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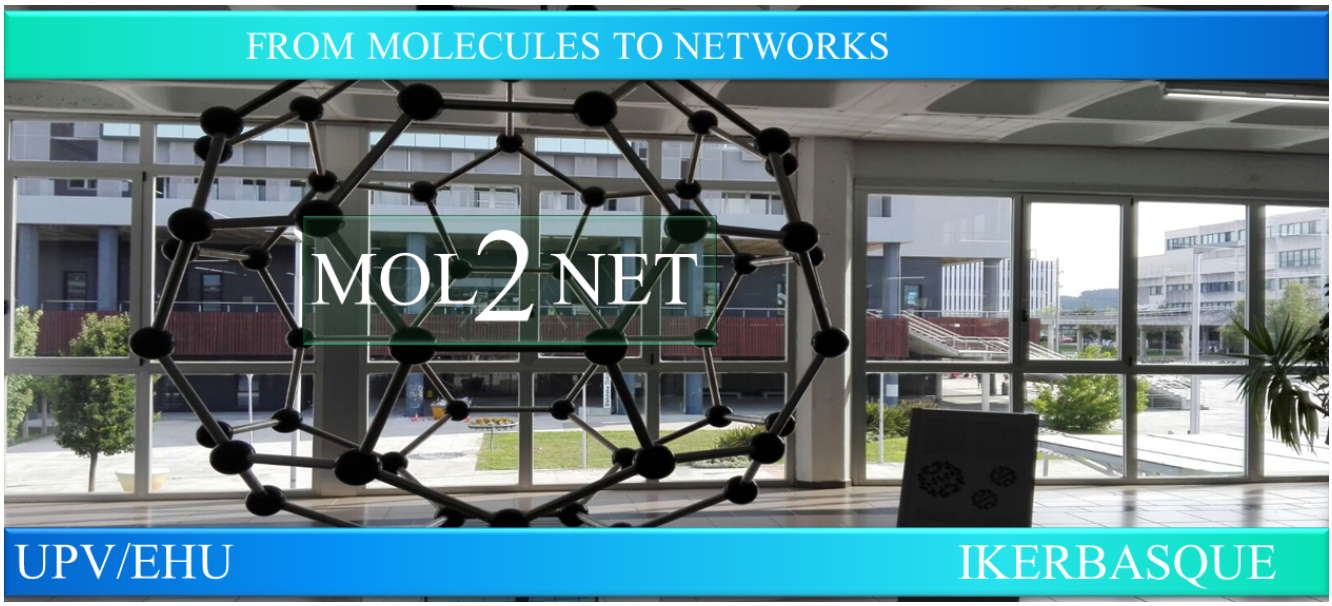

Ethnoveterinary medicinal plant knowledge and practice among the Zemmour and Zayane tribes in the Middle Atlas region of Morocco.

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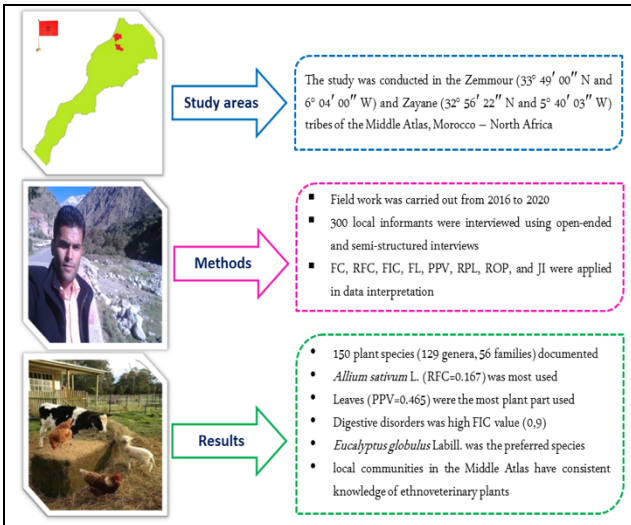
Graphical Abstract	**Abstract.**
	The popular use of medicinal plants in healthcare practices among the indigenous communities provides the basis for natural drug discovery development. The present research was aimed to



document detailed ethnoveterinary knowledge of medicinal plants used for medicinal purposes. The field study was carried out from January 2016 to December 2020 in Zemmour and Zayane tribes (Middle Atlas). In total, 300 local informants were interviewed, using open-ended and semi-structured interviews. The benefits, coverage, and importance of ethnoveterinary was expressed through several quantitative indices including Informant Consensus Factor (FIC), Fidelity Level (FL), Relative Popularity Level (RPL), Rank Order Priority (ROP), and Jaccard Index (JI). A total of 150 plant species belonging to 129 genera and 56 families were found to be used in ethnoveterinary practices. The most commonly used ethnoveterinary plant species in the study areas was *Allium sativum* L. (16.7%). Leaves were found to be the most frequent plant part used (46.5%). The highest FIC value was 0.9 for digestive disorders. *Artemisia herba-alba* Asso and *Asparagus officinalis* L. show a 100% fidelity level for diarrhea and rabies respectively. Rank Order Priority (ROP) results showed that *Eucalyptus globulus* Labill. (ROP=74), was the most preferred species for the treatment of fever. The present study showed that local communities in the Middle Atlas have consistent knowledge of ethnoveterinary plants. We invite the attention of chemists and pharmacologists for further phytochemical and pharmacological investigations of medicinal plants having high ROP, FL, and FIC values in this study.

Introduction

Ethnoveterinary medicine refers to the collective knowledge of an indigenous community about relationships between people and nature. This relationship has been continuing from time immemorial [1]. Nature has been a source of medicinal plants for thousands of years and an impressive number of modern drugs have been isolated from natural sources [2]. Generally, the use of plants as a remedy to common illnesses of humans and other animals has been accepted among indigenous people. A long socio-cultural association of tribal peoples with the ecosystem resulted in the development of indigenous knowledge around communities

that includes the use of plant-based medicines to cure human and animal health [3]. Ethnoveterinary medicine (EVM) is a system based on folk traditional skills, methods, knowledge, theories, beliefs, and practices for curing various diseases, healthful husbandry, and maintaining good health of our animals [4–6].

This knowledge and skills of ethnoveterinary practices are learned through experience and transmitted orally from generation to generation [7]. Today, despite industrial development, this traditional knowledge has vanished in some parts of the developed world [6]. This constitutes a threat to the evolution and sustainability of indigenous knowledge over time. The importance of this body of knowledge is best explained by the African proverb, “When a knowledgeable old person dies, a whole library disappears” [8]. On the other hand, EVM is still playing an important role in livelihood development and sustainable livestock farming in many poor rural areas of the globe [9], and often becomes the only available means for farmers to treat animals illnesses. The use of EVM to control livestock diseases has been cited by the World Health Organization [10], who estimated that 80% of the population living in developing countries relies exclusively on traditional medicine for their primary health care. More than half of the world's population still relies entirely on plants for medicines, and plants supply the active ingredients of most traditional medical products.

Livestock plays an important role in the socio-economic life of Morocco. With a large human population and about 36 million economically strong potential consumers, the domestic demand for these food products is increasing rapidly; the demand often exceeds the supply. The livestock population in Morocco is estimated to consist of 3 441 million cattle, 19 880 million sheep, 5 732 million goats, and 456 000 million poultry birds according to the 2nd Livestock census [11]. Although the heads of livestock in Morocco are numerous; the high mortality and health risks due to various diseases and parasitic infections have posed a serious threat to the development of livestock farming in Morocco. Each year about 12% of the livestock and 25% of the poultry birds die due to various diseases and the weakness of health care. The number of veterinarians does not exceed 1 500 nationally. At present we have one veterinarian for every 374 000 animals covering 12 regions and a 710 850 km^2 area [12].

In many developing countries, farmers and herders interface indigenous ethnoveterinary knowledge and modern veterinary health care systems to treat their livestock. Presently the knowledge about the usage of ethnoveterinary medicinal plants is in the guardianship of elders of the tribes. Their documentation is necessary to transfer this knowledge to other community members in written form. In the light of the above, the main objective of this research is the documentation of ethnoveterinary knowledge of plant species used by the

indigenous people of Zemmour and Zayane tribes for control and treatment of various livestock ailments.

Materials and Methods

Study areas

The study was conducted in the Zemmour and Zayane tribes of the Middle Atlas Mountains. Khemisset province (Zemmour tribes), is located 86 km East of Rabat at 33° 49′ 00″ north latitude and 6° 04′ 00″ west longitude at an altitude of 409 meters above sea level (masl). It receives a total annual rainfall of 485 mm, and an annual mean maximum and minimum temperature of 33 °C and 19 °C. The average annual humidity ranges from 58 – 85% [13]. On the other hand, Khenifra province (Zayane tribes), is situated within the coordinate of 32° 56′ 22″ north latitude and 5° 40′ 03″ west longitudes, with an elevation ranging 860 - 3340 meters above sea level (m.a.s.l). The annual mean temperature of Khenifra province ranges between 34.3 °C - 1.6 °C and the annual mean rainfall ranges 484.6 – 786 mm [14].

The vegetation surrounding Middle Atlas Mountains is a mixture of *Juniperus thurifera* L., *Eucalyptus globulus* Labill., *Olea europaea* subsp. *maroccana*, *Pinus pinaster* Aiton, *Cedrus atlantica* (Endl.) Manetti ex Carrière, and *Quercus suber* L. The livestock available in these study areas are goats, cattle, sheep, poultry, horses, mules, and camels. sheep, poultry, cattle, and production particularly play a central role in the farming system. The socio-economic condition of these regions solely depends on seasonal rain. The predominant agricultural activities involve mixed farming, which broadly includes the cultivation of cereal crops, commercial crops including primarily wheat, and production of livestock [15].

Field survey

An ethnoveterinary field survey was undertaken in the rural areas and tribal villages of Khemisset and Khenifra provinces (Zemmour and Zayane tribes) to gather information on the traditional usage of plants in the livestock health care system. It was conducted from January 2016 to December 2020 using field observations, semi-structured questionnaire-based interviews, and open-ended interviews [16, 17] with cattle holders, shepherds, nomads, knowledgeable elders, local farmers, village leaders, and traditional practitioners who were optional to share their indigenous knowledge. We selected these study areas based on the availability of practice of popular medicine and the recommendations of agricultural developing agents and local authorities.

In total, 300 informants (including 240 males and 60 females) between the different age groups from 40 to 100 were purposively selected and interviewed. The questionnaire was prepared and designed (Annex A), which comprised of two parts i.e., the first part contained

socio-demographic data of the participants included age, gender, occupation, education, community, number of livestock, if any, etc. The second part is devoted to the medicinal plants frequently used for curing various ailments of the animals, such as local plant names, parts used, methods of preparation, the dosage used, mode and route of application, and diseases treated. Questionnaires were first developed in English, later translated into local languages (Amazigh and Arabic dialect).

Plant species collection and identification

The botanical materials of 150 plant species were collected in the field under the supervision of the informants. During the interview, the local names of the plant were also asked from the informants. Specimens of plants that were mentioned by the informants for the treatment of livestock ailments were registered with local names, photographed, numbered, pressed, dried, and arranged alphabetically by vernacular name, scientific name family name, and ethnoveterinary practices. Of these 150 medicinal plant species collected from the Zemmour and Zayane tribes, most of them 83 (55.3%) were obtained from the wild habitats whereas 51 (34%) were from agricultural fields, and sixteen (10.7%) of the medicinal plants such as *Zingiber officinale* Roscoe, *Glycyrrhiza glabra* L., and *Lawsonia inermis* L. were not occurring in the study areas but utilized by the indigenous communities to treat different ailments by purchasing from herbal markets when the need arises. Voucher samples were also collected for each plant, identified by using floristic and taxonomic references, especially Catalogue of vascular plants of Northern Morocco, including identification keys [18], Moroccan Flora Practice: Vascular Plant Determination Manual. Pteridophyte, Gymnosperm, Angiosperm [19], Practical flora from Morocco. Volume 2 [20], Moroccan vascular flora: inventory and chorology [21], Morocco Practice Flora, Volume 3 [22]. Further, taxonomic names of plant species were confirmed from online databases namely: The Plant List (http: //www. theplantlist.org).

Ethics statement

The study was authorized by the *Ethics Committee of Plant, Animal Productions, and Agro-industry Laboratory, Department of Biology, Faculty of Sciences, Ibn Tofail University* No. NHEL/06/06/2016.

Quantitative analyses of ethnoveterinary data

The data collected by interviewing participants were analyzed by various quantitative indices such as Fidelity Level (FL), Relative Popularity Level (RPL), Rank Order Priority (ROP), Jaccard Index (JI), and Informant Consensus Factor (FIC).

Fidelity level (FL)

Fidelity level (FL) is the percentage of informants, who claim the use of a specific species for the same major use, which can be carried out through fidelity level formulated by Alexiades [23]. FL (%) $= \frac{Np}{N}$ X 100. Where, Np is the number of participants who reported the use of grass for a specific purpose and N is the sum of participants who claimed the use of grass for any purpose. A high level of FL reflects the high use of plant species in specific diseases in the study area.

Relative popularity level (RPL)

Relative popularity level (RPL) is the ratio between several ailments treated by a particular plant species and the total number of informants for any disease. However, plant species with comparable FL may vary in their healing potential. A correction scale is therefore introduced, in which all the encountered plant species are divided into popular and unpopular groups. The relative popularity level (RPL) assumes a value of 0 and 1, with "1" being the complete popularity of a plant for major ailments and "0" no ailments treated by a plant species [24]. The relative popularity level (RPL) of the plant species is calculated and designated as popular or unpopular. For popular plant species, RPL was arbitrarily selected equal to 1 that represents the complete popularity of a species for the cure of ailments and 0 value represents that no ailment was treated by this species [25].

Rank order priority (ROP)

Rank order priority (ROP) is a correction factor, used for appropriate ranking of the plant species with various FL and RPL values. The ROP or the corrected FL values for the medicinal plants were calculated by Friedman et al. [26] (ROP = FL x RPL).

Jaccard index (JI)

The Jaccard Index (JI), also known as the Jaccard Similarity Coefficient, is a measurement that is used to compare study data with that of other ethnobotanical studies conducted in other parts of Morocco as well as other countries in the world, and also among the indigenous communities in the studied areas. JI is calculated using the following formula [27]: $JI = \frac{c \times 100}{a+b-c}$. Where, a represent the number of plants in an area A, b is the number of plants in area B and c is the number of plants common to area A and B.

Factor Informant Consensus (FIC)

To determine common species used and homogeneity of use in various areas, we calculated the Factor Informant Consensus (FIC). FIC values close to one indicates that there is homogeneity in the use of medicinal plants between the informants, while FIC values close to 0 suggest that there is little or no exchange of knowledge between informants [16]. FIC value

can be calculated by the formula: $FIC = \frac{Nur-Nt}{Nur-1}$. Where Nur is the number of use reports in a particular category and Nt is the number of species that were used as medicine in a particular category. In this analysis, we tested whether knowledge is shared between the localities inhabited by the Zemmour and Zayane tribes.

Results

Demographic features

Data were collected from 300 participants (240 males and 60 females) of ages 40 to 100 years, including cattle holders, shepherds, nomads, knowledgeable elders, local farmers, village leaders, and traditional practitioners. Among the 300 interviewed people, 160 (53.33%) were from Zemmour tribes (30 in El Kansera, 20 in Sidi Boukhalkhal, 26 in Tiddas, 24 in Maaziz, 30 in Tiflet, 30 in Khemisset), and 140 (46.67%) from Zayane tribes (25 in Molay Bouazza, 20 in Bouhsoussen, 23 in Agulemous, 24 in Sidi Lamin, 20 in Arougo, 28 in Khenifra). In the present study male participants were higher than females. Men were predominantly represented in the sampling due to their presence in agricultural fields. The prevalence of male informants is because females of the study area were reluctant to converse with male strangers. Besides, females rarely engage in agricultural activities and livestock farming during interviews because of the traditions and customs that govern these Amazigh tribes. Based on demography these informants were categorized into various classes as given in Table 1.

Table 1 Demographic data about participants in the study areas.

Tribes	Name of the area	No. of informants	Percentage	Age groups	Gender	
					Male	Female
Zemmour	El Kansera	30	10 %	43–85	24	6
	Sidi Boukhalkhal	20	6.67 %	62–68	15	5
	Tiddas	26	8.67 %	41–83	22	4
	Maaziz	24	8 %	54–93	21	3
	Tiflet	30	10 %	40–70	23	7
	Khemisset	30	10 %	56–85	24	6
Zayane	Molay Bouazza	25	8.33 %	63–100	21	4
	Bouhsoussen	20	6.67 %	53–96	13	7
	Agulemous	23	7.66 %	48–76	20	3
	Sidi Lamin	24	8 %	73–89	19	5
	Arougo	20	6.67 %	47–81	16	4
	Khenifra	28	9.33 %	67–95	22	6

Taxonomic classification of plant species

In this study, a total of 150 medicinal plant species were used by local people of the Zemmour and Zayane tribes to treat livestock diseases (Table 2). Those medicinal plants were botanically distributed across 129 genera and 56 families. Data from the present study suggested that the highest number of plant species was found in the Lamiaceae family with 18 species (12%) followed by Asteraceae 17 species (11.33%), Fabaceae 11 species (7.33%), Apiaceae 10 species (6.66%), Poaceae and Fabaceae 7 species for each family (4.66%). Data on plant species used for the veterinary purpose by the local community are presented (Fig. 2).

Plant parts used

Local people of Zemmour and Zayane use various parts of the medicinal plants for veterinary purposes (Table 2). Our investigation showed that the leaves were the most used part (46.5%) of the medicinal plants, followed by seeds (12.6%), aerial parts (12%), whole plant (9%), flowers (5%), bulbs (4.9%), fruits (3.9%), roots (3.2%), stems (2.9%), respectively.

Method of preparation

Several methods of preparation (Table 2) are employed by the local people of Zemmour and Zayane, the most preferred method of preparation was decoction (38%), followed by infusion (35%), crushing (11%), cataplasm (7%), fumigation (6%), and raw (3%).

Route of administration

As shown in Table 2, the administration routes of medicinal plants were different and special. 76 % of the herbal remedies 33% were taken orally. Few remedy preparations were taken nasally (10%), applied locally in the mouth (6%) brushing (4.5%), or topically (3.5%).

206 **Table 2.** List of medicinal plants used by the Zemmour and Zayane tribes for ethnoveterinary purposes.

Family and Botanical name	Local name (Amazigh/Arabic dialect)	Plant parts	Preparation and administration	Animals/species	Ethno-veterinary uses	%
Amaranthaceae						
Chenopodium album L.	Beremran, Awjdim	Leaf	In / Or	Sheeps, Goats, Cows	Bronchitis, Diuretic, Goatpox, Wound	2.3%
Amaryllidaceae						
Allium cepa L.	Azalim	Bulb	Cr / Mo	Sheeps	Indigestion, Flu, Gout, Skin edema	14.7%
Allium sativum L.	Tiskert	Bulb	Ca / To	Goats, Dogs, Sheeps	Ectoparasites, Hemorrhoids	16.7%
Anacardiaceae						
Pistacia atlantica Desf.	Btem	Leaf	In / Or	Sheeps	Diarrhea, Anthelminthic, Indigestion	9.3%
Pistacia lentiscus L.	Drou	Leaf	Fu / Na	Sheeps	Diarrhea, Asthma, Fever, Gastritis	12%
Apiaceae						
Ammi majus L.	Ich Omlal	Flower	In / Or	Cows, Sheeps	Asthma, Toothache, Listeriosis	6.3%
Ammi visnaga (L.) Lam.	Bou Okmam	Flower	De / Or	Sheeps	Colic, Asthma, Toothache, Wound	7.7%
Carum carvi L.	Tikiru	Seed	De / Or	Cats, Cows, Sheeps	Flatulence, Lameness, Hemorrhoids	4.7%
Coriandrum sativum L.	Lqzbor	Seed	De / Or	Camels	Mastitis, Knee Pain, General weakness	2.7%
Cuminum cyminum L.	Kamon	Seed	De / Or	Horses	Diarrhea, Mastitis, Sore Eyes	5%

Daucus carota L.	Khizzo	Whole plant	De / Or	Sheeps	Eczema, Uterine disorders, Flu	3.3%
Eryngium ilicifolium Lam.	Asnane	Aerial parts	De / Or	Cows, Goats	Earache, Cough, Asthma, Indigestion	2.3%
Ferula communis L.	Aboubal, Taggult	Aerial parts	De / Or	Goats, Mules, Sheeps	Constipation, Lactation problem	7%
Festuca caerulescens Desf.	Aguezmir	Flower	Cr / Na	Sheeps	Excessive bleeding, Asthma, Anorexia	1.7%
Thapsia garganica L.	Thorah	Leaf	In / Or	Cows, Sheeps	Dysuria, Lameness, Dysmenorrhea	4%
Apocynaceae						
Caralluma europaea (Guss.) N.E.Br.	Daghmous	Whole plant	De / Or	Cows, Sheeps	Diarrhea, Fever, General weakness	8%
Nerium oleander L.	Alili	Leaf	Cr / Na	Donkeys, Sheeps	Snake Bite, Chickenpox, Ulcer	12%
Araceae						
Arisarum vulgare O.Targ.Tozz.	Kawhzin, Ayrna	Aerial parts	De / Or	Goats, Sheeps	Gastritis, Lameness, Pediculosis	2%
Aristolochiaceae						
Aristolochia baetica L.	Barztam	Leaf	In / Or	Sheeps, Cows	Wound, Rheumatism, Diarrhea	3%
Aristolochia paucinervis Pomel	Barztam	Leaf	In / Or	Goats, Sheeps	Headache, Fever, Sore eyes, Colic	1.7%
Asparagaceae						
Asparagus acutifolius L.	Taskomt	Stem	De / Or	Dogs, Donkeys	Infertility, Snakebite, Rabies, Wound	8.3%

Asparagus albus L.	Tazzout	Stem	De / Or	Dogs, Goats, Horses	Gout, Diuretic, Rabies, Fever	6%
Asparagus officinalis L.	Taskomt	Stem	De / Or	Dogs, Cows	Rabies,	8.7%
Drimia maritima (L.) Stearn	Azalim nouchen	Bulb	De / Or	Goats, Sheeps	Asthma, Jaundice, Listeriosis, Asthma	7.3%
Asteraceae						
Artemisia herba-alba Asso	Izri	Leaf	In / Or	Cats, Goats, Sheeps	Diarrhea	15%
Artemisia absinthium L.	Chiba	Leaf	Ca / Br	Goats, Sheeps	Indigestion, Bronchitis, Gout	16%
Atractylis gummifera Salzm. ex L.	Addad	Whole plant	De / Or	Goats, Cows	Albinism, Anthrax, Wound, Gastritis	11.3%
Carduus nutans L.	Akroua ighial	Whole plant	De / Or	Goats, Sheeps	Colic, Goatpox, Cough, Ulcer	8.7%
Carlina racemosa L.	Alddad	Root	De / Or	Mules	Lactation problem, Dysmenorrhea	6%
Calendula arvensis M.Bieb.	Jmarth	Aerial parts	De / To	Goats, Sheeps	Constipation, Hemorrhoids, Toothache	3.7%
Calendula officinalis L.	Jmarth	Aerial parts	In / Or	Goats, Camels	Constipation, Hemorrhoids, Indigestion	1.3%
Carduus martinezii Pau	Anane oghiol	Aerial parts	Cr / Na	Horses, Sheeps	Sheeppox, Fever, Ectoparasites	3%
Centaurea maroccana Ball	El osfour	Aerial parts	De / Or	Cows	Cholera, General weakness, Swellings	7.7%
Cynara humilis L.	Thimet	Leaf	Ca / Na	Mules	Dysentery, Pediculosis, Fever	5.7%
Echinops strigosus L.	Thassakra	Root	De / To	Sheeps	Dysuria, Infertility, Hemorrhoids	5%
Lactuca serriola L.	Assafar nssem	Leaf	In / Or	Dogs	Lactation problem, Snakebite	8%

Mantisalca salmantica (L.) Briq. & Cavill.	Thazmourth	Leaf	Cr / Na	Sheeps	Dysuria, Infertility, Diarrhea, Dystocia	4%
Matricaria chamomilla L.	Babounj	Leaf	In / Or	Goats, Sheeps	Cough, Diarrhea, Hemorrhoids	10%
Scolymus hispanicus L.	Thaghdiwt	Leaf	Fu / Or	Camels, Sheeps		9%
Silybum marianum (L.) Gaertn.	Akroua Ighial	Leaf	Ca / Br	Goats, Horses, Sheeps	Lactation Problem, Rheumatism	5.7%
Sonchus tenerrimus L.	Tifaf	Whole plant	De / Br	Sheeps	Headache, Gout, Lactation problem	7.7%
Boraginaceae						
Borago officinalis L.	Telkit ochenc	Leaf	In / Or	Cows	Pneumonia, Eczema, Hemorrhoids	2.7%
Eruca sativa Mill.	Echeriad	Leaf	Cr / To	Goats, Sheeps	Naval pain, Jaundice, Asthma, Colic	2%
Brassiaceae						
Brassica rapa L.	Tarkimt	Seed	De / Or	Cows, Horses	Bronchitis, Knee pain, Gout	5.7%
Diplotaxis catholica (L.) DC.	Kerkaz	Flower	De / Or	Sheeps	Asthma, Jaundice, Cough, Enteritis	8%
Lepidium sativum L.	Hab Rchad	Seed	De / Or	Goats, Camels	Mastitis, Lameness, Fever, Indigestion	5.3%
Cactaceae						
Opuntia ficus-indica (L.) Mill.	Zaaboul, Aknary	Flower	Cr / Br	Goats, Camels, Cows	Indigestion, Diarrhea, Listeriosis	6.7%
Cannabaceae						
Cannabis sativa L.	Lhchich	Leaf	In / Or	Sheeps	Pediculosis. Tick infestation, Wound	5%

Capparaceae						
Capparis spinosa L.	Taylult	Fruit	Ca / Na	Sheeps	Ulcer, Dysentery, Sore eyes, Toothache	11%
Caryophyllaceae						
Corrigiola telephiifolia Pourr.	Thawsarghine	Whole plant	De / Or	Sheeps	Flatulence, Dysentery, Skin edema	6.3%
Silene vulgaris (Moench) Garcke	Thighighet	Flower	Fu / Mo	Goats, Sheeps, Cows	Infertility, Sheeppox, Hemorrhoids	10.3%
Spergularia maritima (All.) Chiov.	Ozima	Leaf	Cr / Br	Chikens	Rheumatism, Cough, Diarrhea	3.3%
Cistaceae						
Cistus albidus L.	Rbibit	Aerial parts	De / Or	Mules	Albinism, Jaundice, Asthma	3.3%
Cistus ladaniferus Stokes	Rbibit	Aerial parts	In / Or	Cows, Sheeps	Diarrhea, Diuretic, Jaundice, Wound	2.3%
Cistus salviifolius L.	Rbibit	Aerial parts	Ca / Or	Goats, Donkeys	Pneumonia, Swellings, Anorexia	1.7%
Cistus villosus L.	Rbibit	Aerial parts	De / Or	Rabbits, Sheeps	Gout, Dysuria, Snakebite, Eczema	2.7%
Convolvulaceae						
Convolvulus althaeoides L.	lwayth ozguar	Leaf	In / Or	Camels, Sheeps	Constipation, Naval Pain, Colic	4.7%
Cucurbitaceae						
Citrullus colocynthis (L.) Schrad.	Afrziz	Seed	De / Or	Cows, Sheeps	Flatulence, Eczema, Anthrax, Anorexia	13.3%
Cucurbita maxima Duchesne	Thakssayet	Fruit	Cr / Br	Mules, Sheeps	Gastritis, Excessive bleeding, Dystocia	4%

Cupressaceae						
Juniperus communis L.	Azuka	Leaf	In / Or	Rabbits	Ulcer, Skin edema, Ulcer, Swellings	10.7%
Juniperus oxycedrus L.	Thakka	Leaf	Ca / To	Sheeps	Naval Pain, Diuretic, Diarrhea	9.7%
Tetraclinis articulata (Vahl) Mast.	Araâr	Leaf	In / Or	Goats, Sheeps	Ulcer, Headache, Fever, Constipation	8.7%
Ericaceae						
Arbutus unedo L.	Assasno	Leaf	Cr / Mo	Sheeps	Diarrhea, Vitiligo, Cough, Jaundice	4.3%
Erica terminalis Salisb.	El Khalanj	Whole plant	De / Or	Cats	Lameness, General Weakness	2.3%
Euphorbiaceae						
Euphorbia helioscopia L.	Hlaba	Leaf	In / Or	Mules	Wound, Dysentery, General weakness	4.3%
Ricinus communis L.	Lkrnek	Leaf	Ca / Na	Goats, Horses, Sheeps	Constipation, Sheeppox, Dystocia	8%
Fabaceae						
Acacia arabica (Lam.) Willd.	Telh	Leaf	In / Or	Goats, Sheeps	Dysentery, Abortion, Skin edema	6.7%
Astragalus sesameus L.	Thabawcht	Aerial parts	De / Or	Cows	Anorexia, Diarrhea, Fever, Flu	5.3%
Cassia angustifolia M.Vahl	Sna Mekki	Aerial parts	Cr / To	Cows, Sheeps, Goats	Constipation, Dystocia, Wound	8.7%
Ceratonia siliqua L.	Slighwa	Seed	De / Or	Sheeps	Eczema, Sore eyes, Hemorrhoids	14.3%

Fabaceae						
Cicer arietinum L.	Lhmes	Seed	De / Or	Cows, Sheeps	Diarrhea, Anthrax, Cough, enteritis	8%
Glycyrrhiza glabra L.	Ark Sous	Stem	De / Or	Cows	Cough, Bronchitis, Toothache	6%
Lupinus angustifolius L.	Thibawchine	Leaf	In / Or	Goats, Horses	Ringworm, Goatpox, Fever, Gastritis	8.3%
Medicago murex Willd.	Fessa	Aerial parts	De / Or	Donkeys	Asthma, Rheumatism, Dysmenorrhea	5.3%
Retama monosperma (L.) Boiss.	Rtem	Leaf	In / Or	Mules, Sheeps	Pneumonia, Diuretic, Asthma	6.7%
Trigonella foenum-graecum L.	Tifidas	Seed	De / Or	Sheeps	Wound, Colic, Paralysis, Jaundice	15.3%
Vicia faba L.	Ibawn	Leaf	In / Or	Sheeps	Constipation, Swellings, Indigestion	14%
Fagaceae						
Quercus suber L.	Thassaft	Leaf	In / Br	Sheeps, Cows	Enteritis, Insect bite, Ulcer	11.7%
Juncaceae						
Juncus acutus L.	Azmay	Leaf	In / Or	Sheeps	Diarrhea, Albinism, Cough, Flu	7.7%
Lamiaceae						
Mentha spicata L.	Nanaa	Leaf	In / Or	Cows, Sheeps	Flatulence, Sheeppox, Wound	2.7%
Mentha pulegium L.	Timijja	Leaf	In / Mo	Camels	Ulcer, Dysentery, Fever, Flu	4%
Ocimum basilicum L.	Lhbek	Leaf	In / Or	Horses, Sheeps	Diarrhea, Dysentery, Skin edema	5%
Vitex agnus-castus L.	Kaf Meryem	Whole plant	De / Or	Mules, Sheeps	Diarrhea, Anorexia, Fever,	7%

					Flu	
Lavandula dentata L.	Amzir	Aerial parts	Cr / Mo	Sheeps	Foot-and-mouth disease, Swellings	13%
Lavandula stoechas L.	Timzra	Leaf	In / Or	Goats, Cows, Sheeps	Flatulence, Diarrhea, Hemorrhoids	12.3%
Marrubium vulgare L.	Mriwt	Leaf	In / Or	Sheeps	Ringworm, Skin edema, Jaundice	11.7%
Marrubium echinatum Ball	Morro	Leaf	In / Or	Goats, Sheeps	Snakebite, Insect bite, Anorexia	9%
Salvia verbenaca L.	Khiyata	Aerial parts	De / To	Cows, Sheeps	Painful urination, Diarrhea	5.7%
Rosmarinus officinalis L.	Azir	Aerial parts	Ca / Br	Horses, Sheeps, Mules	Ulcer, Abortion, Diarrhea, Jaundice	15.7%
Ajuga iva (L.) Schreb.	Timinra	Whole plant	Cr / Na	Sheeps	Foot-and-mouth disease, Dystocia	4%
Calamintha officinalis Moench	Hlahal	Aerial parts	De / Or	Sheeps	Urinary incontinence, Ectoparasites	6.3%
Salvia officinalis L.	Salmya	Leaf	In / Or	Cows	Allergy, Fever, Diarrhea, Enteritis	7.7%
Thymus willdenowii Boiss.	Adouchen; Azoukni	Leaf	In / Or	Horses, Sheeps	Gout, Respiratory distress, Colic	8.3%
Teucrium polium L.	Tayrart	Whole plant	De / To	Mules	Constipation, Cough, Asthma	2.3%
Lavandula multifida L.	Thazoul ighial	Whole plant	De / Or	Donkeys, Sheeps	Scabies, Swellings, Jaundice	7.3%
Salvia argentea L.	Aâjib nothol	Aerial parts	Cr / Na	Goats, Cows	Respiratory distress, Goatpox, Eczema	5.7%
Sideritis hirsuta L.	Fizr	Whole plant	De / Mo	Sheeps	Mastitis, Lameness, Abortion	1.7%
Lauraceae						

Laurus nobilis L.	Rend	Leaf	In / Or	Donkeys, Sheeps	Indigestion, Earache, Chickenpox	13.7%
Linaceae						
Linum usitatissimum L.	Zriat Lkttan	Seed	De / Or	Cows, Sheeps	Mastitis, Paralysis, Ulcer, Dystocia	7.7%
Lythraceae						
Lawsonia inermis L.	Lheni	Leaf	In / Or	Horses	Cracked heels, Vitiligo, Wound	6%
Malvaceae						
Malva sylvestris L.	Lkhbiza	Flower	Ra / Br	Chickens	Diarrhea, Urticaria, Hemorrhoids	3.7%
Meliaceae						
Azadirachta indica A.Juss.	Neem	Leaf	In / Or	Goats, Cows, Sheeps	Wound, Insect bite, Scorpion bite	6.7%
Moraceae						
Ficus carica L.	Tazart	Leaf	In / Or	Goats, Sheeps	Constipation, Painful urination	10.7%
Myristicaceae						
Myristica fragrans Houtt.	Lgoza	Flower	Cr / To	Cows, Sheeps	Bone fracture, Allergy, Abortion	5%
Myrtaceae						
Eucalyptus globulus Labill.	Lkalitous	Leaf	In / Or	Cows, Sheeps	Asthma, Cholera, Flu, Fever, Wound	2.7%
Nitrariaceae						
Peganum harmala L.	Lharmel	Seed	De / Or	Cows, Sheeps	Cough, Anthelminthic, Dystocia	10.7%

Oleaceae						
Olea europaea L.	Zithon	Leaf	In / Or	Sheeps	Constipation, Urticaria, Asthma	6.7%
Olea europaea var. *sylvestris* (Mill.) Lehr.	Azmour	Leaf	In / Na	Cows, Sheeps	Urinary Incontinence, Cholera	5.3%
Papaveraceae						
Glaucium corniculatum (L.) Rudolph	Loubia lakhla	Seed	De / Or	Cows, Sheeps	Hip dislocation, Dysentery, Abortion	1.3%
Papaver rhoeas L.	Bennaamane	Leaf	In / Or	Cows	Diarrhea, Scorpion Bite, Ulcer	8%
Pinaceae						
Cedrus atlantica (Endl.) Manetti ex Carrière	Amkud, Idkil	Leaf	In / Or	Mules	Flatulence, Mastitis, Pediculosis	5.3%
Piperaceae						
Piper nigrum L.	Lbzar	Seed	De / Br	Camels	Cough, Lameness, Anorexia, Flu	7%
Plantaginaceae						
Plantago lagopus L.	Yalma	Leaf	In / Or	Goats, Sheeps	Dysmenorrhea, General weakness	3.3%
Plantago lanceolata L.	Talma	Leaf	In / Or	Sheeps	Diarrhea, Dysentery, Hemorrhoids	4.7%
Plantago major L.	Lilmet	Leaf	In / Mo	Cows, Sheeps	Asthma, Measles, Diarrhea, Gastritis	2%
Plantago psyllium L	Lsan Lhaml	Leaf	In / Or	Sheeps	Hemorrhoids, Swellings, Anorexia	3.7%
Poaceae						

Avena sativa L.	Lkhortal	Seed	De / Br	Cats	Bone fracture, Polyarthritis, Jaundice	2.3%
Bromus rubens L.	Amelsikh	Whole plant	De / Or	Camels	Painful urination, Diarrhea, Eczema	1.7%
Cynodon dactylon (L.) Pers.	Njem	Leaf	In / Mo	Cows, Sheeps	Wound, Fever, Rickets, Ectoparasites	2%
Lolium rigidum Gaudin	Zwan	Seed	De / Or	Goats, Horses, Sheeps	Bone fracture, Rickets, Goatpox	4%
Oryza sativa L.	Rouz	Seed	De / To	Goats, Sheeps	Gastritis, Polyarthritis, Fever, Colic	7.7%
Triticum durum Desf.	Farina	Seed	De / Or	Cows	Leucorrhoea, Anthrax, Cough, Dystocia	10%
Zea mays L.	Asngar	Fruit	Cr / Br	Cows, Sheeps	Bone fracture, Polyarthritis, Gout	11.3%
Polygonaceae						
Rumex crispus L.	Tasmumt	Leaf	In / Or	Goats, Cows, Sheeps	Foot-and-mouth disease, Indigestion	1.7%
Ranculucaceae						
Clematis cirrhosa L.	Dyan Ajbli	Whole plant	De / Na	Goats	Measles, Anorexia, Pediculosis	1%
Rhamnaceae						
Ziziphus jujuba Mill.	Azguar	Leaf	In / Or	Chickens, Sheeps	Dysentery, Enteritis, Chickenpox	9.7%
Rosaceae						
Prunus persica (L.) Batsch	Lkhokh	Leaf	In / Or	Cows	Leucorrhoea, Swellings, Wound	3.3%

Rubiaceae						
Coffea arabica L.	Lqahwa	Seed	De / To	Cows, Horses	Wound, Cough, Sore eyes, Jaundice	3.3%
Rubia peregrina L.	Fuwwa	Root	De / Or	Mules	Constipation, Lameness, Diarrhea	5%
Rutaceae						
Citrus limon (L.) Osbeck	Limon	Leaf	In / Or	Cows, Sheeps	Ectoparasites, Asthma, Hemorrhoids	7.3%
Citrus sinensis (L.) Osbeck	Limon	Leaf	In / Mo	Cows, Sheeps	Rickets, Sheeppox, Cough, Enteritis	6%
Ruta montana (L.) L.	Iwarmi	Leaf	In / Or	Goats, Rabbits	Diarrhea, Burning urination, Eczema	4.3%
Salicaceae						
Salix alba L.	Oud lma	Leaf	In / Na	Cows, Chickens	Anthelminthic, Allergy, Chickenpox	8.3%
Scrophulariaceae						
Verbascum sinuatum L.	Thit yezm	Leaf	In / Or	Goats, Sheeps	Wound, Measles, Jaundice, Ulcer	3.7%
Solanaceae						
Atropa belladonna L.	Belladon	Leaf	In / Or	Goats, Sheeps	Cracked heels, Listeriosis, Cough	2.7%
Capsicum annuum L.	Lflifla Ihran	Fruit	Cr / Mo	Horses	Endoparasites, Dysmenorrhea	4.7%
Datura stramonium L.	Chedcq Ejemel	Leaf	Ra / Na	Mules	Diarrhea, Dysentery, Fever, Toothache	3.3%
Nicotiana tabacum L.	Lmsassa	Fruit	Fu / Br	Cows, Sheeps	Ectoparasites, Cough,	5.7%

					Indigestion	
Solanum sodomaeum Dunal	Maticha ochen	Fruit	Ra / To	Rabbits	Flu, Vitiligo, Scabies, Abortion	1.7%
Solanum tuberosum L.	Batata	Aerial parts	De / Or	Donkeys	Knee pain, Scabies, Anorexia, Dystocia	4.3%
Withania somnifera (L.) Dunal	Ali Amlal	Leaf	In / Or	Sheeps	Ectoparasites, Diarrhea, Sheeppox	4.7%
Theaceae						
Camellia sinensis (L.) Kuntze	Atay	Leaf	In / Or	Cows, Sheeps	Flatulence, Ulcer, Constipation, Flu	5.3%
Urticaceae						
Urtica dioica L.	Tamnzalt	Aerial parts	De / Or	Goats, Camels, Sheeps	Uterine disorders, Listeriosis, Diarrhea	8.7%
Verbenaceae						
Lantana camara L.	Mays nkeltoum	Leaf	In / Or	Sheeps	Listeriosis, Constipation, Wound	2.3%
Vitaceae						
Vitis vinifera L.	Athel	Whole plant	De / Or	Cows, Sheeps	Anthelminthic, Jaundice, Indigestion	5.3%
Xanthorrhoeaceae						
Aloe vera (L.) Burm.f.	Sabra	Whole plant	Cr / Br	Cows, Mules	Diarrhea, Mastitis, Hemorrhoids	7%
Asphodelus microcarpus Salzm. & Viv.	Inghri	Bulb	De / To	Donkeys, Sheeps	Respiratory distress, Cough, Enteritis	9%
Zingiberaceae						
Curcuma longa L.	Lkharqoum	Root	De / Or	Cows, Goats, Sheeps	Jaundice, Enteritis, Swellings	6.3%

Zingiber officinale Roscoe	Skinjbir	Root	De / Or	Goats, Sheeps	Ulcer, Flu, Allergy, Mastitis, Colic	9.3%
Zygophyllaceae						
Tribulus terrestris L.	Lheska	Leaf	In / Mo	Horses, Sheeps, Cows	Cough, Flu, Hip dislocation, Gastritis	2%

-

De: Decoction; **In:** Infusion; **Cr:** Crushing; **Ca:** Cataplasm; **Fu:** Fumigation; **Ra:** Raw; **Na:** Nasal; **Or:** Oral; **Mo:** Mouthwash; **Br:** Brushing; **To:** Topical.

Factors associated with the use of medicinal plants in ethnoveterinary medicine

The use of medicinal plant species in ethnoveterinary medicine varies between different countries and cultures. These plants have been used in treating various diseases even without the knowledge of their constituents and accurate functions [28]. Other reasons for the use of herbal medicine include isolation of rural areas; the inexistence of health infrastructures; high cost of pharmaceutical drugs and low income of indigenous communities; taboos, and beliefs on plant medicines utilization; and improvements in the quality of herbal medicines with the development of scientific evaluation [29],

Dosage and side effects

There is no standardized measure on the dose of herbal remedies and their side effects were not known in the study area. The quantity of medicinal plants used as reported by various informants depends on the concentration after processing, age of the animal, and type of disease. For example, the same plant species (*Citrullus colocynthis* (L.) Schrad., *Allium sativum* L., and *Rosmarinus officinalis* L.) with specific part is recommended in different doses to treat similar ailments.

Source and transfer of ethnoveterinary plant knowledge

The highest popular medicinal plant knowledge was acquired from family members 46% that is from the grandfather and grandmother, followed by the veterinarian (35%), social media (12%), and reading books (7%).

Medicinal plants reported

The floristic analysis of the plants indicated by the local communities as medicinal plants made it possible to identify 150 plant species. The results show that the frequency of use of different medicinal plants varies from one species to another. In this study, the percentage (%) of the reported species ranged from 1% to 16.7% (Table 2). The highest percentage was calculated for *Allium sativum* L. (16.7%), *Artemisia absinthium* L. (16%), and *Rosmarinus officinalis* L. (15.7%). However, the low percentage species and their respective values were *Calendula officinalis* L. (1.3%), *Glaucium corniculatum* (L.) Rudolph (1.3%), and *Clematis cirrhosa* L. (1%).

Animals treated

A total of 11 animals were cited and ranked according to the importance of the indigenous people of Zemmour and Zayane. Sheep were the most commonly treated animals (2 193 citations) with 102 medicinal plants, followed by cows (50 medicinal plants, 952 citations), goats (42 medicinal plants, 841 citations), mules (21 medicinal plants, 362 citations), horses (15 medicinal plants, 272 citations), donkeys (8 medicinal plants, 185 citations), dogs (5 medicinal plants, 143 citations), chickens (4 medicinal plants, 75 citations), cats (4 medicinal plants, 73 citations), rabbits (4 medicinal plants, 58 citations), and camels (3 medicinal plants, 39 citations).

Ethnoveterinary disease categories

Inhabitants of the Zemmour and Zayane used 150 medicinal plants to treat various health disorders in livestock. The 2 231 use reports were classified into 11 health diseases categories following the

International Classification of Primary Care classification system (ICPC) [30]. Most use records were in the category digestive problems (812 use reports; FIC=0.900) and the highest number of plant species used to treat it (82 plant species). Poison bites had the second FIC value (66 use reports; 8 plant species; FIC=0.892), followed by general health (235 use reports; 28 plant species; FIC=0.885) and microbial infection (243 use reports; 34 plant species; FIC=0.864). The least FIC was associated with bone problems (53 use reports; 12 plant species; FIC=0.788) (Table 3).

Table 3. Categories of diseases with FIC value and number of use reports.

Diseases category	Number of uses reports	Number of taxa used	FIC Value
Digestive problems: Indigestion, Enteritis, Flatulence, Ulcer, Diarrhea, Constipation, Gastritis, Anthelminthic, Colic, Hemorrhoids	812	82	0.900
Poison bites: Snakebite, Insect bite, Scorpion bite	66	8	0.892
General health: Lameness, Swellings, General weakness, Anorexia, Sore eyes, Pediculosis	235	28	0.885
Microbial infection: Cholera, Ectoparasites, Endoparasites, Dysentery, Measles, Jaundice, Chickenpox, Rabies, Anthrax, Sheeppox, Goatpox, Foot-and-mouth disease, Listeriosis	243	34	0.864
Skin: Allergy, Albinism, Eczema, Ringworm, Urticaria, Cracked heels, Vitiligo, Skin edema, Scabies	166	24	0.861
Fever and cough: Fever, Cough	178	28	0.847
Urinary problems: Diuretic, Painful urination, Burning urination, Dysuria, Urinary incontinence	40	7	0.846
Respiratory problems: Bronchitis, Flu, Pneumonia, Asthma, Respiratory distress	187	30	0.844
Sexual and related disorders: Excessive bleeding, Dystocia, Leucorrhoea, Uterine disorders, Infertility, Abortion, Dysmenorrhea, Lactation problem, Mastitis	141	23	0.843
Pain and Wounds: Wound, Toothache, Naval pain, Earache, Headache, Knee pain, Gout	110	21	0.817
Bone problems: Bone fracture, Polyarthritis, Rickets, Hip dislocation, Paralysis, Rheumatism	53	12	0.788

Relative popularity level (RPL) of species

One hundred and fifty plant species were mentioned for various disease categories by 300 informants, interviewed during this study. Thirty of these and their primary uses are presented in Table 4; of these 30 plant species, 14 medicinal plants, which were cited by a few to 50 informants were declared unpopular, whereas the 16 plant species mentioned by 50 informants or more were classified as

popular. The separating line between the popular and unpopular groups falls at the point where an average number of uses per plant disease increases with a further increase in the number of informants. Medicinal plant with a high popularity level (RPL=0.87) was *Eucalyptus globulus* Labill., followed by *Artemisia absinthium* L., *Rosmarinus officinalis* L., *Trigonella foenum-graecum* L. and *Citrullus colocynthis* (L.) Schrad. (RPL=0.6 for each). The correlation between the numbers of informants who claimed the use of certain plant species for a particular disease is given in Fig. 1.

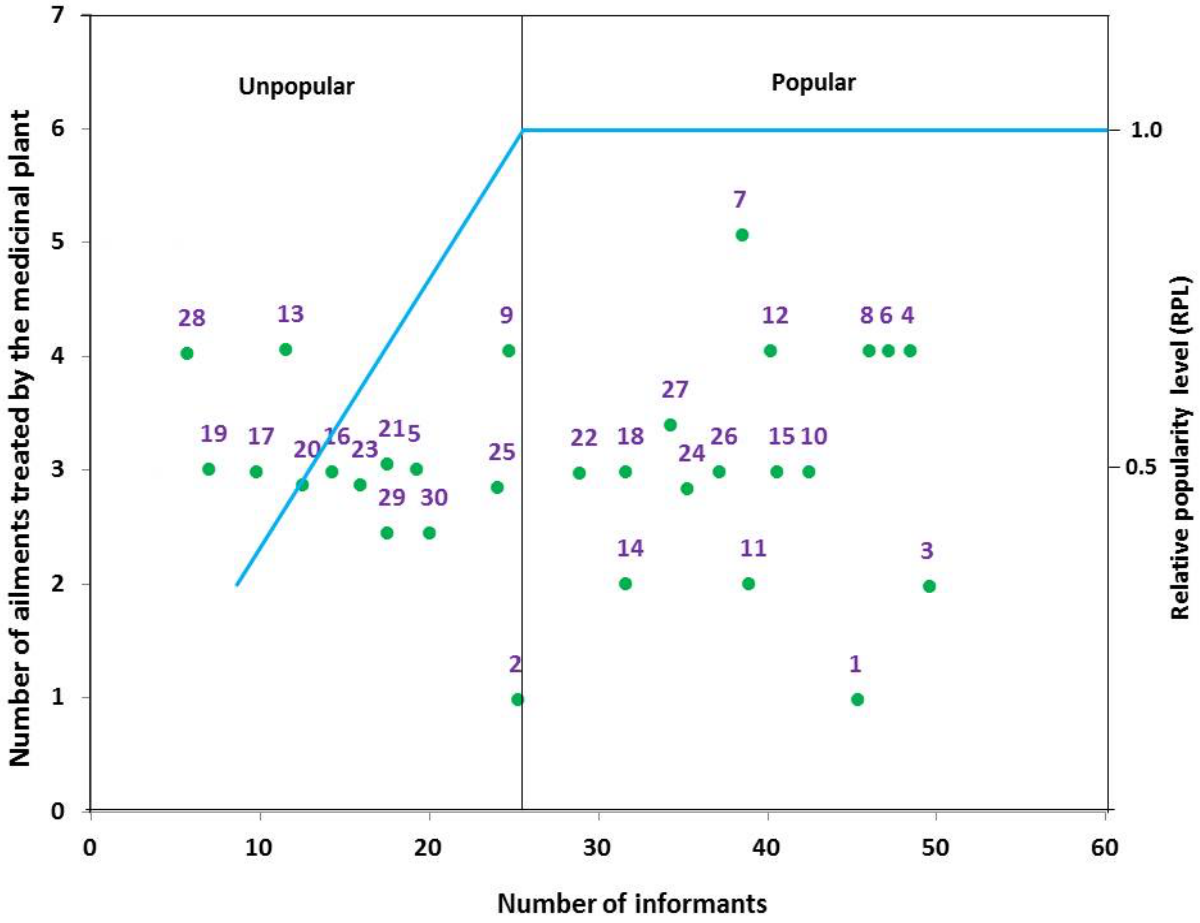


Fig. 1. Correlation between the numbers of informants claimed use of 30 plant species for a particular disease.

Fidelity level (FL)

Fidelity level (FL) was used to classify the recorded plant species based on their claimed relative effectiveness. The present study revealed 30 plant species having high FL values. The fidelity level of these most important medicinal plants ranged from 65% to 100% (Table 4). *Artemisia herba-alba* Asso and *Asparagus officinalis* L. show a 100% fidelity level for diarrhea and rabies respectively. Other species with high FL values were: *Allium sativum* L. (ectoparasites), *Artemisia absinthium* L. (indigestion), *Opuntia ficus-indica* (L.) Mill. (anthrax), *Rosmarinus officinalis* L. (ulcer), *Eucalyptus globulus* Labill. (fever), *Trigonella foenum-graecum* L. (colic), *Thymus willdenowii* Boiss. (Respiratory distress), *Ceratonia siliqua* L. (hemorrhoids), *Lavandula dentata* L. (swellings), *Citrullus colocynthis* (L.) Schrad. (eczema), *Mentha pulegium* L. (flu), *Ficus carica* L. (constipation), *Laurus nobilis* L. (earache), *Ocimum basilicum* L. (dysentery), *Cistus albidus* L. (jaundice), *Peganum harmala*

L. (anthelminthic), *Teucrium polium* L. (asthma), *Ruta montana* (L.) L. (burning urination), *Lawsonia inermis* L. (wound), *Ziziphus jujuba* Mill. (chickenpox), *Cedrus atlantica* (Endl.) Manetti ex Carrière (mastitis), *Marrubium vulgare* L. (ringworm), *Salix alba* L. (allergy), *Lavandula stoechas* L. (flatulence), *Quercus suber* L. (enteritis), *Plantago major* L. (gastritis), *Glycyrrhiza glabra* L. (toothache), and *Retama monosperma* (L.) Boiss. (diuretic) with FL 95%, 92%, 89%, 88%, 86%, 84%, 83%, 81%, 80%,79%, 77%, 75%, 74%, 72%, 71%, 70%, 69%, 68%, 66%, 64%, 63%, 62%, 61%, 60%, 59%, 58%, 57% and, 55% respectively.

Rank order priority (ROP)

The ROP value is used to rank appropriately the plant species with various FL values. Of the 30 species, only four species attained ROP above 50. Based on ROP value; *Eucalyptus globulus* Labill. was widely utilized species by the informants to relieve fever with ROP=74. The other plant species with significant ROP were: *Artemisia absinthium* L., *Rosmarinus officinalis* L., and *Trigonella foenum-graecum* L. (55, 52, and 50, respectively). However, *Artemisia herba-alba* Asso (ROP=16) and *Asparagus officinalis* L. (ROP=15), were used to relieve diarrhea and rabies, respectively by the people of the Zemmour and Zayane. The ROP values are thus obtained are given in Table 4.

Table 4. Highly utilized plant species with major ailments, NA, FL, RPL, and ROP.

	Plant species	Major ailments	NA	FL	RPL	ROP
1	*Artemisia herba-alba* Asso	Diarrhea	1	100%	0.16	16
2	*Asparagus officinalis* L.	Rabies	1	100%	0.15	15
3	*Allium sativum* L.	Ectoparasites	2	95%	0.38	36
4	*Artemisia absinthium* L.	Indigestion	4	92%	0.6	55
5	*Opuntia ficus-indica* (L.) Mill.	Anthrax	3	89%	0.5	44
6	*Rosmarinus officinalis* L.	Ulcer	4	88%	0.6	52
7	*Eucalyptus globulus* Labill.	Fever	5	86%	0.87	74
8	*Trigonella foenum-graecum* L.	Colic	4	84%	0.6	50
9	*Thymus willdenowii* Boiss.	Respiratory distress	4	83%	0.6	49
10	*Ceratonia siliqua* L.	Hemorrhoids	3	81%	0.5	40
11	*Lavandula dentata* L.	Swellings	2	80%	0.4	32
12	*Citrullus colocynthis* (L.) Schrad.	Eczema	4	79%	0.6	47
13	*Mentha pulegium* L.	Flu	4	77%	0.6	46
14	*Ficus carica* L.	Constipation	2	75%	0.4	37
15	*Laurus nobilis* L.	Earache	3	74%	0.5	37
16	*Ocimum basilicum* L.	Dysentery	3	72%	0.5	36
17	*Cistus albidus* L.	Jaundice	3	71%	0.5	35
18	*Peganum harmala* L.	Anthelminthic	3	70%	0.5	35
19	*Teucrium polium* L.	Asthma	3	69%	0.5	34
20	*Ruta montana* (L.) L.	Burning urination	3	68%	0.49	33
21	*Lawsonia inermis* L.	Wound	3	66%	0.51	33
22	*Ziziphus jujuba* Mill.	Chickenpox	3	64%	0.5	32

23	*Cedrus atlantica* (Endl.) Manetti ex Carrière	Mastitis	3	63%	0.49	30
24	*Marrubium vulgare* L.	Ringworm	3	62%	0.48	29
25	*Salix alba* L.	Allergy	3	61%	0.49	29
26	*Lavandula stoechas* L.	Flatulence	3	60%	0.5	30
27	*Quercus suber* L.	Enteritis	3	59%	0.53	31
28	*Plantago major* L.	Gastritis	4	58%	0.6	34
29	*Glycyrrhiza glabra* L.	Toothache	3	57%	0.45	25
30	*Retama monosperma* (L.) Boiss.	Diuretic	3	55%	0.45	24

NA: Number of ailments treated; **FL:** Fidelity level;
RPL: Relative popularity level; **ROP:** Rank order priority.

Jaccard index (JI)

The Jaccard Index was performed to develop a relationship between this study and previously reported studies by botanists and ethnobiologists, one from other regions of Morocco and another from outside Morocco. The original application information of ethnomedicinal plants within our study was compared with 20 previous ethnobotanical research studies published from various countries, including teen studies in Morocco.

Relationship with researchers from Morocco

In total, the Jaccard index (JI) was calculated for 10 regions of Morocco with the JI ranged from 15.74 to 3.98 (Table 5). The highest JI index (JI=15.74) was found with a previous report from High Atlas Central [31], followed by the study conducted in High Atlas, Morocco [32] with JI=13.07, Beni Mellal Region [33] with JI=11.97, City of Khenifra [34] with JI=11.64, Middle Region of Oum Rabai [35] with JI=9.72, Izarène Region [36] with JI=5.60, Forest Achach [37] with JI=5.40, Zaër Region [38] with JI=5.02, and Moroccan Rif [39] with JI=4.54. The lowest JI such as 3.98 was recorded from Gharb Region [40].

This present study shares the greatest number of common species (74) with the study from High Atlas Central, Morocco that reported a total of 248 species [31] with 34 species having similar uses and 40 species having dissimilar uses. Similarly, 59 species are common between our study and a study from Central High Atlas, Morocco [32] with 13.77% similar uses and 21.56% dissimilar uses. Forty three plant species, in our study, were found common to the studies reported from Forest Achach, Morocco [37], 38 species are common between our study and a study from the City of Khenifra, Morocco [34]. Other studies from Zaër Region [38], Beni Mellal Region [33], Middle Region of Oum Rabai [35], Izarène Region [36], Gharb Region [40], and Moroccan Rif [39], share 32, 30, 29, 26, 24, and 15 plant species common to our study respectively (Table 5).

Relationship with researchers from outside Morocco

In the comparison of our study with other studies from outside Morocco, the percentage of similarity ranged from 4.62% to 33.33% (Table 5). The highest degree of similarity was observed in the Island of

Sardinia, Italy [41] with SU=33.33%, and South Pacific Island countries [42] with SU=20.83%. The Jaccard index (JI) was also calculated for comparing the study area with the overall study area, the JI ranged from 1.92 to 6.41 (Table 5). The highest JI index was found with a previous report from South Pacific Island countries [42] with JI=6.41, and West Bank, Palestine [43] with JI=5.36. The lower JI index such as JI=1.92 was found with the study conducted in Mutas District, Zimbabwe [44].

Table 5. Comparison between this study and other studies from Morocco, and outside Morocco.

Ref.	TRS	PDU	% DU	PSU	% SU	PPSA	PPAA	CPBA	JI
[33]	69	13	18.84	17	24.64	120	39	30	11.97
[40]	149	14	9.40	10	6.71	136	125	24	3.98
[36]	53	18	33.96	8	15.09	124	27	26	5.60
[32]	167	36	21.56	23	13.77	91	108	59	13.07
[37]	269	26	9.67	17	6.32	107	226	43	5.40
[34]	89	21	23.60	17	19.10	112	51	38	11.64
[35]	66	15	22.72	14	21.21	121	37	29	9.72
[31]	248	40	16.13	34	13.71	76	174	74	15.74
[38]	228	17	7.46	15	6.58	118	196	32	5.02
[39]	41	6	14.63	7	17.07	135	26	15	4.54
[44]	21	3	14.29	3	14.29	144	15	6	1.92
[45]	51	4	7.84	5	9.80	141	42	9	2.80
[46]	24	3	12.5	4	16.67	143	17	7	2.56
[41]	42	9	21.43	14	33.33	127	19	23	3.03
[47]	36	4	11.11	7	19.44	139	25	11	4.46
[48]	117	5	4.27	7	5.98	138	105	12	2.97
[43]	165	6	3.64	14	14	130	145	20	5.36
[42]	48	6	12.5	10	20.83	134	32	16	6.41
[49]	173	6	3.47	8	4.62	136	159	14	2.79
[50]	43	7	16.28	6	13.95	137	30	13	3.73

Ref.: References, **PDU:** Plants with various uses, **PSU:** Plants with similar uses, **PPSA:** Plants only present in the study area, **PPAA:** Plants only present in the aligned area, **CPBA:** Common plants of both areas, **TRS:** Total reported species.

Discussion

Overall, this study revealed the veterinary use of 150 medicinal plant species, distributed among 129 genera and belonging to 56 families to treat 11 categories of diseases, recorded from 300 participants of ages between 40 to 100 years, including cattle holders, shepherds, nomads, knowledgeable elders, local farmers, village leaders, and traditional practitioners. These results indicate that the study area has a rich diversity of ethnoveterinary medicinal plants and indigenous knowledge associated with conventionally used species. Similar results have also been found in other areas of Middle Atlas [34, 51–53]. This comparison confirms the richness of the area in the diversity of ethnomedicinal plants.

The families most mentioned by the informants were the Lamiaceae family followed by Asteraceae and Fabaceae. This is probably because of the abundance of these families in the Middle Atlas flora

and their traditional uses known by the indigenous communities of Zemmour and Zayane. The present study is in line with the finding presented in other areas of Morocco and other [25, 33, 37, 39, 40, 49, 54–57].

In this study, the analysis revealed that there were 9 kinds of plant parts that were used for herbal tea as medicinal materials. Leaves and seeds are the most frequently harvested plant part for the preparation of various medicinal recipes of livestock. The preference for the use of leaves in the preparation of herbal medicines by the healers is likely due to the year-round availability of leaves, and the fact that they are easier to collect, store, process, and handle. Leaves and seeds are the renewable parts of the plant and their collection does not result in fatality. It is thought that leaves contain more easily extractable phytochemicals, crude drugs, and many other mixtures that may be proven as valuable in phytotherapy [58, 59]. In the same way, several ethnobotanical studies in Morocco and other countries [24 , 33, 35, 37, 40, 50, 58, 60–64] have revealed that the leaves of the medicinal plants were repeatedly used for the treatment of human and livestock ailments.

In our research, we identified 150 plant species used by indigenous communities of Zemmour and Zayane to treat livestock diseases. The highest % was calculated for *Allium sativum* L., *Artemisia absinthium* L. and *Rosmarinus officinalis* L. In the scientific review, *Allium sativum* L. is highly reported in various studies conducted all over the world. The positions of these plant species correspond to the fact that they were reported by a maximum number of informants. These plant species are native to the Middle Atlas and have been known to local cultures over a long period. Moreover, these medicinal plants are dominant in the study area and the Zemmour and Zayane people are, therefore, very familiar with them. These results are important as they could form an important research baseline for subsequent evaluation of plant-derived medicinal compounds, potentially resulting in future drug discoveries [65].

The results showed that the majority of remedies were prepared from decoction. The major solvent with the plant was water, but milk, butter, tea, and honey, oils were also extensively used as ingredients. These results show that the local population believes in decoction mode and found it suitable for heating the body and disinfecting the plants [38]. On the other hand, the decoction provides assemble the greatest for the active constituents and attenuates or eliminates the toxic effect of some compounds. Decoction and infusion are the most common traditional remedy methods that are used by patients, who prepare plant parts by mixing them with water, tea, or soup [66–68] and in other countries [25, 50, 58, 69–71]. Oral mode of administration is a preferred route total across the globe [54,72–77]. The majority of indigenous people prepared remedies that were applied mostly by oral consumption. The administration of oral treatment may be defined by a high degree of internal illnesses in the region [78].

The study revealed that dosages of medicinal plant medicine were not specific and their side effects were not known. This is dangerous because it is possible to overdose oneself with the remedy without

knowing. 11 various diseases were reported to be treated by 150 plant species. Among them, digestive system diseases were commonly treated disorders. During the study, it was observed that local people of Zemmour and Zayane purchased herbals mainly for digestive diseases. The possible reasons for the occurrence of common digestive disorders may be health conditions, deficiency of pure water, the stress in livestock, lack of pasture due to drought that sweeps the Middle Atlas from time to time, as well as toxic substances present in pastures. The predominance of remedies for digestive system disorders agrees with many ethnomedicinal studies conducted in other regions [48, 79–82]. This is consistent with the statement that traditional pharmaceutical products are usually limited to the treatment of mild and chronic diseases [83]. Besides, high FIC values can be used to pinpoint interesting species in search of bioactive compounds [84]. Meanwhile, the lowest FIC was found in dental pains and fever showing less or no consensus of using plants against these diseases. The lowest FIC doesn't mean that plants are not important for those categories. The lowest FIC may be due to the unavailability of information in study participants.

In our work, medicinal plant species with a high relative popularity level were: *Eucalyptus globulus* Labill., followed by *Artemisia absinthium* L., *Rosmarinus officinalis* L. The high popularity of these plant species might be attributed to their high efficacy and the awareness of Zemmour and Zayane people which specifies their use as herbal medicine. At the base of the RPL index, plant species are divided into popular and unpopular groups. In this study, 14 medicinal plants, which were cited by a few to 50 informants were declared unpopular, whereas the 16 plant species mentioned by 50 informants or more were classified as popular. Popular species are those reported by more than half the number of informants or above and the rest of the species are declared as unpopular. Medicinal plant species with high RPL values should be screened for comprehensive phytochemical and pharmacological studies. The remaining 14 plant species are classified as unpopular. Considering the ROP is a local variable because the local culture associated with a typical ecosystem determines the ROP of medicinal plants then this is a parameter that we cannot globalize.

The healing potential of each species may vary and is expressed by its FL value [25]. The fidelity level (FL) of the 30 most important plant species ranged from 65 to 100%. *Artemisia herba-alba* Asso and *Asparagus officinalis* L. show a 100% fidelity level for diarrhea and rabies respectively. These species may be proven as important medicinal plants on further evaluation through phytochemical, pharmaceutical, and biological activities [85]. Likewise, elevated values of FL for a plant species confirm its distinct characteristics to treat a particular illness [86]. On the other hand, plant species with low FL infer that they were less preferred. However, it can also entail that medicinal plants used to manage and treat one ailment have a 100% fidelity level compared to those that are used as remedies for more than one type of aliments [87]. Besides, plants with low FL% should not be abandoned as dwindling to remark them to the future generation that it could increase the risk of the gradual disappearance of the knowledge [88].

Rank Order Priority (ROP) is an index calculated to explain the distribution of knowledge of the species about the richness of the resources cited in the studied use category [89]. This study revealed that *Eucalyptus globulus* Labill. (ROP=74), *Artemisia absinthium* L. (ROP=55), *Rosmarinus officinalis* L. (ROP=52), *Trigonella foenum-graecum* L. (ROP=50) had the highest values of ROP, this means that these species are the most important medicinal plants for ethnoveterinary practices of indigenous people of Middle Atlas. Moreover, this is probably due to decreasing popularity of herbal medicines among the local communities of the study area. While medicinal species such as *Artemisia herba-alba* Asso (ROP=16) and *Asparagus officinalis* L. (ROP=15) had a lower priority among medicinal plants used by the local population.

The results of this research were compared with those from twenty national and international studies conducted in other areas similar in terms of their climatic conditions and cultural values to the study area. The data show that across 116 medicinal plants, the similarity percentage ranges 33.33 from 4.62 while the dissimilarity percentage ranges from 33.96 to 3.47. The highest degree of similarity index was with studies conducted in High Atlas Central [31], High Atlas, Morocco 2015 [32], and Beni Mellal Region [33] with JI values of 15.74, 13.07, 11.97 respectively. This result may be explained by various reasons:

- The distance between the study area and High Atlas is the second smallest between Zemmour and Zayane tribes and all other regions interfering in this study.
- The Mediterranean sub-humid climate is similar in these two regions. Moreover, these two regions are both characterized by catchment areas, thick forests, and Mountain heights.
- There is similar vegetation and it is also possible that cross-cultural exchange of knowledge could have occurred between local people of Middle Atlas and High Atlas, which also might provide a reason for the high similarity index values.
- The Atlas regions of Morocco are characterized by a low socioeconomic level. Furthermore, the economy of these regions is based on Subsistence farming and herding livestock.
- The customs, folklore, traditions, history, and ethnic values bind the indigenous communities of the two regions because they speak the Amazigh language.

All these factors underwrite this similarity in the use of medicinal plant species for ethnoveterinary purposes between Zemmour and Zayane tribes and High Atlas. Traditional use of plants is influenced by economic factors such as displacement and urbanization processes, changing lifestyles, and social transformations [90, 91].

The lowest JI values were for the studies conducted in the Gujar Tribe, Kashmir Himalaya [46] and Mutas District, Zimbabwe [44]. These studies were carried out at a greater distance from our study location, and thereby reflect a greater difference in ethnoveterinary knowledge due to differences in population size, species diversity, and habitat structure. Furthermore, there would be less chance of the

exchange of cultural knowledge between the areas where these studies were conducted and our study location as the areas are isolated by mountain ranges and cultural variations [24]. Studies have shown that medicinal plants due to their active ingredients and medicinal and antioxidant compounds have beneficial effects on human health and have a therapeutic effect on various organs of the body and various diseases [92–99].

Conclusions

The present investigation revealed that study regions have a great reservoir of ethnoveterinary medicinal plants and indigenous of Zemmour and Zayane have tremendous popular knowledge to utilize these plant species for the treatment of their livestock. The communities still rely on alternative medicine although; modern healthcare services are available, which indicates the significance of medicinal plant-based traditional recipes. Phytotherapy is considered adaptable and sustainable to rural farming communities because of its ease of availability, simple modes of preparation, administration to animals. We believe that the present study will encourage future ethnoveterinary research among livestock ailment management practices in the study areas. For this, plants scoring high FL and FIC values should be subject to pharmacological screening, chemical analysis for bioactive compounds, and potential formulation as standard drug preparations to treat a range of ailments. Furthermore, the flora of the Middle Atlas is currently threatened by soil erosion, deforestation, overgrazing, overexploitation, and which are the main causes of the reduction of medicinal and other plants in the regions. It is therefore essential to have a conservation strategy for the flora of the Middle Atlas, with special emphasis on species that are valued as medicinal and aromatic plants.

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Annex A

Questionnaire Used for Collection of Ethno-Veterinary Data

Date…… **Survey number**……

Part 1. Socio-demographic data of the informant

1. Gender……..….. 4. Education level……
2. Age……..... 5. Family situation……...……
3. Profession……...…… 6. Tribe……...…….
7. How long you are living in the tribe?…….…….…….
8. How much livestock do you have?…..…Sheep ……Goats ……..Cows ..……Horses ……Mules ..…. Donkeys …….Camels ..….. Chickens ……..Rabbits ……..Cats ….....Dogs ...…..Other
9. How many acres do you need for livestock? ……..……..
10. Do you have a veterinarian for your livestock? ……...…..……
11. How many years of experience do you need to be a livestock keeper? ……..…….
12. What are the problems faced by livestock farming in the Middle Atlas? ……..…….

.....

13. Informants consent for the participation in the study:

I ……hereby give my full consent and consciousness to participate in this study and declare that to the best of my knowledge the information that I have provided is true, accurate, and complete.

Signature / Thumb impression of informant: Date:

……. ……

Part 2. Ethno-veterinary information

1. Vernacular name.....
2. Scientific Name.....
3. Plant Type.....
4. Source of plant .....
5. Harvesting technique.....
6. Plant part used.....
7. The plant (s) associated.....
8. Form of employment.....
9. Method of preparation.....
10. Mode of administration .....
11. Dose used.....
12. Conservation method.....
13. Duration of the treatment.....
14. Toxicity.....
15. Expiration date.....
16. Animal (s) treated.....
17. Disease categories:
    - i. Bone problems.....
    - ii. Digestive problems.....
    - iii. Fever and cough.....
    - iv. General health.....
    - v. Microbial infection.....
    - vi. Pain and Wounds.....
    - vii. Poison bites.....
    - viii. Respiratory problems.....
    - ix. Sexual and related disorders.....
    - x. Skin.....
    - xi. Urinary problems.....
    - xii. Other.....