Quantitative Ethnobotanical Study of Poisonous Medicinal Plants used in the Traditional Pharmacopoeia of the Central Middle Atlas Region: Morocco

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Databases and Inventories

Abstract

Background: This is the first quantitative study of poisonous medicinal plants in which the practitioners of traditional medicine in the Moroccan central Middle Atlas region were interviewed to document and analyze their traditional ethnobotanical knowledge used to prepare plant-based drugs.

Methods: To collect ethnobotanical data on poisonous medicinal plants, 58 practitioners of traditional medicine were interviewed. The quantitative measurement of the obtained data was accomplished by quantitative indices such as the use value (UV), family use value (FUV), relative frequency of citation (RFC), fidelity level (FL), relative importance (RI), informant consensus factor (ICF), and cultural importance index (CI).

Results: Among the 83 poisonous medicinal plants recorded, *Ruta montana* L. had the highest rate of UV (2.293). Furthermore, *Anacyclus pyrethrum* L. demonstrated the highest RFC (0.810), while *Carum carvi* L. had both the highest RI (95) and CI (0.155). Five species were distinguished for their high-fidelity levels, among which *Aristolochia paucinervis* Pomel had the highest FL values for the treatment of dermatological and digestive disorders. The other four species were *Ruta montana* L. for treating respiratory, oral, and neurological diseases, *Urtica urens* L. for treating osteoarticular and urogenital diseases, *Verbascum sinuatum* L. for treating ophthalmic diseases, and *Ammi visnaga,* (L.) Lam. for treating cardiovascular disorders. Ophthalmic disorders had the highest value of ICF (0.743), and a very significant positive correlation was observed between RFC and UV ($R^2 = 0.5968$) and between RI and CI ($R^2 = 0.9999$) was observed.

Conclusions: The present study reveals that traditional medicine practitioners in the central Middle Atlas region utilize many poisonous medicinal plants in traditional herbal medicine. Although these plants have therapeutic virtues, their toxic potency necessitates vigilance in use.

Key words: Poisonous medicinal plants, Quantitative ethnobotany, Taditional phytotherapy, Central Middle Atlas region

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Résumé

Contexte: Le présent travail constitue la première étude quantitative portant sur les plantes toxiques sollicitées par les acteurs de la médecine traditionnelle au Moyen Atlas central marocain ; il a pour but principal d'analyser le savoir culturel et botanique traditionnel utilisé dans la préparation de médicaments à base de plantes.

Méthodes: Pour collecter les données ethnobotaniques concernant les plantes toxiques utilisées en phytothérapie traditionnelle, 58 acteurs de la médecine ancestrale ont été interrogés. L'expression quantitative des données obtenues est réalisée via le calcul de différents indices quantitatifs, tels que :la valeur d'usage (UV), la valeur d'usage des familles (FUV), la fréquence de citation relative (RFC), l'indice de fidélité (FL), le facteur de consensus des informateurs (ICF), l'importance relative (RI) et l'indice de l'importance culturelle (CI).

Résultats: Sur les 83 plantes toxiques inventoriées, *Ruta montana* L. présente la valeur d'usage la plus élevée (UV=2,293), *Anacyclus pyrethrum* L. a la fréquence de citation la plus importante (RFC=0,810), *Carum carvi* L. possède à la fois, l'importance relative (RI) et l'importance culturelle (CI) les plus élevées (RI = 95, CI=0,155). L'indice de fidélité est le plus élevé pour 5 espèces, *Aristolochia paucinervis* Pomel. est la plus utilisée pour le traitement des affections dermatologiques et digestives, *Ruta montana* L. pour les affections respiratoires, orales et neurologiques, *Urtica urens* L. pour celles ostéoarticulaires et urogénitales, *Verbascum sinuatum* L. pour le traitement des maladies ophtalmiques et *Ammi visnaga* (L.) Lam. pour les affections cardiovasculaires. À signaler que les affections ophtalmiques détiennent la valeur la plus élevée du facteur de consensus des informateurs (FIC=0,743). Aussi, une corrélation positive très significative entre RFC et UV (R^2=0,5968) et entre RI et CI (R^2=0,9999) est observée.

Conclusions: Cette étude révèle que les acteurs de la médecine traditionnelle au Moyen Atlas central ont recours à l'utilisation d'un nombre important de plantes toxiques en phytothérapie traditionnelle ; certes, ces plantes ont des vertus thérapeutiques mais leur potentiel toxique impose une grande vigilance.

Mots clés: Plantes médicinales toxiques, Ethnobotanique quantitative, Phytothérapie traditionnelle, Région du Moyen Atlas central.

Background

Morocco, with its distinguished plant richness resulting from the heterogeneity of its habitats, landscapes, climate, and geological events, occupies a remarkable place in the biodiversity of the Mediterranean region (Jamaleddine *et al.* 2017). According to a previous report (Fennane & Ibn Tattou 2012), Moroccan vascular flora comprises 3913 species and 1298 subspecies (including 426 typical subspecies) distributed among 155 families and 981 genera shaped by the empirical knowledge of the Moroccan population over historical time, verbal transmission through generations, and the mixture of Amazigh and Arab-Muslim civilizations where the floral wealth and especially the medicinal potential of plants have been highly valued (Bellakhdar 1997, El Rhaffari & Zaid 2002). This heritage stimulated the curiosity of many Moroccan and Arab researchers, including Ibn Al Baytar (1248), Dâûd al-Antaki (1592), Bellakhdar (1997), and Merzouki (1997) (El Rhaffari & Zaid 2002). Currently, plant medication is becoming increasingly important through scientific studies based on analytical methods and new experiments that test the efficacy of empirical herbal recipes.

Ethnobotany is considered a science that enables to translate traditional wisdom into scientific knowledge based on field work consisting of the understanding of the traditional health system and identifying plant origin substances for therapeutic purposes (Fleurentin 1993). Studies in ethnobotany can be descriptive by focusing on defining a set of plants used by a given community to determine the factors that might explain the use and knowledge of plants or by testing the effectiveness and validity of certain techniques and methods in case of diagnostic ethnobotanical study (De Albuquerque & Hanazaki 2009). Since the 1990s, several data collection techniques have been proposed, and many authors adopted them in their ethnobotanical research; however, the use of these analytical methods can be challenging, and researchers must be aware that "measuring" traditional knowledge involves theoretical and practical dimensions (Houéhanou *et al.* 2016). It is worth mentioning that quantitative studies can be used to test hypotheses and/or knowledge regarding natural resources by referring to the indices that were calculated, which generally incorporate in their calculations other indices that are primary quantitative parameters or basic indices. These comprise the frequency of citation, the relative frequency of citation, the number of uses of the species, and the number of reported uses of the species (Houéhanou *et al.* 2016). Therefore, to complete partial and fragmentary studies conducted throughout Morocco, the objective of the present investigation was to carry out a quantitative study of ethnobotanical data from a survey of medicinal plants recommended by traditional medicine practitioners in the Moroccan central Middle Atlas region.

Materials and methods

The study area

The Middle Atlas is a mountain range that extends over 450 km and covers a total area of 27550 km^2 (El Jihad 2016). It constitutes the water tower of Morocco, with four watersheds of the largest Moroccan rivers:Sebou, Moulouya, Oum Rabia, and Bou Regreg.

Climate

The study area has a Mediterranean-type climate. The altitudinal position, geographical situation, and exposure to oceanic influences cause semi-arid, sub-humid, and humid bioclimates, and their thermal variants range from cool through cold to even very cold (Martin 1981).

Soil

Starting from marl clay formations resting on a continuous slab of lacustrine limestone at the Meknes plain, the Middle Atlas regions evolve into red or brown forest soils formed mainly on limestone or dolomite, regardless of the altitude or exposure, in semi-arid, humid, or sub-humid bioclimates (Mahmoudi & Bertrand 2007).

Ecosystems and study sites

In the central Middle Atlas region, the flora and fauna are very rich; they contain many endemic, rare, and very remarkable species (Benabid 2002). The vegetation is very diverse and the phytocenoses are luxuriant due to precipitation in the form of rain or snow according to the altitude (Benbrahim *et al.* 2004) and have the most important forest potential of Morocco. All types of Moroccan natural ecosystems are represented except those of the arid and Saharan zones (Benabid 2002). This forest potential is a strategic issue for the region as it constitutes a protective and productive heritage, a genetic reservoir of biodiversity, and is therefore an important socio-economic space in addition to being recreational and cultural (Boujrouf 2004).

We conducted our fieldwork in El Hajeb in Elhajeb province, Azrou, Ifrane, and Timahdite in Ifrane province, and Khenifra and M'rirt in Khenifra province (Fig. 1).

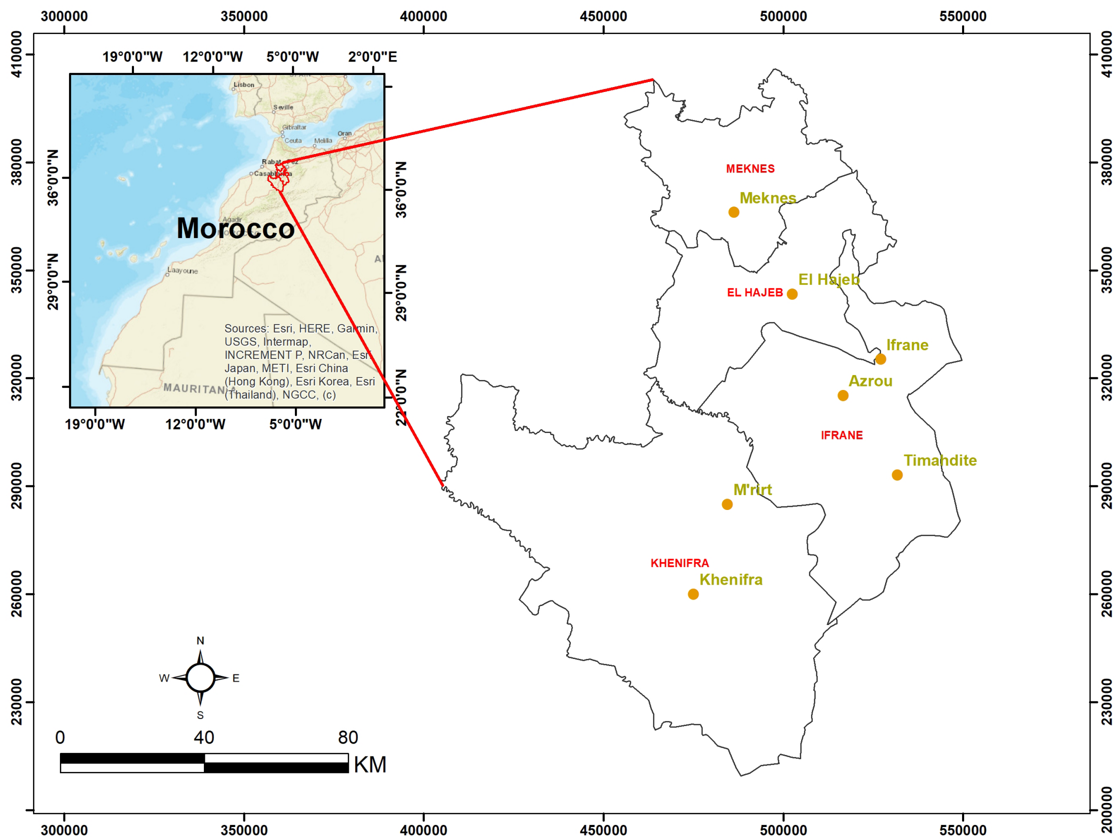

Fig.1. Study area (Red indicates provinces and green indicates cities or villages).

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The characteristics of the informants
To determine the sample size (N), we compiled a list of traditional medicine practitioners in the study area, which enabled us to determine the parent population (P) consisting of 290 different categories:60 traditional healers, 105 herbalists, and 125 pharmacists. To obtain a representative sample, the ratio between the desired sample and the parent population (N/P) must be between 15% and 20% (Nacoulma *et al.* 2006). In our case (N/P = 20%), N was equal to 58, including 12 traditional healers, 21 herbalists, and 25 druggists who were all from the study area and represent the 58 practitioners of traditional medicine chosen based on their reputations in the field. In their opinion, herbal medicine is a heritage based on ancestral knowledge transferred from one generation to the next and the plants represent an integral part of their daily lives. Most of the respondents were men aged 18 to 70 years.

Data collection and interview methods
We used the free listing technique commonly used in social and behavioral sciences, ethnozoology, and ethnobotany (Miranda *et al.* 2007). The 58 respondents were asked to list the medicinal plants they knew, and the interviews were conducted over a seven-month period. The interviews were conducted in Arabic. The surveys were rarely completed in a single outing because the informants would not provide all the information in one session. We sometimes had to return several times to the informant and show patience and availability to collect the information that was directly relevant to our ethnobotanical survey.

The choice of criteria
***Inclusion criteria*:** Only plants that are spontaneous or cultivated in the study area and are used by the respondents were selected.
***Exclusion criteria*:** Any plants not used by the respondents or that do not grow in the study area were excluded.
Systematic determination
Each listed poisonous medicinal plant was sampled and numbered for taxonomic determination in the laboratory according to Morocco's practical flora (Fennane *et al.*1999, Fennane *et al.* 2007, Fennane *et al.* 2014)

Data analysis
Statistical analysis
The recorded data were tabulated using spreadsheets (Excel) and analyzed statistically using SPSS Statistics 20 software. We calculated the standard descriptive statistics and correlation analyses based on simple linear regression.

Quantitative analyses of the ethnobotanical data
The collected data were used to calculate various quantitative indices, including the use value (UV), family use values (FUV), relative frequency of citation (RFC), fidelity level (FL), informant consensus factor (ICF), relative importance (RI), and cultural importance index (CI) (Pardo-de-Santayana *et al*. 2007, Cadena-González *et al*. 2013, Nawash *et al*. 2013, Vitalini *et al*. 2013, Yassen *et al*. 2015).

Use value (UV)
The use value (UV) was used to demonstrate the relative importance of plants known locally. It was calculated using the following formula (Vitalini *et al.* 2013):

$$UV = \sum_{i=1}^{i=N} Ui/N$$

where Ui= the number of uses mentioned by an informant i and N= the total number of informants interviewed.

Family use values (FUV)
The family use values (FUV) were used to identify the significance of plant families. It was calculated using the following formula (Cadena-González *et al.* 2013):

$$FUV = UV_s/N_s$$

where UV_s = the use value of species belonging to the same family and N_s = the total number of species present in a given family.

Relative frequency of citation (RFC)
The relative frequency of citation (RFC) was used to demonstrate the local importance of each species. It was calculated using the following formula (Vitalini *et al.* 2013):

$$RFC = FC/N$$

where FC = the number of informants mentioning the use of the species and N = the total number of informants interviewed.

Fidelity level (FL)
The fidelity level (FL) was used to determine the most ideal species used to treat a specific ailment (Musa et al. 2011). It was calculated using the following formula (Nawash *et al.* 2013):

$$FL (\%) = (N_p/N) \times 100$$

where N_p = the number of the informants who reported using a given species to treat an illness and N = the total number of informants interviewed.

Informant consensus factor (ICF)

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The informant consensus factor was used to measure the agreement between informants about the use of plants for specific use categories. It was calculated using the following formula (Heinrich *et al.* 1998):

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

where N_{ur} = the number of use reports for a particular ailment category and N_t = the number of plants mentioned for the treatment of this particular ailment category.

The ICF ranged from zero to one. A value close to one indicates a high intracultural consensus (most of the informants used the same species to treat the same illnesses) and a value close to zero indicates a high variation in the use of species (the informants disagreed over which species was used for treatment within a category of illness) (Heinrich M., Ankli A. *et al*. 1998).

Relative importance (RI)

The relative importance (RI) was used to measure the versatile use and true value of plants (Bennett & Prance 2000). It was calculated using the following formula (Yaseen *et al.* 2015):

$$\mathbf{RI = (PP + AC) * 100/2}$$

where PP represents the pharmacological properties, which indicate the relative use reports that were calculated by dividing the number of use reports (UR) attributed to a species by the maximum number of use reports attributed to the most important species (the species with the highest number of use reports), and AC represents the ailments treated, which indicates the relative body systems treated. AC was calculated by dividing the number of body systems treated by a given species by the maximum number of ailment categories treated by the species that were used most widely.

Cultural importance index (CI)

The cultural importance index (CI) was used to assess the importance of each species (Singh *et al.* 2019). It was calculated using the following formula (Pardo-de-Santayana *et al.* 2007)

$$\mathbf{CI} = \sum_{i=1}^{i=NU} \mathbf{URi/N}$$

Where URi= the number of use reports of species for different use categories (i, varying from only one use to the total number of uses) and N = the total number of informants interviewed.

Results and discussion

The results demonstrate that among the 125 medicinal plants listed, 83 were reported to be poisonous and were distributed over 36 families and 74 genera.

Use value (UV)

The UV of the toxic plants recommended in the study area ranged from 2.293 to 0.017 (Table 1). The toxic species showing a strong potential for ethnobotanical use are *Ruta montana* L. (2.293), *Urtica urens* (1.914), *Ammi visnaga* (L.) Lam (1.328), *Aristolochia paucinervis* Pomel (1.241), *Verbascum sinuatum* L. (1.207), *Marrubium vulgare* L. (1.155), *Anacyclus pyrethrum* L. (0.759), *Chenopodium ambrosioides* L. (0.879), *Laurus nobilis* L. (0.621), *Corrigiola telephiifolia* Pour. (0.603), and *Solanum sodomaeum* L. (0.569).

The high UV reflects the importance attributed to a species by the respondents as a result of its therapeutic virtues and not necessarily its availability in the study area; however, it may also express the harvesting pressure that could be exerted on the species (Dossou *et al.* 2012). It also does not specify whether a plant has multiple or unique uses (Zougagh *et al.* 2019). The intensive use of certain species presents a real health risk because they are highly recommended by the traditional medicine practitioners in the central Middle Atlas region despite their toxicity (Najem *et al.* 2018a). Among these, *Aristolochia paucinervis* (Pomel.) was mentioned, which is very toxic, related to the presence of aristolochic acid with carcinogenic and nephrotoxic potency. It alters the liver and kidney enzymes (Bnouham *et al.* 2006, Rankou *et al.* 2015). In 2005, the Oncology Department of the University Hospital of Casablanca in Morocco reported two deaths and 5 cases of aplastic anemia due to the use of *Aristolochia paucinervis* Pomel. In 2010, according to statistics from the Moroccan Poison Center, 16% of kidney failure cases were recorded in patients with malignant tumors who used the plant during traditional cancer treatment (Benzakour *et al.* 2011). Similarly, the furanocoumarins of *Ruta montana* L. are toxic to the kidney and liver, and even carcinogenic, because they alter the nucleic acids and can thus cause lesions of the genome (Seak & Lin 2007). These furanocoumarins are phototoxic induced by contact with the leaves, followed by exposure to the sun, causing acute dermatitis that resembles a first- or second-degree burn; secondarily, the skin will undergo hyperpigmentation that can persist (Masri *et al.* 2015). *R. montana* is not used in Europe but is still solicited by traditional healers, especially in the Mediterranean and South America (Masri *et al.* 2015)

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Table 1. List of toxic plants used in the traditional pharmacopoeia of the central Middle Atlas

Family / scientific names	Local names	Herbarium specimen number	Ui	UV	Fc	RFc	UR	CI	PP	AC	RI
Acanthaceae											
Acanthus mollis L.	Sebana	2682/IS/N°38	13	0.224	9	0.155	2	0.034	0.22	0.2	21.11
Amaranthaceae											
Chenopodium ambrosioides L.	Mkhinza	247/IS/N°36	51	0.879	24	0.414	2	0.034	0.22	0.2	21.11
Anacardiaceae											
Pistacia atlantica Dsf.	Lebtem	1810/IS/N°38	30	0.517	22	0.379	3	0.052	0.33	0.3	31.67
Pistacia lentiscus L.	Drou	1809/IS/N°38	23	0.397	14	0.241	1	0.017	0.11	0.1	10.56
Apiaceae											
Ammi majus L.	Aatrilal	2025/IS/N°38	12	0.207	11	0.190	1	0.017	0.11	0.1	10.56
Ammi visnaga (L.) Lam	Bachnikha/ khala	2024/IS/N°38	77	1.328	21	0.362	3	0.052	0.33	0.3	31.67
Anethum graveolens L.	Chibt	2041/IS/N°38	1	0.017	1	0.017	2	0.034	0.22	0.2	21.11
Angelica archangelica L.	hachichat malaeka	23/PTM	5	0.086	5	0.086	6	0.103	0.67	0.6	63.33
Carum carvi L.	Kerwiya	30/PTM	22	0.379	17	0.293	9	0.155	1.00	0.9	95.00
Coriandrum sativum L.	Kesbour	1955/IS/N°38	7	0.121	3	0.052	1	0.017	0.11	0.1	10.56
Ferula communis L.	Boubal, Ikellikha	2044/IS/N°38	15	0.259	9	0.155	3	0.052	0.33	0.3	31.67
Foeniculum vulgare P. Mill.	Besbas	1991/IS/N°38	18	0.310	5	0.086	3	0.052	0.33	0.3	31.67
Pimpinella anisum L.	Habat hlawa	46/PTM	27	0.466	9	0.155	4	0.069	0.44	0.4	42.22
Apocynaceae											
Nerium Oleander L.	Defla	2079/IS/N°38	17	0.293	14	0.241	3	0.052	0.33	0.3	31.67
Aristolochiaceae											
Aristolochia paucinervis Pomel	Bereztam	81/IS/N°36	72	1.241	32	0.552	3	0.052	0.33	0.3	31.67
Asteraceae											
Achillea millefolium L.	Kala	61/PTM	9	0.155	6	0.103	2	0.034	0.22	0.2	21.11
Atractylis cancellata L.	Nejma	2870/IS/N°40	4	0.069	4	0.069	3	0.052	0.33	0.3	31.67

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Anacyclus pyrethrum L.	Akirkarha Igenthes	3145/IS/N°40	44	0.759	47	0.810	3	0.052	0.33	0.3	31.67
Anthemis nobilis L.	Babounj roumi	3139/IS/N°40	15	0.259	6	0.103	1	0.017	0.11	0.1	10.56
Artemisia arborescens L.	Chiba	3213/IS/N°40	6	0.103	3	0.052	1	0.017	0.11	0.1	10.56
Artemisia herba-alba Asso.	Chih abiad	3207/IS/N°40	13	0.224	5	0.086	3	0.052	0.33	0.3	31.67
Atractylis gummifera L.	Dad	2828/IS/N°40	19	0.328	13	0.224	2	0.034	0.22	0.2	21.11
Chrysanthemum parthenium Bern.	Uqhuwan	3197/IS/N°40	7	0.121	5	0.086	4	0.069	0.44	0.4	42.22
Echhinops spinosus L.	Chouk lahmar	2824/IS/N°40	21	0.362	13	0.224	3	0.052	0.33	0.3	31.67
Launaea arborescens (Batt.) Maire	Intrim	3323/IS/N°40	6	0.103	4	0.069	3	0.052	0.33	0.3	31.67
Santolina rosmarinifolia L.	Ouzouaza	3125/IS/N°40	7	0.121	6	0.103	2	0.034	0.22	0.2	21.11
Senecio sp.	Achbat salma	770/IS/N°40	7	0.121	6	0.103	1	0.017	0.11	0.1	10.56
Berberidaceae											
Berberis vulgaris L.	Adoudrih, ârgîs	48/IS/N°36	12	0.207	5	0.086	2	0.034	0.22	0.2	21.11
Boraginaceae											
Borrago officinalis L.	Bouchanaf	2187/IS/N°38	12	0.207	10	0.172	2	0.034	0.22	0.2	21.11
Heliotropium europaeum L.	Khaniza ratba	2170/IS/N°38	7	0.121	5	0.086	1	0.017	0.11	0.1	10.56
Brassicaceae											
Brassica napus L.	Left fajli	824/IS/N°36	8	0.138	4	0.069	2	0.034	0.22	0.2	21.11
Brassica nigra (L.) W.D.J.koch	Khardal aswad	817/IS/N°36	11	0.190	7	0.121	1	0.017	0.11	0.1	10.56
Diplotaxis sp.	Charyat	202/IS/N°36	3	0.052	3	0.052	3	0.052	0.33	0.3	31.67
Lepidium sativum L.	Hab erchad	905/IS/N°36	12	0.207	6	0.103	2	0.034	0.22	0.2	21.11
Buxaceae											
Buxus sempervirens L.	Bakss	1711/IS/N°38	3	0.052	3	0.052	3	0.052	0.33	0.3	31.67

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Caprifoliaceae											
Sambucus nigra L.	Sembouqa	2746/IS/N°40	7	0.121	4	0.069	3	0.052	0.33	0.3	31.67
Caryophyllaceae											
Corrigiola telephiifolia Pour.	serghina	348/IS/N°36	35	0.603	30	0.517	4	0.069	0.44	0.4	42.22
Saponaria vaccaria L.	Hamrat erras	559/IS/N°38	6	0.103	4	0.069	2	0.034	0.22	0.2	21.11
Cistaceae											
Cistus ladaniferus L.	Touzal	704/IS/N°36	9	0.155	9	0.155	1	0.017	0.11	0.1	10.56
Cyperaceae											
Cyperus longus L.	Arouk esaad	3702/IS/N°40	10	0.172	8	0.138	3	0.052	0.33	0.3	31.67
Ericaceae											
Arbutus unedo L.	Bakhanou Sasnou	1062/IS/N°36	5	0.086	2	0.034	1	0.017	0.11	0.1	10.56
Euphorbiaceae											
Euphorbia helioscopia L.	Halib assou	1744/IS/N°38	9	0.155	7	0.121	1	0.017	0.11	0.1	10.56
Euphorbia resinifera Berg.	Louban maghribi	1727/IS/N°38	8	0.138	4	0.069	3	0.052	0.33	0.3	31.67
Fabaceae											
Astragalus gummifera Labill.	Ktira	229/PTM	7	0.121	4	0.069	2	0.034	0.22	0.2	21.11
Astragalus lusitanicus Lam.	Fouila	1315/IS/N°38	9	0.155	9	0.155	3	0.052	0.33	0.3	31.67
Trigonella foenum graecum L.	Halba	1553/IS/N°38	18	0.310	7	0.121	3	0.052	0.33	0.3	31.67
Lamiaceae											
Ajuga iva (L.) Schreb.	Chandgoura	2250/IS/N°38	16	0.276	11	0.190	4	0.069	0.44	0.4	42.22
Calamintha officinalis Moench.	Manta	301/PTM	11	0.190	7	0.121	4	0.069	0.44	0.4	42.22
Hyssopus officinalis L.	Azoufa yabsa	2449/IS/N°38	13	0.224	6	0.103	5	0.086	0.56	0.5	52.78
Lavandula pedunculata (Miller) Cav. subsp. atlantica (Br.-Bl.) Romo	Khzama	2317/IS/N°38	18	0.310	11	0.190	2	0.034	0.22	0.2	21.11
Marrubium vulgare L.	Mariouta	2313/IS/N°38	67	1.155	21	0.362	3	0.052	0.33	0.3	31.67
Mentha pulegium L.	Fliyou	2453/IS/N°38	11	0.190	7	0.121	4	0.069	0.44	0.4	42.22
Ocimum basilicum L.	Lahbak	291/PTM	14	0.241	11	0.190	3	0.052	0.33	0.3	31.67

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Origanum majorana L.	Mardadouch	2427/IS/N°38	11	0.190	11	0.190	4	0.069	0.44	0.4	42.22
Origanum vulgare L.	Mrou	2429/IS/N°38	8	0.138	4	0.069	2	0.034	0.22	0.2	21.11
Rosmarinus officinalis L.	Azir	2305/IS/N°38	12	0.207	3	0.052	2	0.034	0.22	0.2	21.11
Salvia officinalis L.	Salmiya	573/IS/N°38	8	0.138	4	0.069	2	0.034	0.22	0.2	21.11
Salvia verbenaca L.	khiyata	2392/IS/N°38	15	0.259	10	0.172	1	0.017	0.11	0.1	10.56
Teucrium polium L.	Jaâda, Ayrar	2297/IS/N°38	20	0.345	9	0.155	3	0.052	0.33	0.3	31.67
Lauraceae											
Laurus nobilis L.	Wrak moussa	78/IS/N°36	36	0.621	14	0.241	2	0.034	0.22	0.2	21.11
Liliaceae											
Asphodelus microcarpus Parl.	Barouak	3534/IS/N°40	20	0.345	11	0.190	6	0.103	0.67	0.6	63.33
Urginea maritima (L.) Baker	Bassila	3502/IS/N°40	16	0.276	13	0.224	5	0.086	0.56	0.5	52.78
Pinaceae											
Cedrus atlantica (Manetti.) Carr.	Arz Idil	25/IS/N°40	4	0.069	4	0.069	7	0.121	0.78	0.7	73.89
Poaceae											
Agropyrum repens (L.) PB.	Njem	4038/IS/N°40	3	0.052	3	0.052	6	0.103	0.67	0.6	63.33
Arundo donax L.	Ksab	3795/IS/N°40	3	0.052	2	0.034	3	0.052	0.33	0.3	31.67
Portulacaceae											
Portulaca oleracea L.	Rajla	340/IS/N°36	14	0.241	6	0.103	3	0.052	0.33	0.3	31.67
Ranunculaceae											
Delphinium staphysargria L.	Habat rass	93/IS/N°36	6	0.103	4	0.069	5	0.086	0.56	0.5	52.78
Paeonia coralline Retz spp coriacea (Boiss.) Coss.	Habersis	647/IS/N°36	6	0.103	4	0.069	1	0.017	0.11	0.1	10.56
Rhamnaceae											
Ziziphus lotus (L.) Lam.	Nbag	1776/IS/N°38	13	0.224	5	0.086	8	0.138	0.89	0.8	84.44
Rosaceae											
Agrimonia eupatoria L.	Kaba	1178/IS/N°36	4	0.069	4	0.069	3	0.052	0.33	0.3	31.67
Crataegus monogyna Jacq.	Admam	1150/IS/N°36	19	0.328	9	0.155	4	0.069	0.44	0.4	42.22
Rubiaceae											
Rubia peregrina L.	Fouwa	2695/IS/N°40	16	0.276	16	0.276	3	0.052	0.33	0.3	31.67

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Rutaceae											
Ruta montana L.	Figel Iwrni	1815/IS/N°38	133	2.293	25	0.431	2	0.034	0.22	0.2	21.11
Scrophulariaceae											
Digitalis mauritanica (Emberger & Maire) Ivaina L.	Adabi	2605/IS/N°38	8	0.138	8	0.138	2	0.034	0.22	0.2	21.11
Verbascum sinuatum L.	Maslah ndar	2504/IS/N°38	70	1.207	29	0.500	2	0.034	0.22	0.2	21.11
Solanaceae											
Atropa belladonna L.	Zbib lidûr	2124/IS/N°38	13	0.224	12	0.207	2	0.034	0.22	0.2	21.11
Hyoscyamus sp	Sikran	509/IS/N°38	17	0.293	9	0.155	2	0.034	0.22	0.2	21.11
Solanum sodomaeum L.	Hadja	2107/IS/N°38	33	0.569	20	0.345	3	0.052	0.33	0.3	31.67
Taxaceae											
Taxus baccata L.	Dahs, îgen	72/IS/N°36	10	0.172	7	0.121	4	0.069	0.44	0.4	42.22
Thymelaeaceae											
Daphne gnidium L.	Alezzâz	1667/IS/N°38	7	0.121	7	0.121	6	0.103	0.67	0.6	63.33
Daphne laureola L.	Walidrar	1668/IS/N°38	7	0.121	8	0.138	4	0.069	0.44	0.4	42.22
Urticaceae											
Urtica urens	Hariga	209/IS/N°36	111	1.914	31	0.534	3	0.052	0.33	0.3	31.67
Zygophyllaceae											
Peganum harmala L.	Lharmel	422/IS/N°38	11	0.190	4	0.069	1	0.017	0.11	0.1	10.56

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Solanum sodomaeum L. is known for its toxic potency due to its glycoalkaloid content, whose main aglycone is solasodine (Cham & Meares 1987). Ingestion of one to two fruits induces gastrointestinal disorders accompanied by vertigo, confusion, and even hallucinations (Hammiche *et al.* 2013). Poisoning also causes mydriasis, dryness of the mucous membranes, headache, delirium, and coma (Bellakhdar 1997).

The lowest use value is attributed to the species *Anethum graveolens* L. This is likely because this plant or its therapeutic virtues were less known by the respondents.

Therefore, the recommendation of these plants based essentially on oral transmission represents a real health risk. Although practitioners of traditional medicine have over time discovered the virtues of these plants, they cannot control their phytochemical and pharmacotoxicological properties (Najem *et al*. 2018b).

Family use values (FUV)

The families with the highest UV are Rutaceae (2.293), followed by Urticaceae (1.914), Aristolochiaceae (1.241), and Amaranthaceae (0.879) (Table 2). These families are reported only by one species for each and have different use reports:133 for Rutaceae, 111 for Urticaceae, 72 for Aristolochiaceae, and 51 for Amaranthaceae. The families with low FUV are Buxaceae and Poaceae (0.052).

Although some families are the most represented in terms of poisonous medicinal plants in the study area (Najem *et al.* 2019a), they do not have high FUV, such as Lamiaceae with 13 species, 224 use reports, and FUV = 0.297; Asteraceae with 12 species, 158 use reports, and FUV = 0.227; and Apiaceae with 9 species, 184 use reports, and FUV = 0.352. Thus, we can deduce that the ethnobotanical value of the use of families does not depend on their number of taxa, but rather on the importance and use value of those taxa.

Relative frequency of citation (RFC)

The RFC value ranges from 0 to 1; when it nears 0, it demonstrates that none of the respondents referred to this plant as useful and when it nears 1, it indicates that this plant was considered useful by almost all respondents (Tardio & Pardo-de Santayana 2008). Thus, our results show that the RFC of medicinal plants used by the respondents in traditional recipes ranges between 0.81 and 0.017. Poisonous medicinal plants with high RFC are *Anacyclus pyrethrum* L. (0.810), *Aristolochia paucinervis* Pomel (0.552), *Urtica urens* L. (0.534), *Corrigiola telephiifolia* Pour. (0.517), and *Verbascum sinuatum* L. (0.50) (Table 1). These plants were well known by the practitioners of traditional medicine, because, in addition to their therapeutic virtues, they are widespread in the study area.

Table 2. Family use values of poisonous medicinal plants solicited in traditional herbal medicine in the central Middle Atlas region

Familles	Uvs	Ns	FUV
Acanthaceae	0.224	1	0.224
Amaranthaceae	0.879	1	0.879
Anacardiaceae	0.914	2	0.457
Apiaceae	3.172	9	0.352
Apocynaceae	0.293	1	0.293
Aristolochiaceae	1.241	1	1.241
Asteraceae	2.724	12	0.227
Berberidaceae	0.207	1	0.207
Boraginaceae	0.328	2	0.164
Brassicaceae	0.586	4	0.147
Buxaceae	0.052	1	0.052
Caprifoliaceae	0.121	1	0.121
Caryophyllaceae	0.707	2	0.353
Cistaceae	0.155	1	0.155
Cyperaceae	0.172	1	0.172
Ericaceae	0.086	1	0.086
Euphorbiaceae	0.293	2	0.147
Fabaceae	0.586	3	0.195
Lamiaceae	3.862	13	0.297
Lauraceae	0.621	1	0.621
Liliaceae	0.621	2	0.310
Pinaceae	0.069	1	0.069
Poaceae	0.103	2	0.052
Portulacaceae	0.241	1	0.241
Ranunculaceae	0.207	2	0.103
Rhamnaceae	0.224	1	0.224
Rosaceae	0.397	2	0.198
Rubiaceae	0.276	1	0.276
Rutaceae	2.293	1	2.293
Scrophulariacea	1.345	2	0.672
Solanaceae	1.086	3	0.362
Taxaceae	0.172	1	0.172
Thymeleaceae	0.241	2	0.121
Urticaceae	1.914	1	1.914
Zygophyllaceae	0.190	1	0.190

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Moreover, *Anacyclus pyrethrum* L. is an endemic toxic medicinal plant popular in Morocco distributed precisely in the study area (Najem *et al.* 2019a).
For the use value, the lowest RFC is recorded by *Anethum graveolens* L. (0.017), which is likely because this plant was little known by the informants or they did not consider it useful for certain diseases.

Relative importance (RI)
Regarding the relative importance index, the most important versatile use is attributed to the plant *Carum carvi* L. (RI = 95) (Table 1), since it has the most pharmacological properties exploited in the most use categories.

Cultural importance index (CI)
The quantitative study showed that the CI value varies between 0.155 and 0.017 (Table 1). The poisonous medicinal plants used in the study area with the highest CI values are *Carum carvi* L. (0.155), *Ziziphus lotus* (L.) Lam. (0.138), *Cedrus atlantica* (Manetti.) Carr. (0.121), *Angelica archangelica* L. (0.103), *Asphodelus macrocarpus* Parl. (0.103), *Agropyrum repens* (L.) PB. (0.103), and *Daphne gnidium* L. (0.103). The plants with the lowest CI values are *Pistacia lentiscus* L., *Ammi majus* L., *Coriandrum sativum* L., *Anthemis nobilis* L., *Artemisia arborescens* L., *Senecio* sp., *Heliotropium europaeum* L., *Brassica nigra* (L.) W.D.J. Koch, *Cistus ladaniferus* L., *Arbutus unedo* L., *Euphorbia helioscopia* L., *Salvia verbenaca* L., *Paeonia coralline* Retz spp. *coriacea* (Boiss.) Coss., and *Peganum harmala* L.

Fidelity level (FL)
The calculation of the fidelity index enables to determine the most used toxic species applied to treat a given disease. A high FL indicates a high usage of the plant species for a particular ailment, whereas a low FL demonstrates a wide range of medicinal uses but with a low frequency for each ailment (Yaseen *et al.* 2015).
The species with the highest fidelity for the treatment of a wide range of diseases is *Ruta montana* L., which has the highest FL for the treatment of respiratory (FL = 43.10%), oral (FL = 43.10%), and neurological diseases (FL = 18.97%) (Table 3).

Table 3. Fidelity level of toxic medicinal plants solicited in traditional herbal medicine in the central Middle Atlas

Illness category	Fidelity level of species (%)
Dermatological disorders	*Aristolochia paucinervis* Pomel. (55.17), *Ruta montana* L. (43.10), *Urtica urens* L. (39.66), *Solanum sodomaeum* L. (34.48), *Marrubium vulgare* L. (29.31), *Verbascum sinuatum* L. (24.14), *Nerium oleander* L. (17.24), *Salvia verbenaca* L. (17.24).
Respiratory disorders	*Ruta montana* L. (43.10), *Marrubium vulgare* L. (36.21), *Urtica urens* L. (36.21), *Chenopodium ambrosioides* L. (29.31), *Corrigiola telephiifolia* Pour. (25.86), *Verbascum sinuatum* L. (17.24), *Ammi visnaga* (L.) Lam. (15.52), *Digitalis mauretanica* (Emberger& Maire) Ivaina L. (15.52), *Nerium oleander* L. (12.07), *Anacyclus pyrethrum* DC. (15.52), Teucrium polium L. (15.52).
Cardiovascular diseases	*Ammi visnaga* (L.) Lam. (20.69), *Digitalis mauretanica* (Emberger & Maire) Ivaina L. (13.79), *Echinops spinosus* L. (12.07), *Pistacia lentiscus* L. (10.34).
Urogenital disorders	*Urtica urens* L. (39.66), *Ruta montana* L. (36.21), *Ammi visnaga* (L.) Lam. (25.86), *Aristolochia paucinervis* Pomel. (22.41), *Solanum sodomaeum* L. (22.41), *Acanthus mollis* L. (12.07).
Osteoarticular disorders	*Urtica urens* L. (43.10), *Chenopodium ambrosioides* L. (41.38), *Verbascum sinuatum* L. (29.31), *Laurus nobilis* L. (22.41), *Urginea maritima* (L.) Baker. (22.41), *Anacyclus pyrethrum* DC. (15.52), *Astragalus lusitanicus* Lam. (15.52), *Ferula communis* L. (13.79), *Ruta montana* L. (13.79), *Taxus baccata* L. (12.07).
Digestive tract disorders	*Aristolochia paucinervis* Pomel. (29.31), *Carum carvi* L. (29.31), *Rubia tinctorum* L. (27.59), *Marrubium vulgare* L. (27.59), *Pistacia lentiscus* L. (24.14), *Ruta montana* L. (22.41), *Ammi visnaga* (L.) Lam. (20.69), *Laurus nobilis* L. (20.69), *Corrigiola telephiifolia* Pour. (18.97), *Origanum majorana* L. (18.97), *Ocimum basilicum* L. (17.24), *Chenopodium ambrosioides* L. (17.24), *Teucrium polium* L. (15.52), *Pimpinella anisum* L. (15.52), *Cistus ladaniferus* L. (15.52).
Neurological disorders	*Ruta montana* L. (18.97), *Cyperus longus* L. (8.62), *Pistacia atlantica* Dsf. (3.45).
Ophthalmic disorders	*Verbascum sinuatum* L. (50.00), *Ocimum basilicum* L. (6.90), *Berberis vulgaris* L. (5.17), *Ferula communis* L. (3.45), *Foeniculum vulgare* P. Mill. (3.45).
Oral disorders	*Ruta montana* L. (43.10), *Ammi visnaga* (L.) Lam. (36.21), *Laurus nobilis* L. (20.69), *Marrubium vulgare* L. (20.69), (18.97), *Pistacia atlantica* Dsf. (15.52), *Echinops spinosus* L. (15.52), *Anacyclus pyrethrum* DC. (12.07), *Atractylis gummifera* L. (12.07).

In the Mediterranean region, *Ruta montana* L. is a panacea and its uses are similar (Boulos 1983, Pollio *et al.* 2008). *Aristolochia paucinervis* Pomel. also has high fidelity for the treatment of dermatological diseases (FL = 55.17%) and digestive diseases (FL = 29.31%). Other ethnobotanical studies have shown that *Aristolochia paucinervis* Pomel. is used to treat aortic palpitations, constipation and intestinal disorders, colic, and gaseous gangrene; it is also used to treat skin diseases and infections such as ringworm, dermatitis, impetigo, and fungal infections. Many traditional healers prescribe the ingestion of a mixture of small amounts of root powder with honey or salted butter to treat abdominal pain, particularly epigastric distress (Bellakhdar *et al.* 1991, Bellakhdar 1997, Sijelmassi 2011, Ouarghidi *et al.* 2013). The study informants indicated that *Urtica urens* L. is used most often to treat osteoarticular (FL = 43.10%) and urogenital (FL = 39.66%) diseases, in line with earlier reports (Nassiri *et al.* 2016).

However, other plants show a restricted fidelity for the treatment of a single disease category; this is the case for *Ammi visnaga* (L.) Lam. (FL = 20.69%) and *Verbascum sinuatum* L. (FL = 50.00%), which are used for treating cardiovascular and ophthalmic diseases, respectively.

According to the respondents, parts of the plants used in medication (column 4 in Table 1) can cause poisoning (Najem *et al.* 2019a, Najem et al. 2019b). This could be due to excessive use (duration and dose) or preparation and administration errors (Najem *et al.* 2018a).

Informant consensus factor (ICF)

Table 4 shows that the ICF varies between 0.035 and 0.743. Ophthalmic disorders have the highest ICF (0.743), with 36 use reports for 10 species, followed by neurological disorders (0.733) and cardiovascular diseases (0.613). Plants with a high ICF value are thought to be effective for treating particular diseases and should be investigated for the discovery of new active molecules. Also, the high ICF value reflects an agreement among the respondents on the recommendation of certain toxic plants to treat a given disease.

The lowest agreement between the informants (ICF = 0.035) is observed for the poisonous medicinal plants used to treat digestive tract diseases. This can be explained by a lack of communication between the traditional medicine practitioners, the wealth of the active plants available to treat these kinds of diseases (56 species used), or the similarities in these plants' active compounds, resulting in similar effects.

Table 4. Informant consensus factor of poisonous medicinal plants solicited in traditional herbal medicine in the central Middle Atlas region

Illness category	**N_t**	**N_{ur}**	**FCI**
Dermatological disorders	38	58	0.351
Respiratory disorders	25	55	0.556
Cardiovascular diseases	13	32	0.613
Urogenital disorders	36	55	0.352
Osteoarticular disorders	30	56	0.473
Digestive tract disorders	56	58	0.035
Neurological disorders	5	16	0.733
Ophthalmic disorders	10	36	0.743
Oral disorders	21	51	0.600

Correlation analysis

The UV and the RFC appear to be significantly correlated with a high determination coefficient (R^2 = 0.6; Fig. 2). There is no correlation between the RFC and RI (R^2 = 0.00189) or between the RFC and CI (R^2 = 0.00204). Similarly, there is no correlation between the UV and the RI (R^2 = 0.000997) and between the UV and the CI (R^2 = 0.000928) (Fig. 3). In contrast, a highly significant correlation is observed between the RI and the CI (R^2 = 0.9999), which implies that any species studied has cultural importance and significant versatile use.

Conclusions

The ethnobotanical results of this study affirm the conservation of traditional herbal heritage by the practitioners of traditional medicine in the central Middle Atlas region; unfortunately, many of the plants that were used as phyto-remedies to treat various diseases were reported toxic and their frequent use was confirmed by the calculation of quantitative indices such as the UV, RFC, FUV, FL, IR, CI, and ICF.

The recourse of these practitioners to poisonous medicinal plants for the preparation of their recipes reveals a dangerous health risk, especially with irrational use. The present results can be used to complete the Moroccan medicinal flora database. A draft of more thorough studies, especially chemical and pharmacotoxicological research, will be submitted to more precisely understand the use of such poisonous plants by traditional medicine practitioners for traditional herbal medication.

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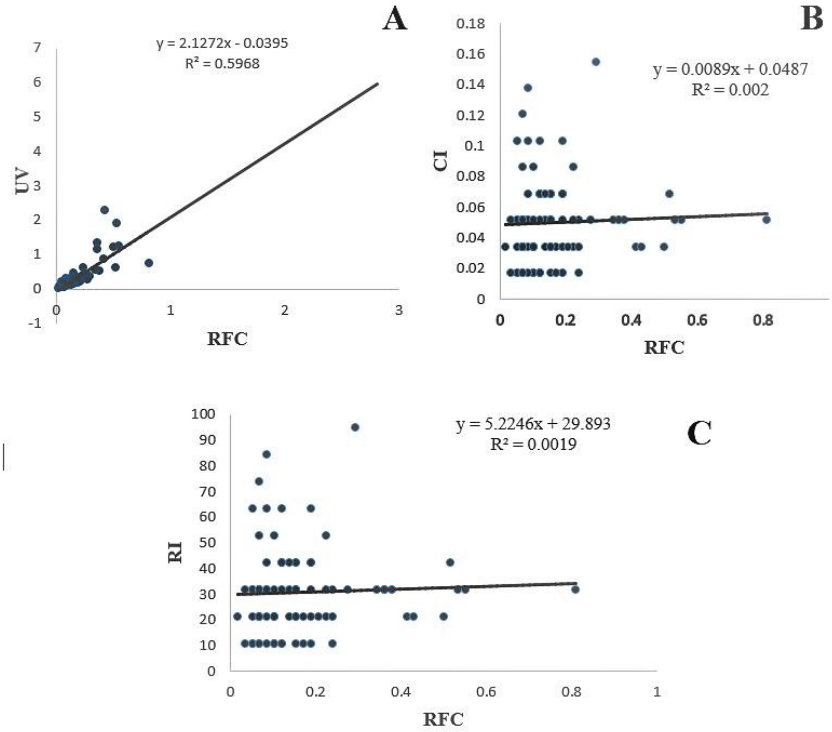

Fig. 2. Correlation between the relative frequency of citation (RFC) and the different quantitative indices:(A) use value (UV), (B) cultural importance index (CI), and (C) relative importance (RI).

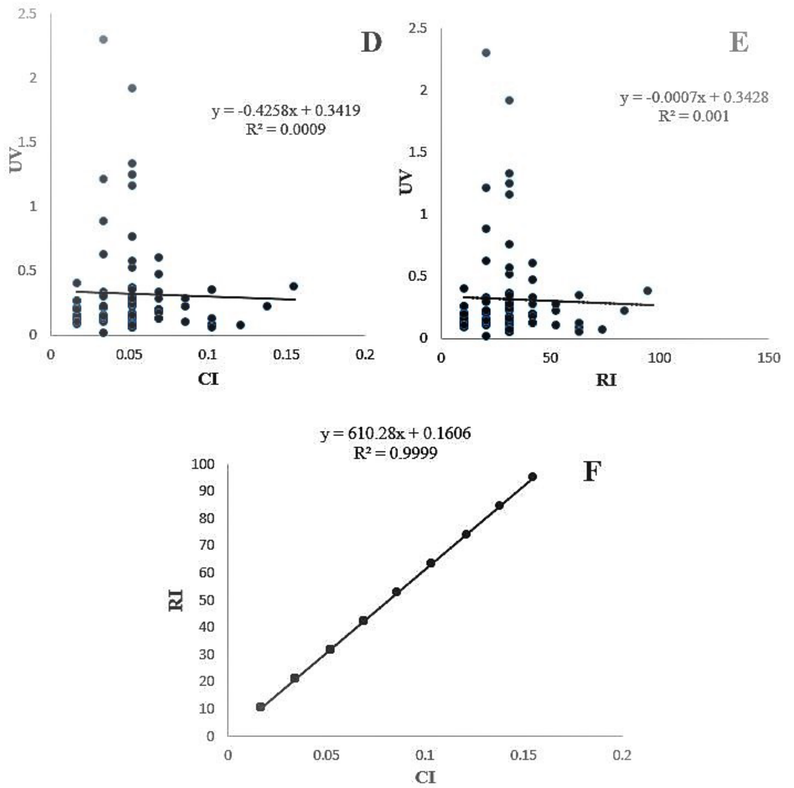

Fig. 3. Correlation among the different quantitative indices:(D) between the use value and the cultural importance, (E) between the use value and the relative importance, and (F) between the relative importance and the cultural importance.

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Declarations

List of abbreviations:
Cultural Importance Index:CI
Family Use Values:FUV
Fidelity Level:FL
Informant Consensus Factor:ICF
Relative Frequency of Citation:RFC
Relative Importance:RI
Use Value:UV

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

Consent for publication*:* Not applicable.

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Authors' contributions:
MN wrote the manuscript, conducted the ethnobotany survey, and calculated the; LN and JI contribvuted to the manuscript.

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