura	2250/IS/N°38	Abundant in the study area	Spring	Fresh/dry	Leaf, Root, Stem, Flowers	Internal: oral	18.97	63.64
Calamintha officinalis Moench.	Manta	301/PTM	Abundant in the study area	Summer	Fresh/dry	Leaf, Flowers	Internal: oral	12.07	14.29
Hyssopus officinalis L.	Azoufa yabsa	2449/IS/N°38	Clear forests, rocks, stony ground and medium mountains of the study area	Summer	Dry	Leaf, Fruit Flowers	Internal: oral External: bandaging	10.34	100
Lavandula pedunculata (Miller) Cav. subsp. atlantica (Br.-Bl.) Romo	Khzama	2317/IS/N°38	Medium mountains of the study area	Spring	Dry	Stem, Flowers	Internal: oral External: bandaging, massage	18.97	36.36
Marrubium vulgare L.	Mariouta	2313/IS/N°38	Very abundant (Ruderal plant)	Spring and summer	Fresh/dry	Leaf, Root, Stem, Flowers	Internal: oral	36.21	14.29

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							External: bandaging Others		
Mentha pulegium L.	Fliyou	2453/IS/N°38	Wetlands of the plains and the low and medium mountains	Summer	Fresh/dry	Leaf, Stem	Internal: oral	12.07	42.86
Ocimum basilicum L.	Lahbak	291/PTM	Cultivated in personal gardens	Summer	Fresh/dry	Leaf, Flowers	Internal: oral	18.97	54.55
Origanum majorana L.	Mardadouch	2427/IS/N°38	Cultivated in the study area	Summer	Fresh/dry	Leaf, Flowers	Internal: oral	18.97	45.45
Origanum vulgare L.	Mrou	2429/IS/N°38	Spontaneous in the clear forests and matorrals of the mountains of the study area	Spring and early summer	Fresh/dry	Leaf, Flowers	Internal: oral	6.90	75
Rosmarinus officinalis L.	Azir	2305/IS/N°38	Southern slope of central Middle Atlas in association with Red Juniper and Alfa	End of winter and spring	Fresh/dry	Leaf, Flowers	Internal: oral External: bandaging	5.17	66.67
Salvia officinalis L.	Salmiya	573/IS/N°38	Spontaneous and cultivated in the study area	Spring and summer	Fresh/dry	Leaf, Stem, Flowers	Internal: oral	6.90	50
Salvia verbenaca L.	khiyata	2392/IS/N°38	Spontaneous on the edge of fields and paths	Spring	Fresh/dry	Leaf	Internal: oral External: bandaging	17.24	20
Teucrium polium L.	Jaâda, Ayrar	2297/IS/N°38	Azrou region	Summer	Fresh/dry	Leaf, Flowers	Internal: oral	15.52	22.22
Lauraceae									
Laurus nobilis L.	Wrak moussa	78/IS/N°36	some specimens grown in personal gardens	All year	Fresh/dry	Leaf, Root, Seeds	Internal: oral	24.14	7.14
Liliaceae									
Asphodelus macrocarpus Parl.	Barouak	3534/IS/N°40	Abundant in the region of El Hajeb	Spring and summer	Dry	Root	Internal: oral External: bandaging	18.97	9.09
Urginea maritima (L.) Baker	Bassila	3502/IS/N°40	Abundant in the region of El Hajeb	From spring to early autumn	Dry	Leaf, Fruit, Seeds	Internal: oral	22.41	100
Pinaceae									
Cedrus atlantica (Manetti.) Carr.	Arz	25/IS/N°40	Abundant in the study area	Autumn	Dry	Fruit	Internal: oral External: massage	6.90	50
Poaceae									
Agropyrum repens (L.) PB.	Njem	4038/IS/N°40	Matorrals, fields, uncultivated places, plains and low mountains	Summer	Dry	Leaf, Flowers	Internal: oral	5.17	33.33

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Arundo donax L.	Ksab	3795/IS/N°40	Spontaneous or cultivated in hedgerows, water margins, flats, plains and low mountains in the study area	End of summer and winter	Fresh/dry	Stem	Internal: oral External: bandaging	3.45	50
Portulacaceae									
Portulaca oleracea L.	Rajla	340/IS/N°36	Abundant near watercourse	Spring	Dry	Leaf	Internal: oral	10.34	66
Ranunculaceae									
Delphinium staphysargria L.	Habat rass	93/IS/N°36	Forests, matorrals, plains and low mountains of the study area	Autumn	Dry	Seeds	Internal: oral External: bandaging	6.90	100
Paeonia coralline Retz spp coriacea (Boiss.) Coss.	Habersis	647/IS/N°36	Khenifra region	Summer	Dry	Root, Flowers	Internal: oral	6.90	75
Rhamnaceae									
Ziziphus lotus (L.) Lam.	Nbag	1776/IS/N°38	Non-forest areas, plains and low and medium mountains of the study area	Autumn	Dry	Leaf, Root	Internal: oral	8.62	20
Rosaceae									
Agrimonia eupatoria L.	Kaba	1178/IS/N°36	Fresh grassy valleys, matorrals, plains and mountains of the study area	Summer	Dry	Leaf, Flowers	Internal: oral	6.90	25
Crataegus monogyna Jacq.	Admam	1150/IS/N°36	Spontaneous in the study area	Spring and summer	Fresh/dry	Leaf, Fruit, Flowers	Internal: oral	15.52	88.89
Rubiaceae									
Rubia peregrina L.	Fouwa	2695/IS/N°40	Forests, matorrals, plains, low and middle mountains in the study area	End of spring and summer	Dry	Leaf, Root, Stem	Internal: oral	27.59	6.25
Rutaceae									
Ruta montana L.	Figel	1815/IS/N°38	Abundant in the study area	Spring and summer	Fresh/dry	Leaf, Root, Stem, Flowers	Internal: oral External: bandaging, massage, others	43.10	100
Scrophulariaceae									
Digitalis mauretanica (Emberger & Maire) Ivaina L.	Adabi	2605/IS/N°38	Ifrane region	Spring and summer		Leaf	Internal: oral	13.79	100
Verbascum sinuatum L.	Maslah ndar	2504/IS/N°38	Cedar ecosystem (Region of Azrou, Ifrane and khenifra)	Summer and early autumn	Dry	Leaf, Root, Flowers	Internal: oral External: bandaging	50.00	48.28

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							Others		
Solanaceae									
Atropa belladonna L.	Zbib lidûr	2124/IS/N°38	Azrou region	Summer and autumn	Dry	Leaf, Fruit, Root, Flowers	Internal: oral	20.69	100
Hyoscyamus sp	Sikran	509/IS/N°38	Khenifra region	Autumn	Dry	Leaf, Seeds	Internal: oral	15.52	77.78
Solanum Sodomeum L.	Hadja	2107/IS/N°38	Subspontaneous in the study area	Autumn	Dry	Fruit	Internal: oral External: bandaging	34.48	100
Taxaceae									
Taxus baccata L.	Dahs, îgen	72/IS/N°36	Ifrane region (Vittel)	Spring and early summer	Dry	Leaf, Root, Stem, Flowers	Internal: oral	12.07	85.71
Thymeleaceae									
Daphne gnidium L.	Alezzâz	1667/IS/N°38	Under the cover of the olive tree	Summer and autumn	Dry	Leaf	Internal: oral External: bandaging	12.07	100
Daphne laureola L.	Walidrar	1668/IS/N°38	Forest of Quercus canariensis and Quercus ilex (Azrou Escarpment)	Winter	Dry	Leaf, Stem	Internal: oral	13.79	87.50
Urticaceae									
Urtica urens	Hariga	209/IS/N°36	Very abundant (Ruderal plant)	Spring and summer	Fresh/dry	Leaf, Root, Seeds	Internal: oral External: bandaging Others	53.45	51.61
Zygophyllaceae									
Peganum harmala L.	Lharmel	422/IS/N°38	Southern slope of the central Middle Atlas (plain of Moulouya) in association with Alfa and Mugwort	Summer	Dry	Root, Seeds	Internal: oral External: bandaging, massage	6.90	100

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Genera

The inventoried plants are grouped into 74 genera, almost all the genera identified, 87.84%, are known by a single species. Only nine, or 12.16%, have two species each: *Pistacia*, *Ammi*, *Artemisia*, *Brassica*, *Euphorbia*, *Astragalus*, *Origanum*, *Salvia* and *Daphne*.

Endemism

The Moroccan vascular flora is famous for its originality. Indeed, endemism represented by 640 species (16%) and 280 subspecies (32%) (Fennane 2012). The medicinal and aromatic plants used in traditional Moroccan herbal medicine are only represented by 743 taxa with 40 endemic in Morocco (Jamaleddine 2017). However, endemic toxic medicinal plants of Morocco used in traditional medicine of central Middle Atlas are represented only by three species: *Lavandula pedunculata* (Miller) Cav. subsp. atlantica (Br.-Bl.) Romo, *Euphorbia resinifera* Berg. and *Digitalis mauretanica* (Emberger& Maire) Ivanina (L.). Endemism takes a much larger extension when we integrate species shared with neighboring territories: Iberian Peninsula and Algeria. Thus, 7 species are involved, therefore, a percentage of 8.43% (Tab. 3, Fig.10).

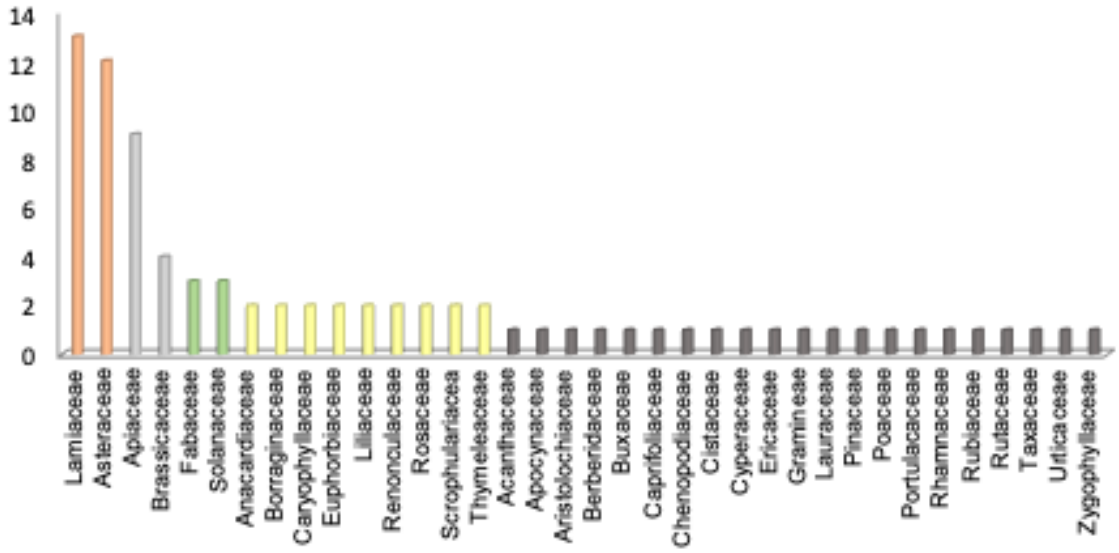

Fig. 9. Distribution of the toxic plants of the main families, expressed as a percentage of the total of toxic plants listed in the study area.

Table 2. Classification of some families by number of species in the flora of Morocco and number of toxic medicinal species used in the central Middle Atlas

Botanical family	**Number of species in the flora of Morocco** (Fennane 2012)	**Number of toxic medicinal species used in central Middle Atlas**
Asteraceae	550	12
Fabaceae	424	3
Brassicaceae	212	4
Lamiaceae	202	13
Apiaceae	153	9

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Fig.10. Endemic toxic medicinal species in the study area.
A: *Lavandula pedunculata* (Miller) Cav. subsp. atlantica (Br.-Bl.) Romo, B: *Euphorbia resinifera* Berg., C : *Digitalis mauretanica* (Emberger & Maire) Ivanina L., D : *Anacyclus pyrethrum* L., E : *Paeonia coralline* Retz spp coriacea (Boiss.) Coss., F : *Saponaria vaccaria* L., G: *Astragalus lusitanicus* Lam.)

Table 3. Endemic toxic medicinal species in the study area

Endemic category	**Total of species and subspecies** (Fennane 2012)	**Number of toxic medicinal species**	**Names of toxic medicinal species**
EM	920	3	**Lavandula pedunculata* (Miller) Cav. subsp. atlantica (Br.-Bl.) Romo **Euphorbia resinifera* Berg. **Digitalis mauretanica* (Emberger & Maire) Ivanina L.
EMI	300	1	*Astragalus lusitanicus* Lam.
EMA	302	2	**Anacyclus pyrethrum* L. **Paeonia coralline* Retz spp coriacea (Boiss.) Coss.
ES	-	1	*Saponaria vaccaria* L.
Total	**1522**	**7**	
EM Endemic of Morocco, EMI : Endemic of Morocco and the Iberian Peninsula, EMA : Endemic of Morocco and Algeria , ES : Endemic of the Saharan regions			

Plant identification and likelihood of confusion

All the toxic medicinal plants identified are well known in the Moroccan traditional pharmacopoeia and are used by the actors of traditional medicine of the central Middle Atlas. In fact, these vernacular names are given in different ways: by describing the appearance of the plant, or its part employed, or even its physiological effect. This sometimes leads users to fall into the error of naming and identifying plants (El Rhaffari *et al.* 2002).

Moreover, during the investigations carried out in the different cities of the study area, it was noticed that the vernacular name of a plant could correspond to several species at the same time, although of the same genre. This similarity of names is due to the conformity of the ports and to the polymorphism of certain plants and consequently to the uses of the vegetable drug (El Rhaffari *et al.* 2002). This is the case, for example, of the nettle "Harriga" where at least 3 species are found in the study area, *Urtica membranacea, Urtica urens* and *Urtica pilulifera*and many other plants are in the same situation (Fig.11).

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On the other hand, the same vernacular name is sometimes used for species belonging to different families. A first example is that of "Lehdej" (Hadja) which is used both for the Sodom nightshade "*Solanum sodomaeum*", of the Solanaceae family and for the colocynth "*Citrullus colocynthus*", of the Cucurbitaceae family in other regions (Fig.6), particularly the eastern part of Morocco. Another example is "makhinza" common to the species *Chenopodium ambrosioides* and *Cleome arabica* (in the Saharan region of Draa), respectively belonging to the families Chenopodiaceae and capparidaceae (Fig.12). Table 4 summarizes the different possibilities the use for the same vernacular name for different plant species.

Fig.11. Similarity of names between species belonging to the same genus.
A: *Urtica dioica*, B: *Urtica pilulifera*, C: *Urtica urens*

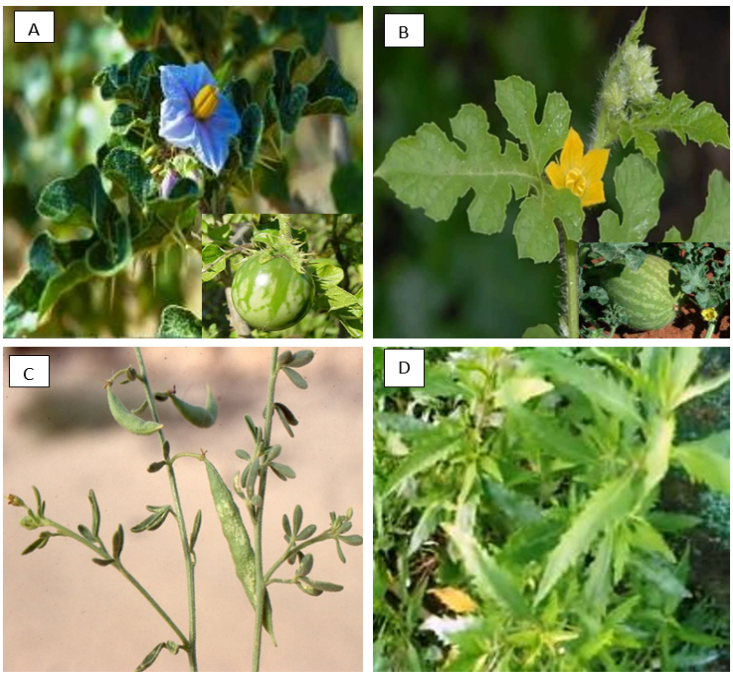

Fig.12. Similarity of names between species belonging to different families.
A: *Solanum sodomaeum*, B: *Citrullus colocynthus* C: *Cleome arabica*, D: *Chenopodium ambrosioides*

This confusion found during plant identification could be the source of inefficiency of the treatments. Also, the chemical composition already varies with the edaphic or climatic races of the same species, both qualitatively and quantitatively (Khia *et al.* 2014) and so this would surely be amplified between different species.

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Table 4. Similarity of vernacular names between different species

Vernacular	species with the same
Barouak	*Asphodelus microcarpus* Salzm. & Viv.
	Asphodelus ramosus L.
Khaniza ratba	*Heliotropium europaeum* L.
	Heliotropium bacciferum L.
	Heliotropium supinum L.
Hamrat erras	*Saponaria vaccaria* L.
	Calendula sp.(Western
	Perralderia coronopifolia Coss.(Western Sahara)
Khala	*Ammi visnaga* L.
	Achillea millefolium L.
Sikran	*Conium maculatum* L.
	Hyoscyamus sp.
Uqhuwân	*Chrysanthemum parthenium*
	Chrysanthemum coranarium
	Chrysanthemum macrocarpum Coss. & Kral.
	Matricaria chamomilla L.
Harriga	*Urtica membranacea* L.
	Urtica urens L.
	Urtica pilulifera L.
Hadja	*Solanum sodomaeum* L.
	Citrullus colocynthis (L.) Schrad.
Makhinza	*Chenopodium ambrosioides* L.
	Amaranthus blitoides S. Wats.
	Cleome arabica L. (in the Saharan region of Draa)

Herbal preparations can become toxic when one or more of their constituents that may have serious toxic effects are not or poorly identified. In 1991 and 1992, the replacement of *Stephania tetrandra* by *Aristolochia fangchi* by simple linguistic confusion in a slimming preparation was the cause of severe nephropathy in female consumers. At least 70 patients had to receive dialysis or kidney transplant, and 18 had a diagnosis of urethral cancer. In this preparation, the presence of aristolochic acid, a nephrotoxic agent, was not identified or mentioned (Martinez 2002). Also, recalling a mistake, occurred in Switzerland in April 2002 that resulted in the death of a person who had taken colchicum leaves (*Colchicum autumnale*, liliaceae) for those of wild garlic (*Allium ursinum*), another liliaceous (Dolivo 2003).

In addition, between 1981 and 2004, 240 cases of poisoning by *Atractylis gummifera* L. known as "Addad" have been reported by the Poison Control and Pharmacovigilance Center of Morocco as a result of misuse for therapeutic purposes or by confusion with another plant, *Scolymus Hispanicus*, better known as "kouk lakhla" or Guernina (Mouaffak 2013).

Previous studies, in the same study area have highlighted several cases of confusion, the most famous is that of a plant widely used by the local population in the treatment of cysts is *Euphorbia resinifera*, whose vernacular name is "Daghmous" with species of the same genus Euphorbia. There is also confusion with distant species such as the case of *Caralluma europaea* belonging to the family Apocynaceae. Other case was recorded is that of the confusion between *Urtica* sp. and *Mercurialis perennis* (family Euphorbiaceae) (Bouiamrine *et al*. 2017).

It is important to know that the use of the root increases the probability of confusion with other plants. The risks of poisoning are then imminent (Ouarghidi *et al*. 2012) especially, once the root separated from the mother plant, and even more, in case of anarchic storage.

Area of plant distribution and harvest period

The results show that the toxic medicinal plants recommended by the actors of traditional medicine are distributed in the different points of the zone of study, with an abundance of a large number of species. This reflects the biodiversity richness of the study area, but also the risk of toxicity, especially since most of the local population isrural.

Regarding the harvest period, it differs from one plant to another and even for the same plant depending on the organ used. The flowers are harvested especially in spring, the fruits in summer and the root in autumn.

Types of toxic medicinal plants

The results of the study show that most toxic medicinal species are spontaneous (86%) rather than cultivated (14%) (Fig. 13); this shows on the one hand, the wealth of the central Middle Atlas in spontaneous plants and on the other hand, the strong exploitation pressure of this flora. If this crop is not managed reasonably, genetic erosion and

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extinction of the species will be major consequences (Fadil *et al.* 2014).

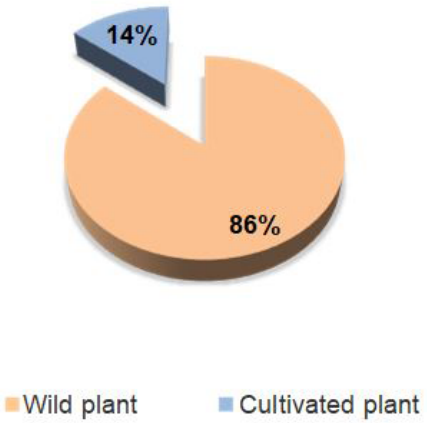

Fig. 13. Types of toxic medicinal plants.

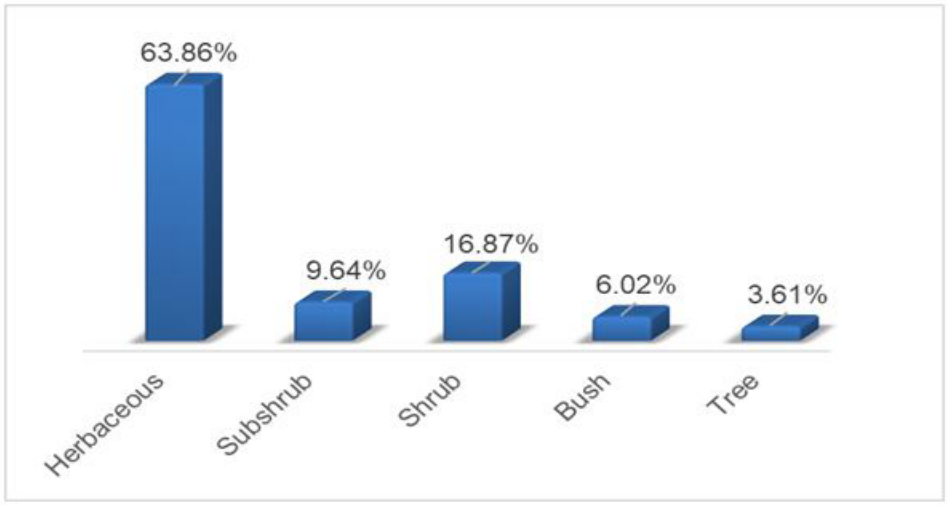

Fig. 14. Life forms of medcinal plants

Used parts

The predominance of use of one organ over another in the therapeutic field stems from its concentration of active ingredients (Bammou *et al.* 2015) and its content of toxic compounds. However, the survey revealed that for some plants, the most toxic parts are the most recommended by practitioners of traditional medicine in the study area. Thus, the risks of poisoning are indisputable.

Among these plants, *Solanum sodomeum* L., the most used part of which is the fruits that are most often responsible for poisoning, especially before their complete maturity (Lahsissene *et al.* 2009). Also, the content of toxic compounds is much higher in the seeds of *Peganum harmala* L. (Frison *et al.* 2008) which are frequently recommended. Likewise the bulb of *Urginea maritima* (L.) Baker. is particularly the most toxic (Bellakhdar 1997, Hmammouchi 1999) and the most used

The high frequency of use of leaves can be explained by the fact that they are at the same time center photochemical reactions and reservoirs of organic matter derived therefrom. They provide the majority of alkaloids, glycosides and essential oils (Ould El Hadj *et al.* 2003).

The root is also among the most used parts. However, the use of this difficult part increases the probability of confusion with other plants (Ouarghidi *et al.* 2012), especially, once the root separated from the mother plant, and even more, in case of anarchic storage (Najem *et al.* 2018 a).

Biological forms of toxic medicinal plants solicited

More than half of the toxic plants recommended by the respondents are herbaceous (63.86%) (Fig. 14). This preference may be due to their abundance and ubiquitous character which makes them more accessible by users (Lulekal *et al.* 2013). Nevertheless, this type of plant is known for its richness in bioactive compounds (Teklehaymanot 2009), including toxic ones. Regarding the different woody forms, they are represented by 36.14%. The perennial nature of these species ensures the availability of at least one organ in each season (Zerbo *et al.* 2007).

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The serious consequences are not limited to confusions due to the use of roots, but also for other organs. Among these organs berries of *Atropa belladonna* L. often taken for those of *Vaccinium myrtillus* L., which play a food and medical role. Another possible confusion between the tomentose leaves of two scrophulariaceae, *Digitalis purpurea* L. and *Verbascum* sp., Used as bechiques (Dolivo 2003). The foxglove has also been confused with *Borago officinalis* L. (Bruneton 2001).

Administration mode

The administration of the remedies is done either internally or externally depending on the chemical nature of the active ingredients and the degree of their toxicity. As a result, a plant can have internal and external use (El Chaar & Apostolides 2005).

Our investigation revealed that the majority of plants reported as toxic are administered internally (83.13%) (Table 1), increasing the risk of intoxication.

Certainly, medicinal plants have side effects when they are improperly performed by patients (Benlamdini *et al*. 2014). Thus, ingestion or contact with vesicant plants, generally containing an irritating latex, a resin or calcium oxalate crystals rapidly causes irritative lesions, accompanied by edema and sometimes laryngeal and digestive phlyctenes if the substance was swallowed. These disorders are induced by Euphorbia, Daphne and many others (Zekkour 2008).

In this sense, the mode of administration recommended by the actors of traditional medicine of the central Middle Atlas, for some plants should be diverted. Indeed, the prescription of *Anacyclus pyrethrum* L. orally causes irritation of the digestive mucous membranes, gastroenteritis, colic, diarrhea, convulsions and tinnitus; even, by contact, it causes skin irritation and mucous membranes, headache nausea, syncope and respiratory disorders (Zekkour 2008).

Therefore, the mode of administration is one of the key parameters, which, if it is not mastered and respected, can generate harmful effects even for an excellent medicinal plant. (Najem *et al*. 2018 a).

Classification of toxic medicinal species by importance of use

The results of the survey found that the most recommended toxic plants by traditional healers of the central Middle Atlas are: *Anacyclus pyrethrum* L. (81.03%), *Aristolochia paucinervis Pomel* (55.17%), *Urtica urens* L. (53.45%), *Corrigiola telephiifolia* Pour. (51.72%), *Verbascum sinuatum* L. (50%), *Ruta montana* L. (43.10%), *Chenopodium ambrosioides* L. (41.38%), *Pistacia atlantica* Dsf. (37.93%), *Ammi visnaga* (L.) Lam and *Marrubium vulgare* L. (36.21%), *Solanum sodomeum* L. (34.48%), *Carum carvi* L. (29.31%), *Laurus nobilis* L., *Nerium oleander* L., *Pistacia lentiscus* L., *Atractylis gummifera* L., *Echhinops spinosus* L. and *Urginea maritima* L. (24.14%) (Fig.15). The abuser use of these plants could be a real danger because of their reputed toxic power. In addition, any lack of knowledge of the requirements of the method of preparation, the route of administration and the appropriate dosage certainly leads to sincere intoxications.

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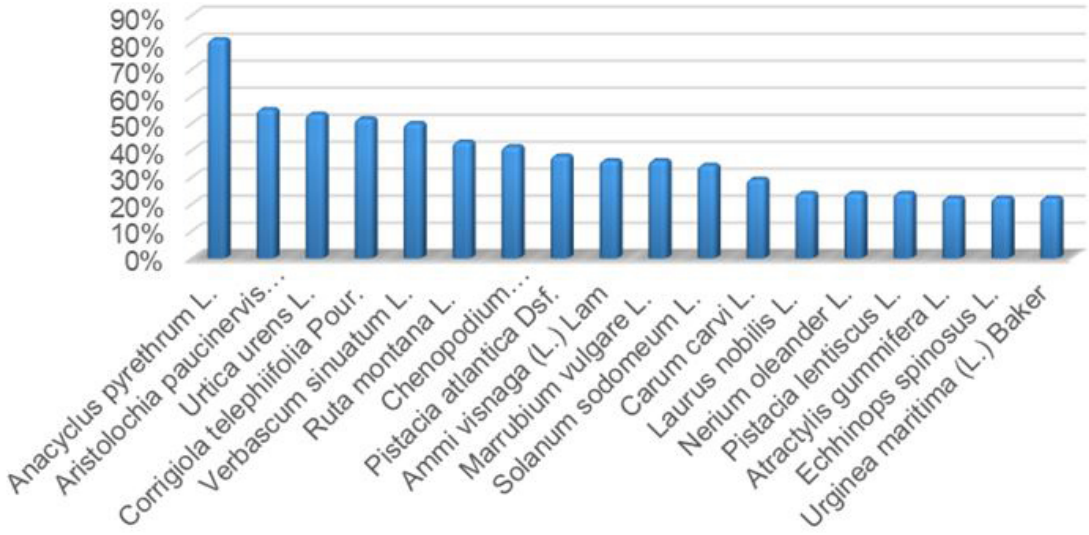

Fig. 15. Classification of toxic medicinal species by importance of use

Conclusions

The study conducted in the moroccan central Middle Atlas, revealed that the attachment of the population to nature and its generosity of medicinal plants, have contributed to the anchoring of ancestral medicinal traditions in the region. Then, the brewing of Amazigh and Arab-Muslim civilizations have fueled over time, a local pharmacopoeia based generally on lived experience, the observation transmitted from generation to generation, usually orally. In addition, the floristic prospection unveiled the wealth of the central Middle Atlas in terms of toxic medicinal plants. This heritage is exploited by the actors of traditional medicine of the region in the preparation of their recipes. Thus, any irrational and uncontrolled use would be the origin of the consequences and serious intoxications. For this, necessary measures should be taken for a better use of these plants.

Declarations

List of abbreviations*:* Not applicable.

Ethics approval and consent to participate: All *participants* gave their prior consent knowing the reason for the study.

Consent for publication*:* Not applicable.

Availability of data and materials: The data was not deposited in public repositories.

Competing interests: The authors do not have any competing interests.

Funding: This research did not receive funding.

Authors' contributions: AD carried out fieldwork. MN carried out data analysis and drafted the manuscript. EHB, JI and LN supervised the work and improved the manuscript. All authors read, reviewed and approved the final version of the manuscript.

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Questionnaire

1- Code	
2- Date	

3- Municipality

◯ 1. Azrou ◯ 2. El Hajeb ◯ 3. Ifrane ◯ 4. Khénifra ◯ 5. Meknes ◯ 6. Mrirt ◯ 7. Timehdit

4- Age

5- Profession

◯ 1. Druggist ◯ 2. Herbalist ◯ 3. Traditional healers

6- Gender

◯ 1. Female ◯ 2. male

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7- Locality
◯ 1. Nomadic ◯ 2. City ◯ 3. Douar ◯ 4. Village

8- Level of education
◯ 1. Illiterate ◯ 2. Primary ◯ 3. Secondary ◯ 4. University

9- Family

10-Genus

11-Species

12-Arabic vernacular name

13-French vernacular name

14-Tamazight vernacular name

15-Type
◯ 1. Cultivated ◯ 2. Wild
You can check multiple boxes

16- Use
◯ 1. Therapeutic ◯ 2. Cosmetic ◯ 3. Other
You can check multiple boxes

17-State of the plant
◯ 1. Fresh ◯ 2. Dried
You can check multiple boxes

18- Used part
◯ 1. Leaf ◯ 2. Fruit ◯ 3. Root ◯ 4. Stem ◯ 5. Seeds ◯ 6. Resin ◯ 7. Flowers ◯ 8. Capsules ◯ 9. Others
You can check multiple boxes

19-Method of preparation
◯ 1. Decoction ◯ 2. Infusion ◯ 3. Maceration ◯ 4. Powder ◯ 5. Poultice ◯ 6. Essential oil ◯ 7. Extract ◯ 8. Cooked ◯ 10. Others
You can check multiple boxes

20-Used dose
◯ 1. Spoonful ◯ 2. Pinch ◯ 3. Handle
You can check multiple boxes

21-Administration mode
◯ 1. Oral ◯ 2. Massage ◯ 3. Rinsing ◯ 4. Bandaging ◯ 5. Others
You can check multiple boxes

22-Duration of use
◯ 1. One-day ◯ 2. One-week ◯ 3. One-month ◯ 4. Until healing
You can check multiple boxes

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23-Treated disease

◯ Dermatological disorders	◯ Respiratory disorders	◯ cardiovascular diseases
◯ Urogenital disorders	◯ Osteoarticular disorders	◯ Digestive tract disorders
◯ Affections of glands	◯ Neurological disorders	◯ Metabolic disorders
◯ Appendices of digestive tract	◯ Ophthalmic disorders	◯ Oral disorders

You can check multiple boxes

24-Toxicity

◯ 1. Yes ◯ 2. No

25- Source of their knowledge of the plants

◯ 1. Parent ◯ 2. Media ◯ 3. Personal experience ◯ 4. Other actors of traditional medicine

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