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Focus on the ethnobotany of north Moroccan sage, false yellowhead, and carrot: insights into their pharmacological potential

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ABSTRACT

Introduction: Medicinal plants, including spontaneous or cultured herbaceous and forest products, represent an inexhaustible source of traditional and effective remedies thanks to their active major compounds. The present work consists of an ethnobotanical study of three species namely, *Daucus carota, Dittrichia viscosa,* and *Salvia officinalis*, commonly used in Taounate region (Northern Morocco) to treat various diseases.

Methods: An ethnopharmacological survey was conducted in Taounate region during a period of three months from January to March 2022, using semi-structured individual interviews. Then, the collected data were analyzed statistically using Microsoft Office software "Excel 2013" and System Package for Social Sciences (SPSS).

Results: Leaves, flowers, and stems were the most common parts used to prepare traditional remedies. Decoction, infusion, and cataplasm were the most used preparation methods, and the oral route was the most common method of administration for the studied plants. Moreover, the plants intervened in the treatment of digestive, genito-urinary, dermatological, neurological, and metabolic diseases.

Conclusion: Information collected during this study shed light on the interesting know-how in traditional herbal medicine in the study area, and on the frequent use of medicinal plants as an alternative to synthetic drugs by the population of Taounate, to treat different diseases. Thereafter, the study's results can constitute an important database for pharmacologists, phytochemists, toxicologists, and clinical researchers for the development of new drugs based on natural substances.

Implication for health policy/practice/research/medical education:
This work reports the ethnopharmacology of *Salvia officinalis, Dittrichia viscosa,* and *Daucus carota* in Northern Morocco. It provides a detailed insight into their bioactive compounds, which could serve the pharmaceutical industries, as active ingredients to develop innovative safe drugs.

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Introduction

Medicinal plants are a great source of medical care in developing countries in the absence of a modern medical organization (1,2). Morocco is among the Mediterranean countries that have a long medical tradition and a traditional know-how of medicinal herbs. Thanks to its geographical location, the Kingdom is a natural framework quite original offering a full range of Mediterranean bio-climate that fosters an interesting flora. In fact, the Moroccan flora comprises about 500 species of potentially medicinal (3).

Salvia officinalis L. (Lamiaceae) is a perennial plant native to the Mediterranean rim (4), also found in Southeast Africa and in Central and South America.

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Sage is also one of the medicinal plants widely used in folk medicine thanks to its therapeutic effects mainly on type 2 diabetes (5), as well as on pain especially pharyngitis (6). In addition, *S. officinalis* has been reported to improve cognitive function for patients having Alzheimer's disease (7). Nowadays, its essential oils (EOs) are used in many industrial fields due to their wide spectrum of biological activities, such as antimicrobial, antiviral, and antioxidant activities (4).

Dittrichia viscosa (syn. *Inula viscosa* Greuter) is common throughout the Mediterranean basin, namely the southern Europe coasts (Spain, Greece, Italy, and Bulgaria), the Middle East (Jordan, Syria, and Turkey), as well as North Africa (8,9). It is used, for its anti-inflammatory and antidiabetic activities. Moreover, it has antipyretic and antiseptic effects, a strong antioxidant activity, and is effective against skin inflammation (10,11).

The genus *Daucus* L. (Apiaceae) develops in temperate areas of Europe, West Asia, and Africa. Some species also grow in North America and Australia. *Daucus carota* L., known as carrot, is recognized worldwide due to its roots being extensively utilized for food and medicinal determinations (6). Their ripe and unripe fruits, flowers, roots, leaves, and stems have shown antibacterial and antifungal properties (12). In addition, they are known to possess numerous biological properties, including antimicrobial, anti-parasitic, antioxidant, anti-steroidogenic, anti-inflammatory, and anti-thrombotic activities. These plants also possess significant effects against cancer and hepatic injuries (13).

Ethnobotany is a broader field that includes all aspects of plant-human interactions, comprising cultural, ecological, and utilitarian aspects, while ethnopharmacology specifically focuses on the medicinal properties and uses of plants within different cultural contexts. The Moroccan population has a strong relationship with the use of medicinal herbs. Several Moroccan regions, particularly Taounate, are very rich in herbs, and the population widely uses herbs for medicinal, cosmetic, and culinary purposes (1-3). Hence, Northern Moroccan people know plenty of information about the beneficial properties of plants and how to use them. However, there is limited work on ethnomedicinal surveys in the Taounate region of Morocco. Therefore, more documentation on Moroccan traditional knowledge is needed. In light of this context, our study targeted three specific medicinal plants, *D. carota* ssp. *carota*, *D. viscosa*, and *S. officinalis*, broadly used by people of Taounate for various purposes. The transmission of ethnomedicinal knowledge is primarily oral and passed down from one generation to the next. By collecting this traditional knowledge, our investigation aims to create a database of these medicinal plants and their traditional uses. Furthermore, this work acknowledges that previous *in vivo* and *in vitro* studies have been conducted on these plants, focusing on their bioactivities and phytochemistry. Therewith, the inclusion of previous studies serves to confirm the ethnomedicinal information collected here.

Materials and Methods

Study area

Taounate is a predominantly rural subdivision of the Moroccan region of Fez-Meknes (34°32′9″ N; 4°38′24″ W), including 44 rural communes and five urban communes (Figure 1), which covers an area of 5.616 km^2. The indigenous population is estimated at 25.880 inhabitants in the 2014 Moroccan census. The climate of Taouante is Mediterranean, characterized by a hot and dry summer season and a cold and wet winter period from October to May. The average temperature is about 16.9 °C and average rainfall reaches 790 mm, according to the classification of Köppen-Geiger (14).

Taounate is located on a multitude of disparate geological units, associated with climatic data and other geographical phenomena, which make this territory a

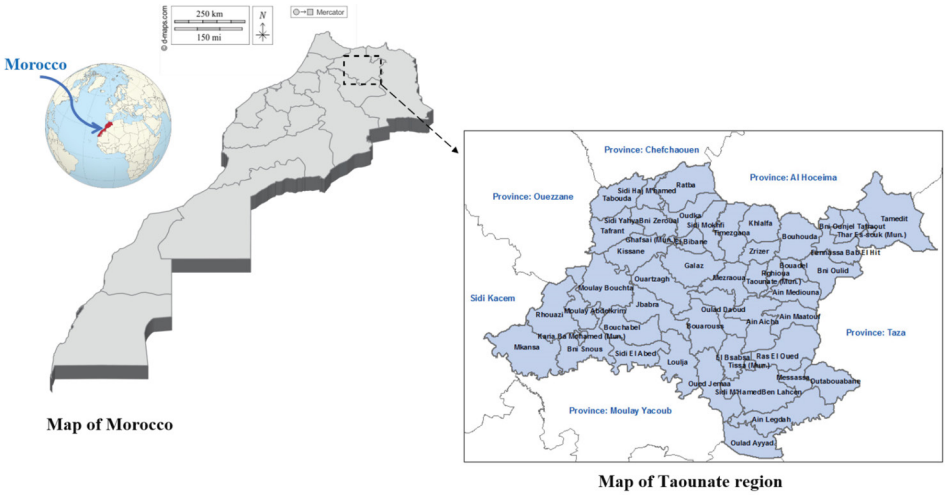

Figure 1. Geographical location of the study area, Taounate (Morocco).

vulnerable space. This territory consists of two distinct parts, the northern part with mountainous relief attached to the Rif area, covers about 40% of the total area of the province, and its altitudes vary and go up to 1800 m, as well as the southern part with hilly relief, attached to the pre-Rif, covers about 60% of the total area with an altitude up to 1000 m in Jbel Zeddour (15).

Ethnopharmacological survey and data analysis

The present survey was carried out using a pre-established questionnaire (Supplementary file 1) submitted to approximately 100 randomly selected and individually questioned individuals. There were no specific selection criteria for the choice of the study participants. The survey was performed during a period of 3 months, from January to March 2022 via semi-structured interviews in Arabic and French. During each interview, lasting about 30 minutes, information about participants (age, educational level, family situation, occupation) and the studied medicinal plants (characters and uses) were collected. These data entered on raw forms were transferred to a database and processed by the IBM SPSS version 21 statistical processing software.

Plants authenticity was carried out by Pr. Amina BARI (Botanist at Sidi Mohamed Ben Abdellah University, Fez, Morocco), and voucher samples, *S. officinalis* (SO 001880111), *D. viscosa* (DV 002260127) and *D. carota* (DC 002010132) (Figure 2) were deposited in the form of dried plants in the herbarium of the Laboratory of Natural Substances, Pharmacology, Environment, Modeling, Health & Quality of Life, Faculty of Sciences. Moreover, the European and Mediterranean Plant Protection Organization's online database (https://www.eppo.int) supplied an EPPO code for each plant species, *S. officinalis* (SALOF44001), *D. viscosa* (INUVI 34981) and *D. carota* (DAUCA29773). An EPPO code provided an ID-identifier of plant species gathering both scientific and common names.

Ethical statement and consent to participate

The present ethnobotanical survey was conducted with the approval of the committee for ethical research of the Laboratory of Natural Substances, Pharmacology, Environment, Modelling, Health and Quality of Life, Sidi Mohamed Ben Abdellah University. Verbal and signed consent was provided by the indigenous population. The participants were informed about the purpose of this study, taking into account confidentiality and anonymity.

Literature background

To confirm the ethnomedicinal usage of *D. carota* ssp. carota, *D. viscosa*, and *S. officinalis*, bibliometric research has been executed on the bioactivities of the selected plants. Information has been composed of PubMed, Scopus, Web of Science, Medline, ScienceDirect, SpringerLink, and Google Scholar. The following Keywords were employed to facilitate the documentation of information: "*Daucus carota*", "*Dittrichia viscosa*", "*Salvia officinalis*" or "ethnobotanical, ethnopharmacological, and phytochemical, and essential oil, and pharmacological". UPAC names of chemical compounds were verified using PubChem databases.

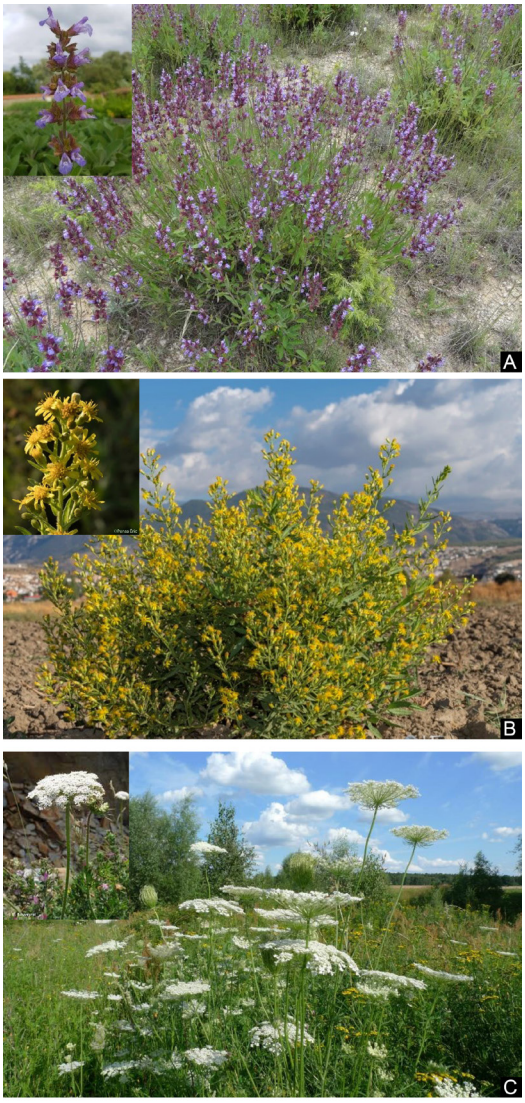

Figure 2. Moroccan *Salvia officinalis* (A), *Dittrichia viscosa* (B), and *Daucus carota* L. ssp *carota* (C) at flowering stage.

Results

Socio-demographic profile of the informants

The use of herbal medicines concerned all age groups (Table 1), with a slight dominance among people having 30 to 40 years (26%), 40-50 years (23%), and >50 years (27%). While the medicinal plant usage was very low (8%) for the youngest informants (<20 years).

Men used the studied medicinal plants at a percentage of 41%, while women represented 59% of users. The latter had a little more knowledge about the use of plants.

Table 1. Socio-demographic profile of respondents

Sociodemographic characteristics	Variable	Percent
Age	<20	8
	20-30	16
	30-40	26
	40-50	23
	50-60	17
	>60	10
Gender	Male	41
	Female	59
Family Situation	Single	32
	Married	68
Educational level	No schooling	35
	Primary	32
	Secondary	24
	University	9
Information origin on medicinal plants use	Experiences of others	71
	Books	11
	Herbalists	18

Herbal remedies were more used by married people (68%) than by singles (32%). This is likely due to the high costs of medical examinations and treatment drugs. The majority of herbal users had primary school level (32%) or were out of school (35%). Those having a secondary level represented an average percentage of 24%. People with high school and university education have used herbs less frequently (9%). The current survey revealed that 71% of the studied population used to refer to the experience of others to use herbal remedies against specific diseases, which is in accordance with the transmission of traditional Arab medicine practices. Besides, 18% of the population referred to herbalists, and 11% to books (Table 1).

Salvia officinalis

a. Denomination, type of plant, technique, and time of harvest

Most respondents in the Taounate region stated that the vernacular name of *S. officinalis* L. is ''Sâlmya'', the plant is spontaneous and harvested manually in the spring.

b. Plant parts used

The traditional care by *S. officinalis* in the study area mainly concerns the aerial parts, particularly the leaves (66%), followed by stems (18%), while other plant parts (Flowers, seeds, and rhizomes) are less used (Figure 3A).

c. Diseases treated by Salvia officinalis

In the study area, genitourinary diseases occupy the first place in terms of traditional care with *S. Officinalis* (33%), followed by neurological (26%) and type 2 diabetes (22%). The least treated disorders are the digestive tract (7%) and dermatological (3%) ones. There were other uses of this plant by the local population with a percentage of 9% (Figure 3B).

d. Posology, preparation methods, and administration mode of remedies

Salvia officinalis is mainly used in the form of herbal tea (79%) and powder (15%). Moreover, decoction is the most common preparation mode (38%), followed by infusion (27%), and the consumption of raw plant (15%).

Dittrichia viscosa

a. Denomination, type of plant, technique, and time of harvest

Most of the people surveyed in the study area stated that the vernacular name of the plant species, *Dittrichia viscosa* is 'Terreklan' or 'Magraman'. The vast majority of responders indicated that this plant is spontaneous and harvested manually in the spring.

b. Plant parts used

The most used parts of *D. viscosa* by the indigenous population of Taounate were the leaves (46%) followed by combinations of different parts (49%), while rhizomes were weakly used (5%) (Figure 4A).

c. Posology

Dittrichia viscosa is used mostly in the form of powder (46%) and extract (41%) in Taounate region. The poultice

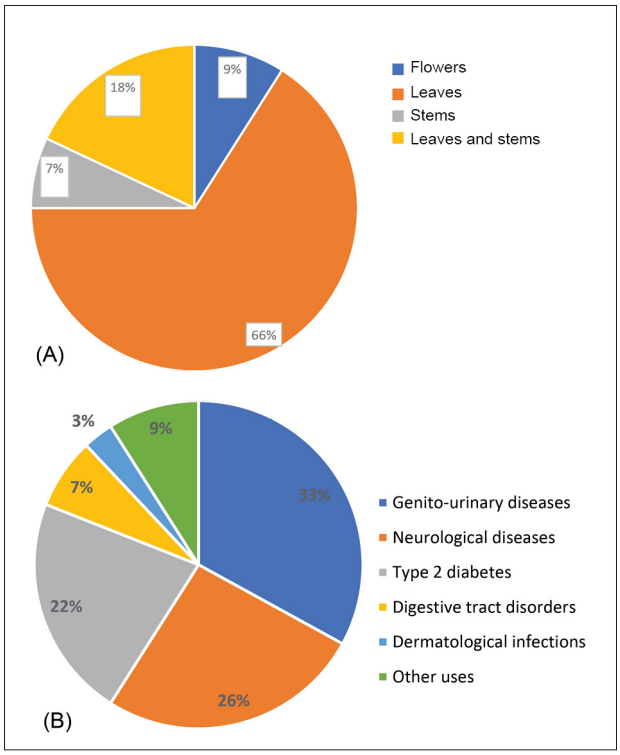

Figure 3. Ethnomedicinal characteristics of *Salvia officinalis*; (A) different plant parts used, (B) treated diseases.

was the most frequent method of preparation (72%) while the other techniques as infusion and decoction represented 28%. In addition, *D. viscosa* was mainly used by rinsing (68%), brushing and rinsing (21%), or brushing alone (11%).

d. Diseases treated by Dittrichia viscosa

Dittrichia viscosa was primarily used to treat dermatological infections (83%). Additionally, it was utilized to treat genito-urinary diseases (10 %) and digestive tract disorders (7%) (Figure 4B).

Daucus carota L. ssp *carota*

a. Denomination, type of plant, technique, and time of harvest

The species *Daucus carota* L. is commonly known as 'zerrîat kizzu'. The majority of respondents indicated that the plant is spontaneous and harvested manually in the spring.

b. Plant parts used

The most used parts of *D. carota* were the leaves and stems at a rate of 78%, followed by seeds (22%) (Figure 5A).

c. Posology

According to the interviewed people, *D. carota* was mainly consumed cooked or raw, and most often administered orally, in the form of powder and juice.

d. Diseases treated by Daucus carota

Daucus carota is mainly used to treat digestive tract disorders (56%), followed by genito-urinary diseases (44%) (Figure 5B).

Ethnomedicinal value and side effects of the three medicinal plants

This ethnobotanical survey revealed a high proportion of traditional medicine users in the Taounate region (74%), while only 26% used to consume modern medicine. Among the traditional medicine users 45% believed in its effectiveness, while 25% used it for its lower cost, 21% for habit, and 9% mentioned drugs ineffectiveness. Most of people using modern medicine believed in its precision (54%) and effectiveness (42%) compared to traditional medicine. Furthermore, 71% of the studied population referred to the experiences of others to use medicinal plants, as remedy against specific diseases, which is in accordance with the transmission of the traditional Arab medicine practices, while 18% referred to herbalists and 11% to books.

Finally, the majority of respondents diagnosed their ailments themselves (74%), 20% resorted to herbalists because they were well-informed about herbal medicine and had inherited the profession and experience, while

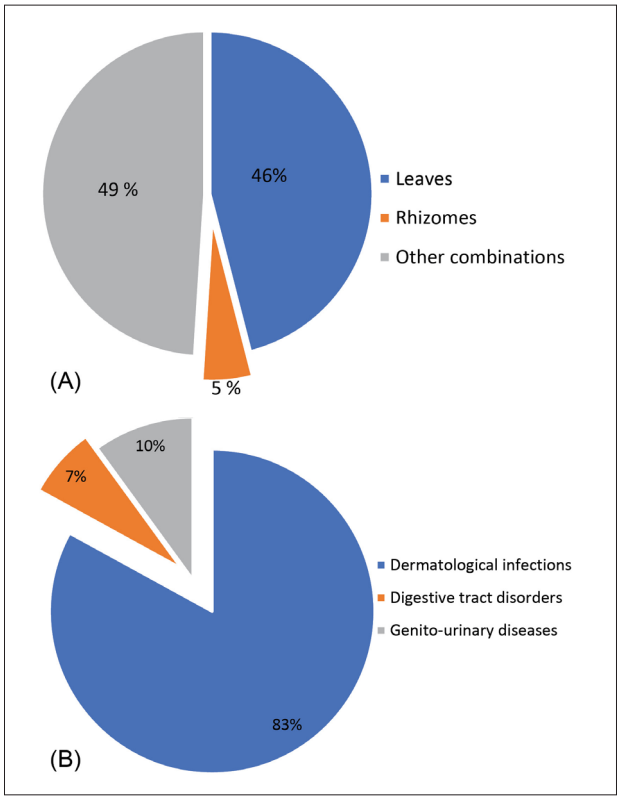

Figure 4. Ethnomedicinal aspects of *Dittrichia viscosa*; (A) plant parts used, (B) treated diseases.

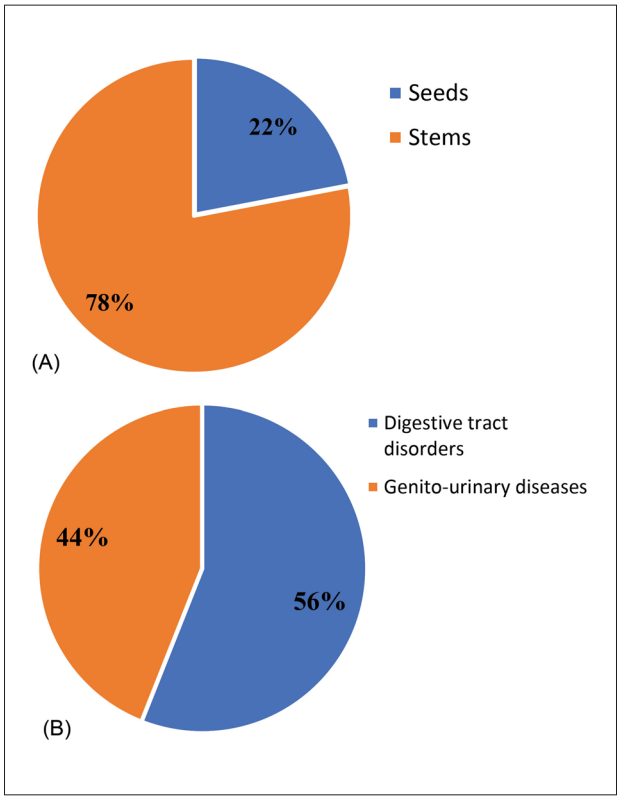

Figure 5. Ethnomedicinal aspects of *Daucus carota*; (A) plant parts used, (B) diseases treated.

a small minority (6%) had made a diagnosis through a doctor.

Discussion

Natural resources, especially medicinal plants have gained much attention in the drug design and discovery to develop novel candidates. This study provides comprehensive information on the ethnomedicinal use of three traditional medicinal plants, namely *D. carota*, *D. viscosa*, and *S. officinalis*. The traditional usages revealed for these plant species were confirmed through bibliometric investigation, highlighting their chemical profiles and health benefits, and pharmacological properties. In this ethnobotanical survey, the sociodemographic characteristics showed that the studied medicinal plants were generally used by older people, especially women (59%). Thereby, the oldest people benefit from a better knowledge of medicinal plants due to the accumulated experience and the popular know-how transmission. The youngest informants (<20 years) had less information about medicinal herbs. These results are concomitant with those reported in the Targuist area by Zouhri and Aarab (16), who found a percentage of 37% for respondents from 30-40 years and 15% for respondents under 30 years. Ouaritini et al (17) also reported a use frequency of medicinal plants of 35% for people between 40 and 50 years old, and only 10% for those having 20-30 years in the Imouzzer region (Morocco). El Hachlafi et al. (18) found low medicinal plants use (7.94%) among young informants (<30) for an ethnopharmacological study of medicinal plants used for chronic disease treatment in the Rabat-Sale-Kenitra region. Furthermore, other ethnobotanical studies showed that women had more traditional phytotherapeutic knowledge than men (16,19,20). Moreover, married people had an attitude toward the use of traditional remedies based on medicinal plants. Similar results were found in the region of Mechrâa Bel Ksiri (Northwest of Morocco) (21), and in Taounate city (20). As indicated before, the ethnomedicinal practices of *D. carota, D. viscosa*, and *S. officinalis* depend on the education levels of the participants. Indeed, the majority of participants had primary school levels or were illiterate. This could be due to an increase in vigilance level about potential adverse effects of medicinal plants, with the individual education level. These findings confirm the results obtained in different areas of Morocco, especially the Targuist, Gharb, and Laayoune regions (16,20,22,23). The studied population adopted their traditional knowledge of the use of these plants, mainly by referring to the experience of other people. This could be explained by the high illiteracy rate in the region and the low resources of the local population, or even by the high popular know-how level of traditional medicine uses of medicinal plants in the study area. This may confirm that the oldest people benefit from a better knowledge of such plants thanks to the accumulated experience and the popular know-how transmission.

Salvia officinalis is a traditional medicinal plant widely used by the Moroccan population to treat various pathological conditions. In this study, the decoction of the aerial parts of *S. officinalis* was mainly used for herbal preparations to treat several illnesses, including genitourinary diseases, neurological disorders (26%), and diabetes mellitus (22%). The predominance of aerial parts utilization is consistent with the results reported by El Yahyaoui et al (23), Kadri et al (24), and El Hachlafi et al (25). The high frequency of decoction use could be explained by the fact that heat suppresses the plant's toxicity (26) and allows the collection of maximum molecules and mitigates the toxicity of some recipes. Indeed, it also prevents the destruction of some ingredients (18). *S. officinalis* is mainly administered orally. The dominance of oral administration is in accordance with the results of other studies (18,27), and comes back to the ease and speed of absorption of the active compounds contained in the plant (28,29).

Nowadays, several researches have shown that *S. officinalis* EOs are used in many industrial fields due to their wide biological and pharmacological properties, such as antimicrobial, antiviral, antioxidant, anticancer (4), antidiabetic (5), and anti-inflammatory activities. Table 2 presents the main pharmacological, biological, and phytochemical properties of *S. officinalis*.

The antibacterial activity of sage has been clearly demonstrated in the literature against a large number of Gram-positive and Gram-negative bacteria. A previous study showed that the sage EO has a strong antibacterial effect against many bacteria such as *Staphylococcus aureus, Escherichia coli* 1554, *E. coli* 1429, *E. coli* ATCC 25922, *Proteus mirabilis, Pseudomonas aeruginosa* 7244, and *P. aeruginosa* ATCC 27853 with inhibition zones diameters ranging from 15.50 to 30.54 mm at the EO dilution of ¼ (30). Besides, Longaray Delamare et al revealed that EO from Brazilian *S. officinalis* L. possessed an important antibacterial effect on *S. aureus* and *E. coli* (31). Additionally, the antifungal properties of *S. officinalis* EO have been studied against a significant number of fungal isolates. Indeed, Jirovetz et al (32) reported its promising antifungal activity against various species of *Candida* with minimum inhibitory concentrations ranging from 60 to 80 µg/mL. Furthermore, several research teams have evaluated this EO antioxidant potential. Indeed, Kheyar et al (33) found that the volatile oil had a strong reducing power of DPPH (IC_{50} = 360.45 ± 0.57 µg/mL). Moreover, Abad et al (34) evaluated the anti-inflammatory and analgesic effects of *S. officinalis* hydro-alcoholic extract on Vincristine drug-induced peripheral neuropathy in mice in comparison with morphine, and showed its anti-inflammatory potential by decreasing significantly the pain responses following vincristine administration. Regarding anticancer activity, Xavier et al. (35) showed

Table 2. Pharmacological and biological activities of *Salvia officinalis*

Activity	PU	Extract	Study type	Method	Key results	Main Bioactive compounds	References
Antibacterial	AP	EO	*In vitro*	DDM against *S. aureus, E. coli* 1554, *E. coli* 1429, *E. coli* ATCC 25922, *P. mirabilis, P. aeruginosa* 7244 and *P. aeruginosa* ATCC 27853	IZ= 15.50-30.54 mm	α-thujone	(30)
Antifungal	AP	EO	*In vitro*	BDM against *Candida albicans, C. albicans* ATCC 10231, *C. guilliermondii, C. tropicalis* and *C. utilis*	MIC= 60 - 80 µg/mL	Camphor, α-thujone, β-thujone, 1,8-cineole, linalool, linalyl acetate	(32)
Antioxidant	AP	EO	*In vitro*	DPPH, BHT, ascorbic acid	IC_{50} = 360.45 ± 0.57µg/mL IC_{50} = 18.83±1.02 µg/mL IC_{50} = 3.36±0.28 µg/mL	Thymol, carvacrol, Iso-dihydrocarveol	(33)
Anti-inflammatory	AP	EHA	*In vivo*	Effects of hydroalcoholic extract of *S. officinalis* on vincristine-induced peripheral neuropathy in mice	*S. officinalis* extract showed anti-inflammatory effects and decreased pain responses following vincristine administration in mice	Not-identified	(34)
Anticancer	AP	EO	*In vitro*	Effect of *S. officinalis* and *S. fruticosa* aqueous extracts on the proliferation of cell lines derived from human colon carcinomas, HCT15 and CO115	*S. officinalis* induced apoptosis in both cell lines, whereas cell proliferation was inhibited by both sage extracts only in HCT15	Not-identified	(35)
Anti-anxiety	AP	AE	*In vivo*	*S. officinalis* had cholinesterase inhibiting properties and improved memory performance and mood	Inhibition of cholinesterase, improved mood and cognitive performance continued	Not-identified	(36)

PU: part used; AP: aerial part; EO: essential oil; EHA: hydroalcoholic extract; AE: aqueous extract; IZ: inhibitory zone; BDM: broth dilution method; DDM: disc diffusion method; MIC: minimal inhibitory concentration; DPPH: 2,2-diphenyl-1-picryl-hydrazyl-hydrate; IC_{50}: median inhibitory concentration; BHT: butylated hydroxytoluene.

that *S. officinalis* and *Salvia fruticosa* aqueous extracts and rosmarinic acid could induce apoptosis in HCT15 and CO115 cell lines derived from human colon carcinomas. This activity could be due to the inhibition of the MAPK/ERK pathway (35).

Salvia officinalis EOs are broadly rich in bioactive compounds. Terpenoids and phenolic compounds are the two main chemical families of secondary metabolites identified as typical products of this plant species (37). The *S. officinalis* EO includes mainly monoterpenes (Camphor, α- and β-thuyone, 1,8-cineole, and borneol) and sometimes in greater quantities sesquiterpenes (*α*-humulene and β-caryophyllene). There is great chemical variability among the *S. officinalis* EO; however, it can generally be stated that *ß*-thujone and *α*-thujone are predominant (38). Among the phenolic compounds, *S. officinalis* contains rosmarinic, carnosinic, salvianolic, and caffeic acid (39). The EO of *S. officinalis* harvested in the National Park of El-Kala (northeastern Algeria) showed a significant percentage of terpene compounds mainly *α*-thujone, then cineole, camphor, β-thujone, and other minor compounds (borneol, β-humulene, eucalyptol, and L-camphor) (30). *S. officinalis,* from Spain, has a terpene compound chemotype with a predominance of camphor, followed by cineole and a low rate of thujone (40).

As mentioned, the indigenous population of Taounate mainly used the leaves of *D. viscosa* in the form of powder as a poultice to manage the dermatological infections caused by bacteria, fungi, and parasites. This finding is similar to the results previously obtained in the Gharb region, which mentioned that *D. viscosa* was mainly used to treat dermatological infections (22). In addition, the predominance of leaf use is consistent with the results of previous surveys (23,24). The most recent information on the pharmacological and biological properties of *D. viscosa* is presented in Table 3. This plant is known as a traditional remedy, but there is great diversity in its use. In Spain, this plant is used to treat gastro-duodenal disorders, inflammation, and diabetes (41). In Jordan, it is used to treat tuberculosis, bronchitis, and rheumatic fever. The plant is prescribed as an abortion inducer (42,43). It was also reported to have anti-jaundice and powerful disinfectant effects on wounds (44). Interestingly, the flavonoid content of *D. viscosa* could be responsible for its anti-ulcer action (45). Moreover, *D. viscosa* EOs and extracts demonstrated important antifungal activity against *Candida* spp and dermatophytes (46). Moreover, Mssillou et al (47) showed the high antioxidant potential of two *D. viscosa* extracts (acetonic and ethanolic extracts).

According to previous data, the phytochemistry of *D. viscosa* has been investigated. A recent study showed that some *D. viscosa* extracts were rich in phenols, flavonoids, and tannins, with a significant percentage of trimethylsilyl-meso-inositol, followed by 5(4H)-thebenidinone and bis(methylthio)-4-(2-phenylethenyl). While its EO contained a significant percentage of monoterpenes and sesquiterpenes. The major compounds were bornyl acetate, borneol, *α*-amorphene, and caryophyllene oxide (47).

Furthermore, polygodial, phytol, fokienol, intermedeol neo, and caryophyllene oxide were reported as the main compounds of EOs of *D. viscosa* leaves and stems, collected at the flowering stage, in 15 localities of Algeria (48).

Daucus carota is a medicinal plant known for its numerous therapeutic virtues and has shown a number of traditional practices in Moroccan folk medicine. Our survey indicated that the leaves and stems (aerial parts) are the most used parts of *D. carota* and in particular in cooked or raw form. In addition, *D. carota* aerial parts are mainly administered orally to treat several diseases, including digestive and genito-urinary diseases. The predominance properties of the aerial parts are consistent with the results of other studies (20, 24). This could be due to their key roles in the photochemical reactions and in the storage of secondary metabolites (total polyphenols), which are responsible for plant properties (49-51).

In this regard, the results of a literature review regarding the pharmacological and biological properties of *D. carota* are presented in Table 4. The *D. carota* roots are widely used for food and medicinal purposes (6). In addition, the fruits, flowers, roots, leaves, and stems have shown antifungal and antibacterial properties (12). These plant parts have also shown other promising properties, including anti-inflammatory, antiparasitic, antioxidant, antithrombotic, and antisteroidogenic activities, as well as preventive effects against cancer and liver damage (13).

In the literature, the antibacterial and antifungal activities of *D. carota* have been clearly elucidated against a large number of bacterial strains, including both Gram-negative and Gram-positive bacteria. Indeed, *D. carota* seeds EOs exhibited strong antibacterial effects against *S. aureus*, *E. coli, S. typhimurium*, and *C. albicans* with inhibition zone diameters ranging from 8.7 ± 0.7 mm to 26.7 ± 3.3 (52) and from 6.0 ± 00 to 13 ± 00 mm (53).

The extensive ethnomedicinal use of *D. carota* ssp. has also encouraged many research teams to evaluate its antioxidant potential. Meliani et al (54) reported that the methanolic extract of *D. carota* showed the highest radical scavenging activity with the lowest IC_{50} value of 0.068 mg/mL, followed by the aqueous extract (IC_{50} = 0.644 mg/mL), and the EO (IC_{50} = 40.97 mg/mL). Furthermore, Mani et al (55) evaluated the antinociceptive and anti-inflammatory activities of *D. carota* and showed that 200 and 400 mg/kg of its ethanolic extract induced inhibition of histamine, carrageenan, and serotonin-induced edema in rats, as well as arthritis and the analgesic effect of salicylic acid.

In sum this work focused on the ethnopharmacological survey concerning Moroccan *S. officinalis, D. viscosa*, and *D. carota* and drew several conclusions on the ethnobotanical reality of these medicinal plants. The

Table 3. Pharmacological and biological activities of *Dittrichia viscosa*

Activity	PU	Extract	Study type	Method	Key results	Main bioactive compounds	References
Antibacterial	AP AP	EE EAC EO	*In vitro*	DDM BDM against *Bacillus subtilis, Staphylococcus aureus, Salmonella enterica, E. coli, Candida albicans, Aspergillus niger.* DDM against *S. aureus* ATCC2592, *S. aureus* SARM, *Listeria innocua* CLIP 74915, *Bacillus cereus* ATCC 11778, *Enterococcus faecalis, P. aeruginosa* ATCC 27853, *Klebsiella pneumoniae* ATCC700603, *E. coli* ATCC 25922, *Enterobacter cloacae, Acetobacter, Serratia marcescens, Serratia liquefaciens*, ESBL/ BLSE and *S. enterica.*	IZ= 9 ± 0.05 à 3.3 ± 0.08 mm MIC= (0.93 ± 0.00 à 15 ± 0.00) mg/mL MBC= (>20mg/mL) IZ= 18.72 - 17.19 mm	Trimethylsilyl-meso-inositol, 5(4H)-thebenidinone, flavonoids, tannins, polygodial, phytol, fokienol, neo-intermedeol, caryophyllene oxide, Z-nerolidol	(47,48)
Antifungal	AP	EE EAC	*In vitro*	DDM BDM Against *C. albicans, A. niger*	IZ = 7 ± 0.05 - 11.3 ± 0.06 mm MIC= (0.87 ± 0.00 - 10 ± 0.00) mg/mL MBC= (1.75 ± 0.00- >10 ± 0.00) mg/mL	Trimethylsilyl-meso-inositol, 5(4H)-thebenidinone (16.80%). tlavonoids, tannins	(47)
Antioxidant	AP	EE EAC	*In vitro*	DPPH FRAP TAC	IC_{50} = 12.54 ± 0.2 µg/mL for ETOH. IC_{50} = 7.84 ± 0.1 µg/mL for ACE EC_{50}= 6.37 ± 0.012 mg/mL for ETOH EC_{50}= 6 ± 0.022 mg/mL for ACE EC_{50}= 253.52 ± 2.98 mg AAE/g pot ACE EC_{50}= 189.14 ± 4.86 mg AAE/g for ETOH	Trimethylsilyl-meso-inositol, 5(4H)-Thebenidinone (16.80%). Flavonoids, Tannins	(47)

PU: part used; AP: aerial part; EO: essential oil; IZ: inhibitory zone; BDM: broth dilution method; DDM: disc diffusion method; MIC: minimal inhibitory concentration; MBC: minimal bactericidal concentration; EAC: acetonic extract; EE: ethanolic extract; TAC: total antioxidant capacity; FRAP: ferric reducing power; DPPH: 2,2-diphenyl-1-picryl-hydrazyl-hydrate; IC50: median inhibitory concentration

Table 4. Pharmacological and biological activities of *Daucus carota* L. ssp *carota*

Activity	PU	Extract	Study type	Method	Key results	Bioactive compounds	References
Antibacterial	S	EO	*In vitro*	DDM against *E. coli*, *Salmonella typhimurium* and *Staphylococcus aureus*	IZ= 8.7±0.7 - 26.7 ± 3.3 mm	β-Bisabolene; sabinene, geranyl acetate, elemicin.	(52)
Antifungal	S F	EO EO	*In vitro* *In vitro*	DDM against *Candida albicans.* DDM BDM against *C. albicans* (RKMUz - 247)	IZ = 11.0 ± 2.3 - 16.7 ± 2.8 mm IZ = 13 ± 0.0 mm MIC = 12 µL/mL	β-Bisabolene; sabinene, geranyl acetate, elemicin, carotol, daucene, *trans*-*α*-Bergamotene, *trans*-β-farnesene, β-bisabolene, *α*-pinene, β-himachalene	(52,53)
Antioxidant	AP	ME AE EO	*In vitro*	DPPH	IC_{50} = 0.068 mg/mL IC_{50} = 0.644 mg/mL IC_{50} = 40.97 mg/mL	*α*-Pinene, sabinene, β-pinene, limonene, myrcene, terpinene-4-ol, p-cymene.	(54)
Anti-inflammatory	AP	ME	*In vivo*	Effect of the extract on edema induced by carrageenan, serotonin and histamine as well as arthritis in rats.	Inhibition of edema induced by carrageenan, serotonin and histamine in rats as well as arthritis and inhibition of the analgesic effect of salicylic acid.	Not-identified	(55)
Anti-demence	S	EE	*In vitro*	Effects on memory in rats.	Significant improvement in memory of young and old rats induced by scopolamine (0.4 mg/kg, ip) and diazepam (1 mg/kg).	Not-identified	(55)

PU: part used, AP: aerial part, IZ: inhibitory zone, BDM: broth dilution method, DDM: disc diffusion method, S: seeds, F: fruit, ME: methanolic extract; AE: aqueous extract, EO: essential oil.

survey showed that married people, particularly women, were more interested in medicinal plants and that people in the 30–40 age range typically utilized more herbal treatments. Despite the high percentage of illiteracy, the indigenous population is characterized by great know-how in traditional herbal medicine and people rely on traditional medicine for the treatment of several diseases. Furthermore, leaves, flowers and stems are the most used plants parts. Herbal remedies are mainly prepared by decoction, infusion and poultice; and are most often taken orally to treat digestive tract, genito-urinary, dermatological, neurological, and metabolic diseases. Due to the listed therapeutic virtues and the diversity of their chemical composition, the studied plants have great potential as sources of bioactive molecules for the formulation of new drugs. Indeed, literature revealed that essential oils and extracts of these plants are extensively rich in bioactive molecules that are responsible for their medicinal properties as well as their antimicrobial, antioxidant, anti-inflammatory, antidiabetic, and anticancer activities. More pharmacological and clinical studies are necessary to ensure the safety of these plants and to identify novel medicinal properties. Phytochemical investigations are also needed to detect new bioactive constituents of interest in the pharmaceutical and food industries. To confirm the posology of the plant extracts, toxicological tests are also required.

Conclusion

The findings of this research prove the traditional uses of the three studied plants and suggest not only their potential pre-clinical (*in vitro* and *in vivo*) properties, but also their clinical applications. However, further toxicological assessments are also strongly required to ensure the safe use of these medicinal plants.

Authors' contributions

MJ: Contribution to study conception, participation in methodology, data analysis, and writing the first draft of the manuscript; ZBO: Study design and supervision, description of methodology, and botanical identification; RS: Carrying-out the ethnobotanical survey; KFB: Supervision of the work, improvement, and revision of the manuscript. All authors read, reviewed, and approved the final version of the manuscript.

Conflict of interests

The authors declare that they have no conflicts of interest.

Ethical considerations

This ethnobotanical survey was carried out with the approval of the Ethical Research Committee of the Laboratory of Natural Substances, Pharmacology, Environment, Modelling, Health and Quality of Life; Sidi Mohamed Ben Abdellah University (USMBA-SNAMOPEQ 2022-01). Ethical issues (including plagiarism, data fabrication, double publication etc) have been completely observed by the authors.

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Supplementary files

Supplementary file 1. Questionnaire: Ethnobotanical survey.

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