Medicinal flora in Egypt's hyper-arid land: Quantitative insights into distribution, diversity, and conservation status

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Ethnobotany Research and Applications 30:75 (2025) - http://dx.doi.org/10.32859/era.30.75.1-40
Manuscript received: 24/03/2025 – Revised manuscript received: 07/06/2025 - Published: 08/06/2025

Research

Abstract

Background: Egypt was not immune to the climatic changes occurred worldwide, especially during the past five decades, these changes may be accompanied by changes in land use, as well as the extinction of many plant species. This review includes the current status of the Egyptian natural plant resources with special reference to distribution, diversity, and conservation status in different biogeographic regions of Egypt. It also represents baseline information for all subsequent studies related to medicinal plants in Egypt and arid regions.

Methods: Databases were reviewed to get information on the medicinal plants utilized in Egypt. The biological spectrum was determined following Raunkiaer's system. Differentiation indices were used to describe the taxonomic degrees of divergence across the recorded species. Besides, plant species were classified according to their used parts. Species diversity was estimated among biogeographic regions of Egypt and then analyzed using the Chao-Jaccard index. Species' conservation status was evaluated using the IUCN Red List of Threatened Species. A hierarchical cluster analysis and Principal Components Analysis were performed to classify and ordinate the reported species in nine Operation Geographical Units (OGUs), and a heatmap was used to visualize the cluster analysis.

Results: A total of 113 medicinal plant species, belonging to 49 families was documented. Brassicaceae, Fabaceae, Lamiaceae, were the families with higher contribution. In terms of species richness and diversity, the Sinai region was the highest diverse followed by the Mediterranean and Nile regions reflecting their ecological richness and diverse habitats. The least diversified regions were Gebel Uweinat and the Western Desert. Therophytes were the dominant life form, while, hydrophytes and parasites were poorly represented. Twenty Wide Range Species was recorded. The predominant plant parts used were leaves, aerial parts, and seeds. Approximately 54% of the recorded species were included in the IUCN Red List of Threatened Species. Most of them were classified as Least Concern, three as Data Deficient and one as Near Threatened.

Conclusions: Protecting and conserving economic medicinal plants is an urgent need, including improving knowledge about the important ecological requirements of these species, and raising awareness among all stakeholders to protect this heritage and avoid biodiversity loss.

Keywords: Arid environments, Biogeography, Climate change, Desert vegetation, Folk medicine, Threats to biodiversity

Background

The Medicinal plants, renowned for their diverse array of secondary metabolites with significant therapeutic potential, thrive globally and provide essential health support to humanity. Ethnobotany, the field examining the relationship between humans and plants, focuses particularly on how different communities utilize plants, especially for medicinal purposes (Domingo-Fernández *et al.* 2023). These plants serve as a vital source of beneficial therapeutic effects in traditional health systems, particularly for indigenous communities, and are a crucial resource for drug discovery. The interaction between humans and nature has led to the accumulation of extensive traditional knowledge regarding the use of medicinal plants, which is recognized as crucial for preserving plant biodiversity and understanding the dynamic relationships between wild plants, social, and cultural systems. However, this traditional knowledge is at risk due to its oral transmission between generations, coupled with modernization, lifestyle changes, and disinterest among younger generations. Additionally, the lack of systematic documentation further contributes to the potential loss of knowledge about medicinal plants, especially those that are neglected or less preferred. Therefore, ethnobotanical surveys are essential for documenting and preserving this valuable knowledge, which can lead to the valorization of priority medicinal plants with high therapeutic potential for new drug discoveries.

Medicinal plants have been used in many cultures for thousands of years. Traditional plant-based medicine systems continue to play an essential role in health care. In fact, the World Health Organization (WHO) estimates that approximately 80% of the world's population rely mainly on traditional remedies for their health care (Gottlieb & Kaplan 1993). Globally, 422,000 flowering plants are reported (Govaerts 2001). Out of these, about 50,000 plants are used for medicinal purposes (Schippmann *et al.* 2002). These plants are most important elements of biodiversity around the world (Klein *et al.* 2008; Okigbo *et al.* 2008) because of their role in ecosystem services such as healthcare, cultural value and heritage, local economics and human wellbeing, especially in poor areas. Conserving and protecting these kinds of species is vital, including improving knowledge about the important ecological requirements of medicinal plants, and raising awareness among all stakeholders to protect this heritage. Consequently, conservation planning and effective management is important in protecting the most threatened species in order to avoid declines in the diversity of medicinal plants.

Human activities are having a strong impact on plant abundance and distribution, with consequent effects on ecosystem services and human well-being (Klein *et al.* 2008). This growing effect of human activities on biodiversity (Chapin *et al.* 2000) creates an urgent need to understand the elements that determine the distribution and abundance of plants in order to enhance their conservation (Dubuis *et al.* 2011). The identification of species-rich regions and those where geographically limited species co-occur can optimise the creation of Protected Areas (Bojórquez-Tapia *et al.* 1995).

Large human population in developing countries is dependent on plant resources for healthcare because allopathic medicine can cure a wide range of diseases, but its high prices and occasional side effects are causing many people to return to herbal medicines which tend to have a fewer side effect (Kala 2005). In last few decades, traditional knowledge on primary healthcare has been widely acknowledged across the world. It is estimated that 60% of the world population and 80% of the population of developing countries rely on traditional medicine, mostly plant drugs, for their primary health care needs (Shrestha & Dhillion 2003). Therefore, there is an urgent need to document the medicinal and aromatic plants associated with traditional knowledge, because this knowledge orally passes on from one generation to the next; thus, have vulnerability to wiped out. The earliest recorded history of civilization from ancient culture of Africa, China, Egypt and Indus valley revealed evidence in support of the use of herbal medicine by dweller of those regions (Baqar 2001). Use of plants as a source of medicine has been inherited and is an important component of the health care system in Egypt. Keeping the traditional inherent knowledge, nowadays, Egyptians still depend on medicinal plants for primary health care needs (AbouZid & Mohamed 2011).

By the middle of the nineteenth century at least 80% of all medicines were derived from plants. Then, after the scientific revolution which leads to development of the pharmaceutical industry, the synthetic drugs dominated (Gilani & Atta-ur-Rahman 2005). This is particularly true in developing countries, where traditional systems of medicine have a long and uninterrupted history of use. Recognition and development of the medicinal and economic benefits of traditional medicinal plants is on the increase in both developing and industrialized countries, although it varies greatly from region to region (Zhang 1998). Herbal drugs are prescribed widely because of their effectiveness, fewer side effects and are relatively low in cost (Odhav *et al.* 2010).

Most of Egypt's landmass is below 500 m above sea level, which limits potential diversity. About 95% of Egypt land is desert, the Western Desert constitutes one of the most extreme arid desert habitats in the world. Generally, the Nile valley divides Egypt into two geomorphological regions: the eastern dissected plateau and the western flat expanse which form an extension of the Libyan Desert (Figure 1). Although the land to the east of the Nile forms one geomorphological region, it is divided geographically into the Eastern Desert and the Peninsula of Sinai, separated by the Gulf of Suez. Three areas of Egyptian desert may therefore be distinguished: The Eastern Desert, The Western Desert and The Sinai Peninsula. Phytogeographically, Egypt can be divided into 5 main phytogeographic regions: The Western Desert (including the oases and depressions), the Eastern Desert (including Gebel Elba and Red Sea coastal land), the Sinai Peninsula, the Nile Land (including the Nile Valley and the Nile Delta), and the Western Mediterranean Coast (Figure 1).

The hyper-arid land of Egypt has two features relevant to biological diversity: (1) it has been inhabited by active human assemblages since millennia, and (2) it is the home habitat of plant species that are parents and relatives of several foods, crop plants and of hundreds of species that are traditional drug plants. Indigenous species are known for their resistance to disease and drought and their wide range of morphological, physical and chemical adaptation (Bidak *et al.* 2013). The wealth of natural plant resources in Egypt is represented by desert plants that constituted the principal vegetation which composed mainly of xerophytic shrubs, subshrubs and herbs (Zahran & Willis 2009). Ecologically, Egyptian deserts are classified into two types; coastal and inland deserts. These deserts are among the most reproductive systems in the world and provide a disproportionately more services to human well-being than most other systems even those covering larger total areas (Millennium Ecosystem Assessment 2005). However, many of recently recorded human activities result in sever impacts on this desert ecosystem (Hussein *et al.* 2021). The major anthropogenic impacts include over-grazing, over-collection, urbanization, and military activities.

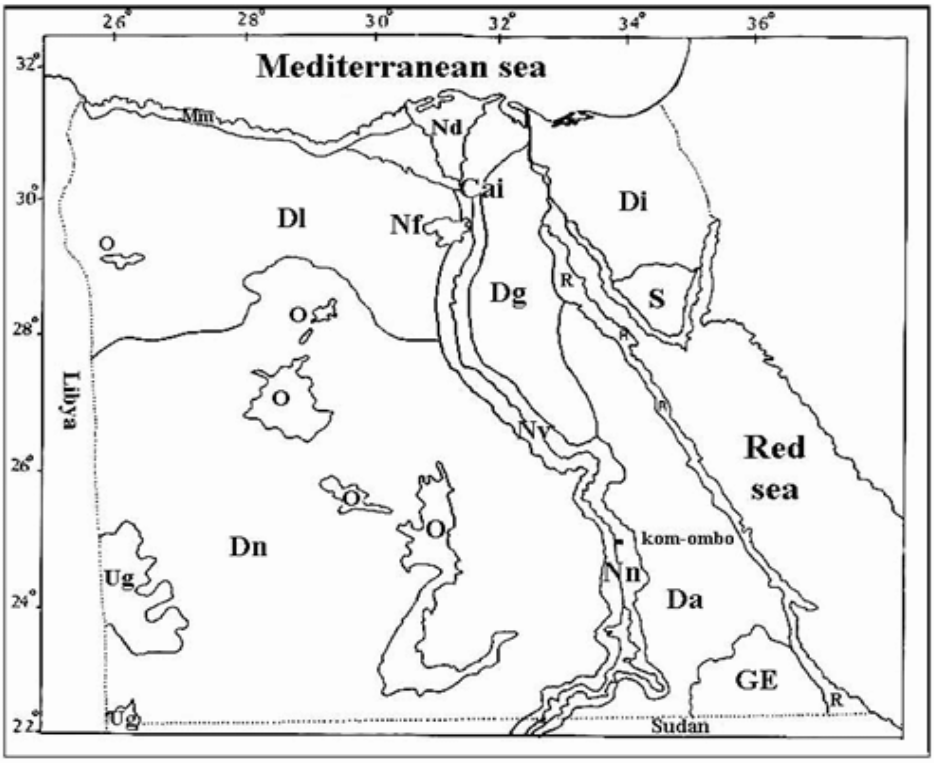

Figure 1. Map indicating the phytogeographical regions in Egypt (after El-Saadawi *et al.* 2015) Cai: Cairo Area; Da: Arabian Desert; Dg: Galala Desert; Di: Isthmic Desert; Dl: Libyan Desert; Dn: Nubian Desert; GE: Gebel Elba; Mm: Western Mediterranean Coastal Land (Mareotic sector); Nd: Nile Delta; Nf: Nile Fayoum; Nn: Nile Nubia; Nv: Nile Valley; O: Oasis; R: Red Sea Coastal Plains; S: Southern Sinai (Sinai proper); Ug: Gebel Uweinat

The ancient Egyptians recorded much of their knowledge of plant drugs and their uses and many of these drugs are still used in medicine. Historic medicine in Egypt is full of recipes for curing various diseases and the use of plants as medicines are well documented on the walls of temples and in the papyri e.g. the famous Ebers Papyrus, written in 1550 B.C. with 876 prescriptions made of 328 different ingredients derived from many plant species. Some examples of the plant's species identified are: Artemisia absinthium, Vachellia nilotica, Balanites aegyptiaca, Bryonia sp., Hyoscyamus muticus, Myrtus communis, Onopordon sp., Aloe, gums, myrrh, pomegranate, colocynth, linseed, squil, coriander, cumin, onions, anise, grapes, castor oil and Ziziphus sp. All plant organs such as roots, rhizomes, flowers, leaves, fruits, seeds, as well as oils were used for medicaments in the form of powders, pills, suppositories, creams, pastes and ointments (Haggag 1997).

Since Pharaonic times, the use of medicinal plants has occurred in Egypt (Manniche 1999). This constituted an integral part of the practiced medicine at that time. Nowadays, Egyptians still depend on medicinal plants for treatment. In a recent study conducted by the Information and Decision Support Centre in Egypt, it was found that 23% of the Egyptian use medicinal plants as a remedy; 52% of them are living in urban areas and 48% are living in countryside. Sinai Peninsula is one of the important centers of medicinal plants in the Arabian deserts. Distributions, utilization in folk medicine, and active constituents of medicinal plants in Sinai have attracted the attention of many ecologists, taxonomists and phytochemists (see Abd El-Wahab *et al.* 2008 for more literature). Environmental conditions and human impacts have a significant influence on diversity and distribution of threatened, endemic, and medicinal plants (Abd El-Wahab *et al.* 2004).

The current review aims to provide a comprehensive overview of medicinal plants in Egypt, benefiting the preservation and dissemination of traditional knowledge. It explores the diversity and distribution of these plants across Egypt's different biogeographical regions, as well as their current conservation status and nativity, using techniques of multivariate analyses. It also represents baseline information for all subsequent studies related to medicinal plants in Egypt and arid region.

Materials and Methods

Study area

Egypt is a low-lying country occupies the north-eastern part of the African continent, with total area of a little more than million km2, representing nearly 3% of the total area of Africa (Abd El-Ghani *et al.* 2017). It extends over about 10 degrees of latitude, being bounded between Lat. 22°N and 32°N, i.e. lies mostly within the temperate zone, less than a quarter being south of the Tropic of Cancer. The whole country forms part of the great desert ‘’Sahara’’ belt that stretches from the Atlantic across the whole of North Africa through Arabia. It is a cross-road territory with its Mediterranean front connecting it with Europe with which it has had biotic exchanges during the Glacials and the Interglacials, and today we know that routes of migratory birds converge through Egypt. Two highway corridors join Egypt with tropical Africa and beyond: The Nile Valley and the basin of the Red Sea. The Sinai Peninsula is the bridge between Africa and Asia.

Egypt is characterized by a hot and almost rainless climate. The average annual rainfall over the whole country is only about 10 mm. Even along the narrow northern strip of the Mediterranean coastal land where most of the rain occurs, the average annual rainfall is usually less than 200 mm and the amount decreases very rapidly inland (southwards). The scanty rainfall accounts for the fact that the greater part of the country is barren and desolate desert.

Literature survey

Various databases were consulted to gather information on the medicinal plants used in Egypt, including published articles from Google Scholar, Scopus, Web of Science, PubMed, DOAJ, and Science Direct. The search terms employed for retrieving relevant articles were "medicinal plants," "ethnobotanical survey," "ethnobotanical study," "folk medicinal plants," "Egypt," and "economic potential of desert plants." Information on the medicinal uses, plant parts utilized, and geographic distribution of these plants was systematically collected. To ensure the accuracy of the recorded plant species, the binomials of recorded plants were validated with the main electronic sources and online global databases such as African Plant Database (APD; http://www.ville-ge.ch/musinfo/bd/cjb/africa), Global Biodiversity Information Facility (GBIF; http://www.gbif.org/occurrence),International Plant Names Index (IPNI; http://www.ipni.org), Plants of the World Online (POWO; http://www.plantsoftheworldonline.org), World Checklist of Selected Plant Families (WCSP; http://wcsp.science.kew.org/home.do), World Flora Online (WFO; https://www.worldfloraonline.org), and WFO Plant List (https://wfoplantlist.org/plant-list).

Distribution in biogeographical regions

This study explored the distribution patterns of medicinal plants across the entire country. The distribution patterns of medicinal plant among the different biogeographical regions of Egypt (Figure 1) were established based on the localities mentioned in the literature (El Hadidi & Fayed 1994/95, Boulos 1995-2009). Each biogeographic region was referred to as an operational geographical unit (OGU) to detect the distribution patterns of the medicinal plants. In this analysis, 10 OGUs were used (see Figure 1 for full names), and presence/absence of each species in different biogeographic regions was recorded. Distribution maps of some medicinal plants were prepared using ArcGIS 10.4 software (ESRI 2016) and based on the geographical locations attained with GPS for each plant species within its OGU.

Taxonomic differentiation

Differentiation indices, which comprised a species differentiation index (Ds), a genus differentiation index (Dg), and a species–family differentiation index (Dsf), were used to describe the taxonomic degrees of divergence across medicinal plant species (Huang *et al.* 2016). The three indices' respective functions were displayed as follows:

Species differentiation index (Ds)=Ns/Ng;
Genus differentiation index (Dg)=Ng/Nf;
Species–family differentiation index (Dsf)=Ns/ Nf

the numbers Ns, Ng, and Nf represent the number of medicinal plant species, genera, and families of medicinal flora, respectively, within an OGU.

Biological spectrum

For the analysis of the biological spectrum, the life form of each species was determined following Raunkiaer's classification system (Raunkiaer 1937) as follows: phanerophytes (PH), Chamaephytes (CH), Hemicryptophytes (H), Geophytes (G), therophytes (TH), parasites (P), hydrophytes (Hy), and climbers (Cl). The t-test feature in SPSS version 16.0 for Windows assessed the significance of the life form distribution patterns in each OGU.

Nativity and endemism

Each of the recorded species was assigned to either native (N) or introduced (NN) using the online global database Plants of the World Online (POWO; http://www.plantsoftheworldonline.org). In this study, the term 'native' (indigenous species) referred to those occur in a given region or ecosystem as a result of only natural processes, with no human intervention (IUCN 2025). They are integral parts of the natural community and play a role in the food web and ecosystem processes. The term 'introduced' (non-indigenous, alien species or exotic plants, non-native) referred to plants that have been brought outside of their original habitats due to deliberately or involuntarily by human activities, and they have an impact on the biodiversity of native plants (Kowarik 1995, Chandra *et al.* 2015). In this investigation, we adopted the definitions proposed by Abd El-Ghani *et al.* (2024) for endemic and near-endemic taxa. Taxa occurring exclusively within the political borders of Egypt are classified as "endemic", whereas those that also occur globally outside Egyptian borders are categorized as "near-endemic". Taxa lacking identification were referred to as "not identified".

Parts of medicinal plants used

Based on data compiled from published literature (Osborn 1968; Boulos, 1983; El-Demerdash 2001; Heneidy & Bidak 2004; Mahmoud & Gairola 2013), the medicinal plant species under study were classified according to their used parts into the following categories: underground (UG), fruit (F), seed (S), leaf (L), inflorescence (IN), aerial part (AP), bark (B), plant secretion (PS), wood (W), and others (O). Each species was assigned to its respective used parts, and its distribution across different biogeographic regions (OGUs) was indicated using a binary system: (+) for used and (-) for not used.

Conservation status

The IUCN, 2025 is the most significant source of information about species conservation worldwide. The conservation status of each species was evaluated using the categories proposed by this system. In this study, a scale of seven categories was used as follows: Data Deficient (DD: there is inadequate information to make assessment of a taxon's risk of extinction), Least Concern (LC: the taxon has been evaluated against the Red List criteria and does not qualify for Threatened or Near-Threatened), Near Threatened (NT: the taxon has been evaluated against the criteria of the Red List criteria and does not qualify for Threatened now, but is close to qualify for the Threatened category in the near future), Vulnerable (VU: the taxon is considered to be facing a high risk of extinction in the wild), Endangered (EN: the taxon is considered to be facing a very high risk of extinction in the wild), Critically Endangered (CR: the taxon is considered to be facing an extremely high risk of extinction in the wild), and Extinct (EX: there is no reasonable doubt that the last individual has died).

Species diversity

The species richness (SR) for each OGU was calculated as the total number of species per a biogeographic region (OGU). Additionally, the Shannon-Wiener diversity index (H') was used to assess relative species evenness, following the formula

H'=−Σpi lnpi; where pi=Ni/N, where Ni is the number of species I in an OGU, and N is the total number of all species in the OGU (Magurran 2021). Species richness (SR) and Shannon-Wiener diversity index (H') represent the α-diversity, and are widely used in ecological studies (Mahdavi *et al.* 2013, Zhang & Zhang 2017). Beta diversity among the 9 OGUs was analyzed using the Chao-Jaccard index; it is more suitable for evaluating the similarity of samples of various sizes with many rare taxa and considers unobserved shared taxa (Chao *et al.* 2005). For this purpose, the program Estimates for Windows version 7.5 (Colwell 2005) was used.

Data processing and analysis

A hierarchical cluster analysis was performed to classify the 68 medicinal plant species recorded in the 9 OGUs using their presence/absence in the corresponding OGU, and a presence percentage (P%) was calculated. Ward's method (minimum variance) as the agglomeration criterion (Orlóci 1978) and squared Euclidean distance dissimilarity matrix in PAST software version 4.03 (Hammer *et al.* 2001) was used as classification tool. To ensure the robustness of the resultant classification of stands, we devised a second classification using Sørensen (Bray-Curtis) as a distance measure and flexible beta at -0.6 as a group linkage method of PC-Ord version 5 for Windows (McCune & Mefford 1999). The latter classification produced nearly identical to the results obtained by the former, which was approved in this study. To visualize the cluster analysis, a heatmap was used using Clustvis: a web tool for visualizing clustering of multivariate data using Principal Component Analysis and heatmap (Metsalu *et al.* 2015). The color intensity in each cell of the heatmap typically represents the strength or frequency of the relationship between an OGU and a species. Darker or more intense colors usually indicate a stronger relationship, while lighter colors suggest a weaker or absent relationship.

A Principal Components Analysis (PCA) was used for ordination of the 9 OGUs along the first two axes, to illustrate the separated species groups. For this purpose, Clustvis (Metsalu *et al.* 2015) was applied to visualize the ordination scatterplot.

All graphs and were performed using RAW Graphs (Mauri *et al.* 2017) which is an open source data visualization framework built with the goal of making the visual representation of complex data. All statistical analyses were performed using SPSS for windows version 16. All photos in this review were taken by the first author (Monier Abd El-Ghani) during several visits to different regions of the country.

Results and Discussion

Taxonomic differentiation

A total of 113 medicinal plant species (included 1 Pteridophyte and 2 Gymnospermae), belonging to 49 families and 97 genera, were documented in Egypt. Among these, 11 families accounted for 64 species, representing over 60% of the total species (Figure 2). Medicinal plant diversity showed that the plant families contributing higher number of medicinal species were Brassicaceae (10 species, (8.8% of the total), followed by Fabaceae and Lamiaceae, each contributing 8 species (7.1% of the total flora). Apiaceae, Asteraceae, and Poaceae were equally represented, with 7 species each (6.2%), while Convolvulaceae and Solanaceae each had 4 species (3.5%). Similarly, Plantaginaceae, Polygonaceae, and Zygophyllaceae each contributed 3 species (2.6%). The small-size families which included 1 or 2 species constituted the majority (38 families) of recorded families forming 49 species (43.4% of the total). Important genera were Cymbopogon (4 species), Plantago (3 species), and Convolvulus (3 species). In North Sinai, Abd El-Wahab *et al.* (2008) documented 281 species of medicinal plants from 52 families of which Asteraceae, Poaceae, Fabaceae, and Brassicaceae, included the highest number of species. Along the coastal Mediterranean region of Egypt, Heneidy & Bidak (2004) indicated that Asteraceae, Fabaceae and Poaceae were the highly represented families. Abdela *et al.* (2022) indicated the dominance of Asteraceae, Fabaceae, Lamiaceae, and Apiaceae among other families in the investigation of medicinal plant species in Nensebo District, south-eastern Ethiopia. In Western Sudan, Muhakr *et al.* (2024) reported that Fabaceae, Asteraceae and Poaceae were represented by highest number of species. Similar results were obtained in this review.

Among the biogeographical regions (OGUs), the genus differentiation index (Dg) was highest in the Mediterranean region (M) at 1.7, followed by the Nile region and Sinai (S), both with equal values of 1.6. In contrast, the species-family differentiation index exhibited a distinct pattern (Table 1), with the Nile region recording the highest index (2.1), while the Gebel Uweinat region (Uw) and the entire Western Desert (Dw) had the lowest indices. In terms of family richness, the Sinai region hosted the highest number of families (42), followed by the Mediterranean region (38) and the Nile region (32). Conversely, the Western Desert and Gebel Uweinat regions had the lowest family counts.

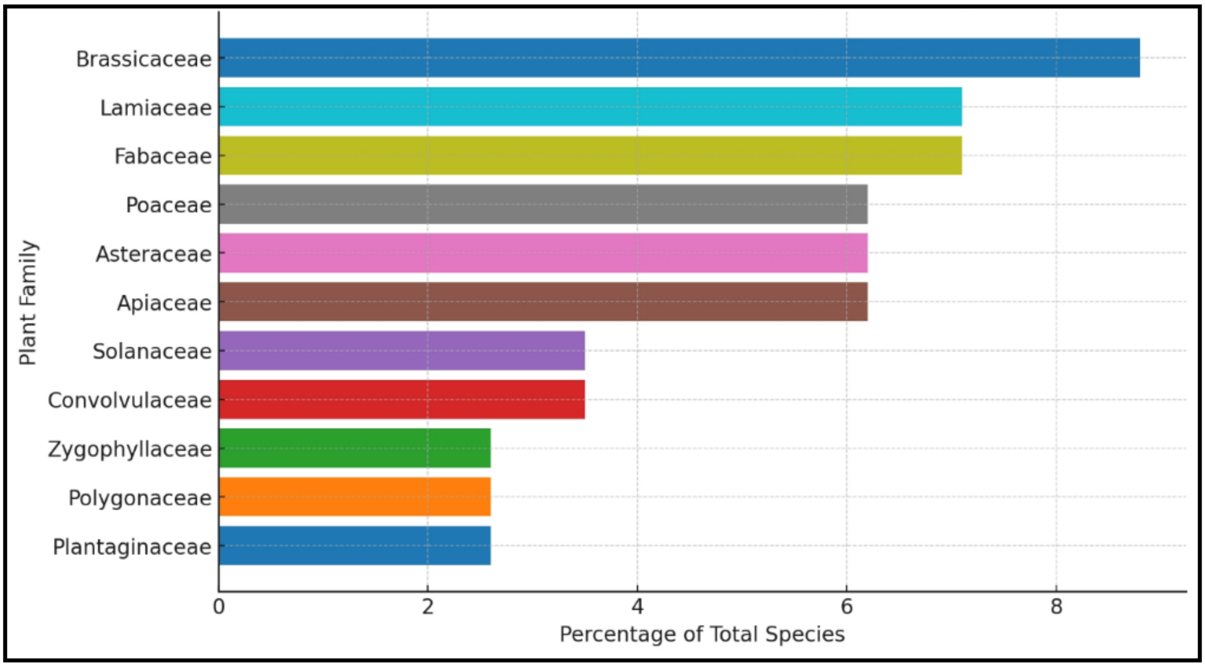

Figure 2. Families with the highest number of species

Table 1. Taxonomic differentiation of medicinal plants for each Operational Geographical Unit (OGU) in Egypt. Ds=Species differentiation index, Dg=Genus differentiation index, Dsf=Species–family differentiation index. For full names of OGUs, see Figure 1.

OGUs	**Taxonomic diversity**			**Differentiation indices**		
	No. of families	**No. of genera**	**No. of species**	**Ds**	**Dg**	**Dsf**
N	32	51	68	1.35	1.6	2.1
O	29	43	45	1.05	1.5	1.5
M	38	64	70	1.09	1.7	1.8
De	18	19	19	1.0	1.05	1.05
Dw	02	02	02	1.0	1.0	1.0
R	16	22	23	1.04	1.37	1.4
GE	20	23	24	1.04	1.15	1.2
S	42	68	77	1.13	1.6	1.8
Uw	03	03	03	1.0	1.0	1.0

Distribution of life forms within families

In general, therophytes were the dominant life form (37 species, 32.7% of the total), hemicyptophytes ranked second (22 species, 19.5%), and equal presentation of chamaephytes and phanerophyte (20 species for each, 17.7% of the total). Hydrophytes and parasites were poorly represented (2 species for each, 1.8%).

Figure 3 illustrated the distribution of the species-richest families within the 4 highly-represented categories of life forms. In context of the number of species, therophytes were represented in all families, with its high presence in Brassicaceae (8 species), chamaephytes included the highest number of species (6 species) in Lamiaceae, the majority of hemicryptophytes (4 species) was included Poaceae, and 3 species of phanerophytes were included in Fabaceae. The most common phanerophytes (6 and 5 OGUs) were *Phoenix dactylifera* L., *Ziziphus spina-christi* (L.) Desf., *Hyphaene thebaica* (L.) Mart., *Pluchea dioscoridis* (L.) DC., *Salix mucronata* Thunb., and *Salvadora persica* L. Common species among the 20 recorded chamaephytes were *Hyoscyamus muticus* L., *Zilla spinosa* (L.) Prantl, *Capparis spinosa* L., and *Senna alexandrina* Mill. Therophytes, which constituted the main bulk of species (37 species), included several common weed species such as

Ammi majus L., *Portulaca oleracea* L., *Urtica urens* L., *Plantago major* L., *Papaver rhoeas* L., *Lepidium sativum* L., *Matricaria chamomilla* L., and *Stellaria media* (L.) Vill.

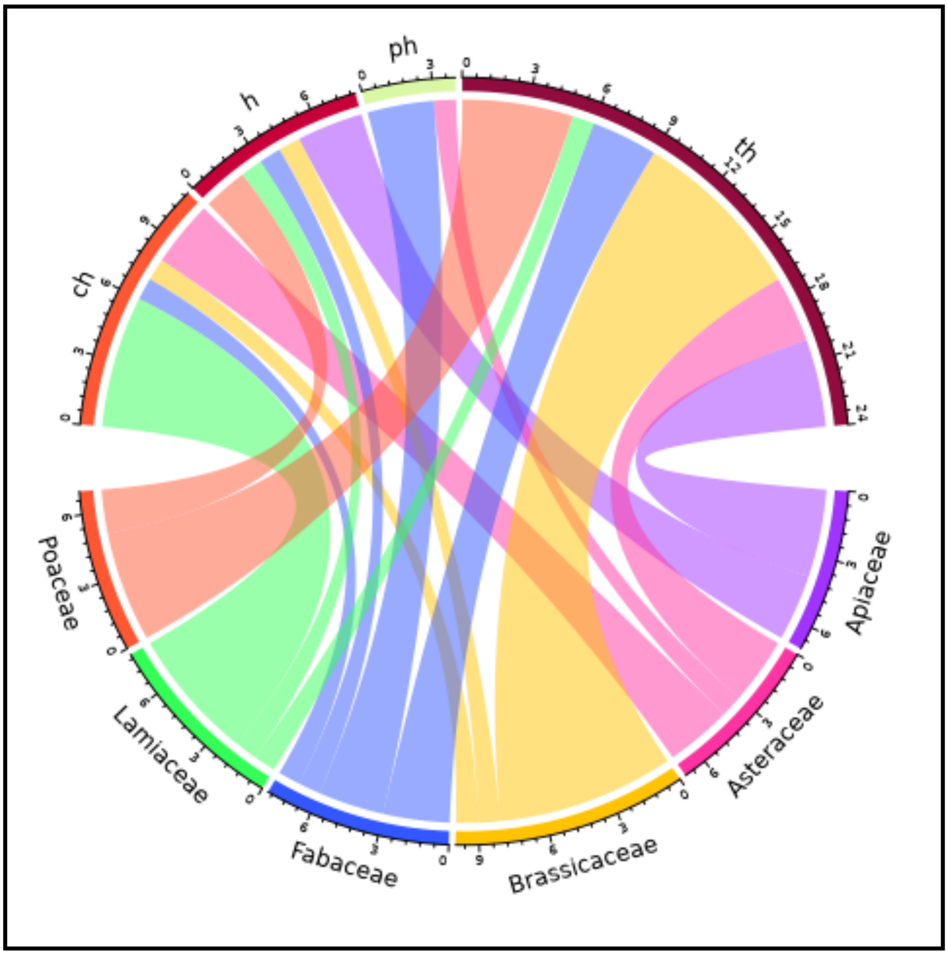

Figure 3. Distribution of the highly-represented categories of life forms within the species-richest families. ph=phanerophytes, ch=chamaephytes, th=therophytes, h=hemicryptophytes. Size of nodes represent the sum of incoming and outgoing links. Relationships are drawn as arcs whose widths represent their values

Distribution of medicinal plants within biogeographic regions (OGUs)

Variations in the distribution of medicinal plants across Egypt's biogeographic regions are striking. Figure 4 illustrates the percentage of medicinal plants found in each region. The Sinai region (S) stands out with the highest percentage at 68.1%, closely followed by the Mediterranean (M) and Nile (N) regions, both at approximately 61%. The Oases (O) region, with a moderate percentage of 39.8%, represents unique habitats within the Western Desert. Together, these regions account for about 70% of Egypt's medicinal flora, reflecting their ecological richness and diverse habitats, including coastal zones, the Nile River and its delta, and mountainous areas like Sinai. In contrast, the Eastern Desert (De), Gebel Elba (GE), and Red Sea (R) regions show lower percentages, ranging from 16.8% to 21.2%. Gebel Elba, known for its unique flora and fauna, benefits from its mountainous terrain and proximity to the Red Sea. The Oases region also contributes significantly to medicinal plant diversity, offering unique desert habitats. The Gebel Uweinat (Uw) region has the lowest percentage at just 2.6%, likely due to its extreme aridity and harsh environmental conditions. This distribution indicated the influence of climatic and environmental factors on diversity of medicinal plants. The Sinai, Mediterranean, and Nile regions, with their favourable conditions and higher moisture levels, support a rich diversity of medicinal plants. In contrast, arid regions like Gebel Uweinat and the Eastern Desert have fewer medicinal plants, consistent with their challenging environments. These findings emphasize the importance of conserving Egypt's biodiverse regions to safeguard its medicinal plant heritage.

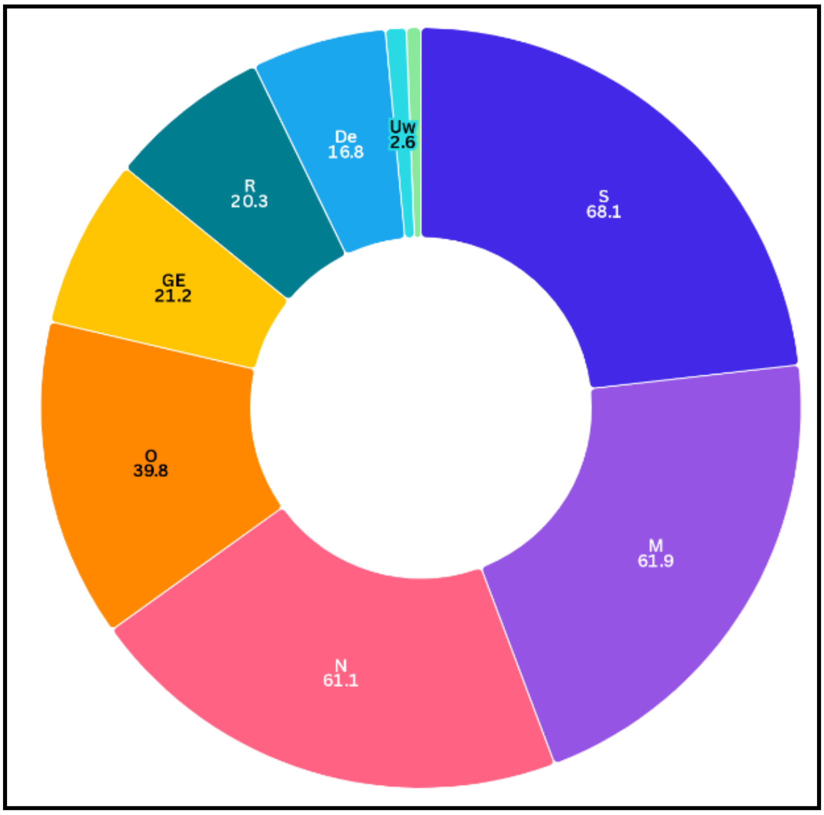

Figure 4. Proportionate of the medicinal plant species in different biogeographical regions of Egypt (OGUs). M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat

Table 2 provides an overview of the distribution of medicinal plant species within 9 Operational Geographic Units (OGUs). These species can be categorized into four groups according to their geographical range: (1) Wide Range Species (WRS), those found in 5 and 6 OGUs; (2) Moderate Range Species (MRS), those found in 3 and 4 OGUs; (3) Narrow Range Species (NRS), those found in 2 OGUs; and (4) Limited Range Species (LRS), those restricted to a single OGU. Figure 5 displayed distribution maps of some medicinal plants in different OGUs.

Wide Range Species (WRS), constituted 20 species recorded in six and 5 OGUs (P=67-55%), indicating a broad distribution range. Examples included *Ziziphus spina-christi*, *Adiantum capillus-veneris*, *Citrullus colocynthis*, *Cyperus rotundus*, *Hyoscyamus muticus*, *Phoenix dactylifera*, and *Zilla spinosa*, which occurred in six OGUs (67%), while *Alhagi graecorum*, *Capparis spinosa*, and *Portulaca oleracea* occurred in five regions (55%). The differences between 67% and 55% highlighted that while many WRS were highly adaptable, some have slightly more restricted ranges, possibly due to specific ecological niches or environmental tolerances.

Moderate Range Species (MRS) comprised a group of 44 species which were recorded in four and three OGUs (P=44-33%). Examples include *Balanites aegyptiaca*, *Ficus carica*, *Trifolium alexandrinum*, *Achillea fragrantissima*, and *Artemisia judaica*. Twenty-one species (47.7% of this group) were among the common weeds of cultivation (Boulos & El-Hadidi, 1994; Abd El-Ghani *et al.* 2015; Hussein *et al.* 2025), amongst others.

Narrow Range Species (NRS) are present in two and three OGUs (22-33%). Examples include *Colchicum autumnale*, *Marrubium alysson*, *Teucrium polium*, *Linum usitatissimum*, and *Nigella sativa*. The decrease from 44% to 22-33% shows a further narrowing of distribution. These species are more specialized and likely require very specific environmental conditions, making them less adaptable and more vulnerable to changes in their habitats.

Limited Range Species (LRS) are present in only one region (11%). Examples include *Capsella bursa-pastoris*, *Cuscuta epilinum*, *Cymbopogon citratus*, *Datura stramonium*, and *Lepidium latifolium*. The sharp decline from 22-33% to 11% underscores the high specialization and limited adaptability of these species. Their restricted range makes them particularly vulnerable to environmental changes and habitat destruction.

Table 2. Distribution of medicinal plants in the OGUs (see Figure 1 for the abbreviations of OGUs). +=present, -=absent. M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat

Species	**Species Abb.**	**N**	**O**	**M**	**De**	**Dw**	**R**	**GE**	**S**	**Uw**	**P(%)**
(1) Wide Range Species (WRS)											
Adiantum capillus-veneris L.	Ac	+	+	+	-	-	+	+	+	-	67
Citrullus colocynthis (L.) Schrad.	Cc	+	+	+	-	-	+	+	+	-	67
Cyperus rotundus L.	Cr	+	+	+	-	-	+	+	+	-	67
Hyoscyamus muticus L.	Hm	+	+	+	-	-	+	+	+	-	67
Phoenix dactylifera L.	Pt	+	+	+	-	-	+	+	+	-	67
Zilla spinosa (L.) Prantl	Zsp	+	-	+	-	+	+	+	+	-	67
Ziziphus spina-christi (L.) Desf.	Zs	+	+	+	-	-	+	+	+	-	67
Alhagi graecorum Boiss.	Ag	+	+	+	-	-	+	-	+	-	55
Capparis spinosa L.	Cs	-	+	+	+	+	-	-	+	-	55
Eruca vesicaria subsp. *sativa* (Mill.) Thell.	Ev	+	+	+	+	-	-	-	+	-	55
Hypericum perforatum L.	Hp	+	+	-	+	-	+	-	+	-	55
Hyphaene thebaica (L.) Mart.	Ht	+	+	-	+	-	+	-	+	-	55
Juncus acutus L.	Ja	+	+	+	+	-	-	-	+	-	55
Pluchea dioscoridis (L.) DC.	Pd	+	+	+	+	-	-	-	+	-	55
Portulaca oleracea L.	Pol	+	+	+	-	-	-	+	+	-	55
Salix subserrata Willd.	Ss	+	+	+	+	-	-	-	+	-	55
Salvadora persica L.	Sp	+	+	-	-	-	+	+	+	-	55
Senna alexandrina Mill.	Sa	+	-	-	+	-	+	+	+	-	55
Tribulus terrestris L.	Tt	+	-	+	-	-	+	+	+	-	55
Urtica urens L.	Ur	+	+	+	+	-	-	-	+	-	55
(2) Moderate Range Species (MRS)											
Achillea fragrantissima (Forssk.) Sch. Bip.	Af	-	+	+	-	-	+	-	+	-	44
Ammi majus L.	Am	+	+	+	-	-	-	-	+	-	44
Anastatica hierochuntica L.	Ah	-	-	-	-	-	+	+	+	+	44
Artemisia judaica L.	Aj	-	-	+	-	-	+	+	+	-	44
Avena sativa L.	Av	+	+	+	-	-	-	-	+	-	44
Balanites aegyptiaca (L.) Delile	Ba	+	+	-	-	-	-	+	+	-	44
Mutarda nigra (L.) Bernh.	Bn	+	+	+	-	-	-	-	+	-	44
Cleome droserifolia (Forssk.) Delile	Cd	-	-	-	-	-	+	+	+	+	44
Convolvulus *arvensis* L.	Ca	+	+	+	-	-	-	-	+	-	44
Coriandrum sativum L.	Ca	+	+	+	-	-	-	-	+	-	44
Ficus carica L.	Fc	+	+	+	-	-	-	-	+	-	44
Lepidium sativum L.	Ls	+	+	-	+	-	-	-	+	-	44
Olea europaea L.	Oe	+	+	+	-	-	-	-	+	-	44
Plantago afra L.	Pa	-	-	-	+	-	+	+	+	-	44
Plantago major L.	Pm	+	+	+	-	-	-	-	+	-	44
Salvia aegyptiaca L.	Sa	-	-	+	-	-	+	+	+	-	44
Silybum marianum (L.) Gaertn.	Sm	+	+	+	-	-	-	-	+	-	44
Solanum nigrum L.	Sn	+	+	+	-	-	-	-	+	-	44
Trifolium alexandrum L.	Ta	+	+	+	-	-	-	-	+	-	44

Withania sommiferum (L.) Dunal	Ws	+	+	+	-	-	-	+	-	-	44
Vachellia nilotica (L.) P.J.H. Hurter & Mabb.	An	+	+	-	-	+	-	-	-	-	33
Ajuga iva (L.) Schreber	Ai	-	-	+	-	-	-	-	+	+	33
Apium graveolens L.	Agr	-	-	+	+	-	-	-	+	-	33
Artemisia herba-alba Asso	Aha	-	-	+	-	-	+	-	+	-	33
Blepharis edulis (Forssk.) Pers.	Be	-	-	-	-	-	+	+	+	-	33
Brassica rapa L.	Br	+	+	+	-	-	-	-	-	-	33
Cichorium intybus L.	Ci	+	+	+	-	-	-	-	-	-	33
Convolvulus althaeoides L.	Cal	-	-	+	+	-	-	-	+	-	33
Cyperus esculentus L.	Ce	+	-	+	-	-	-	+	-	-	33
Ephedra alata Decne.	Ea	-	+	+	-	-	-	-	+	-	33
Foeniculum vulgare Mill.	Fv	+	-	+	-	-	-	-	+	-	33
Malva sylvestris L.	Ms	+	-	+	-	-	-	-	+	-	33
Matricaria chamomilla L.	Mch	+	-	+	-	-	-	-	+	-	33
Mentha spicata L.	Msp	+	+	-	-	-	-	-	+	-	33
Orobanche crenata Forssk.	Oc	+	-	+	-	-	-	-	+	-	33
Papaver rhoeas L.	Pr	+	-	+	-	-	-	-	+	-	33
Peganum harmala L.	Phr	-	-	+	+	-	-	-	+	-	33
Petroselinum crispum (Mill.) Nyman ex A.W. Hill	Pcr	+	-	+	-	-	-	-	+	-	33
Plantago ovata Forssk.	Po	+	-	+	-	-	-	-	+	-	33
Rumex vesicarius L.	Rv	-	-	+	-	-	-	+	+	-	33
Solenostemma arghel (Del.) Hayne	Sar	-	-	-	+	-	-	+	+	-	33
Urtica pilulifera L.	Up	+	-	+	-	-	-	-	+	-	33
Verbena officinalis L.	Vof	+	+	+	-	-	-	-	-	-	33
Zygophyllum coccineum L.	Zc	-	+	-	-	-	+	-	+	-	33
(3) Narrow Range Species (NRS)											
Visnaga daucoides Gaertn.	Av	+	-	+	-	-	-	-	-	-	22
Bistorta officinalis Delarbre	Bo	+	-	+	-	-	-	-	-	-	22
Colchicum autumnale L.	Cau	-	-	+	-	-	-	-	+	-	22
Cymbopogon schoenanthus (L.) Spreng. subsp. *proximus* (Hochst. ex A. Rich.) Mailler & Weiller	Cpro	-	-	-	+	-	-	-	+	-	22
Drimia maritima (L.) Stearn	Dm	-	-	+	-	-	-	-	+	-	22
Faba vulgaris L.	Fvu	+	+	-	-	-	-	-	-	-	22
Hibiscus sabdariffa L.	Hs	+	+	-	-	-	-	-	-	-	22
Juniperus communis L.	Jc	-	-	-	+	-	-	-	+	-	22
Leonotice leontopetalum L.	Ll	-	-	+	-	-	-	-	+	-	22
Linum usitatissimum L.	Lu	+	+	-	-	-	-	-	-	-	22
Lupinus albus L.	La	+	+	-	-	-	-	-	-	-	22
Marrubium alysson L.	Mal	-	-	+	-	-	-	-	+	-	22
Marrubium vulgare L.	Mv	-	-	+	-	-	-	-	+	-	22
Mentha pulegium L.	Mpu	+	+	-	-	-	-	-	-	-	22
Moringa peregrina (Forssk.) Fiori	Mp	-	-	-	+	-	-	-	+	-	22
Narcissus tazetta L.	Nt	-	-	+	-	-	-	-	+	-	22
Nigella sativa L.	Ns	+	-	+	-	-	-	-	-	-	22
Nymphaea lotus L.	Nl	+	-	+	-	-	-	-	-	-	22
Polygonum aviculare L.	Pa	+	-	+	-	-	-	-	-	-	22

Posidonia oceanica (L.) Delile	Po	-	-	+	-	-	-	-	+	-	22
Ricinus communis L.	Rc	-	-	-	+	-	-	+	-	-	22
Sinapis alba L.	Sa	+	-	+	-	-	-	-	-	-	22
Sisymbrium officinale (L.) Scop.	Sof	+	-	+	-	-	-	-	-	-	22
Teucrium polium L.	Tpo	-	-	+	-	-	-	-	+	-	22
(4) Limited Range Species (LRS)											
Capsella bursa-pastoris (L.) Medik.	Cbp	+									11
Cuscuta epilynum Weihe	Ce	+									11
Cymbopogon citratus (DC.) Stapf	Cci	+									11
Cymbopogon nardus (L.) Rendle	Cna	+									11
Datura stramonium L.	Ds	+									11
Lepidium latifolium L.	Lla	+									11
Triticum aestivum L.	Tae	+									11
Zea mays L.	Zm	+									11
Bryonia cretica L.	Bcr			+							11
Coridothymus capitatus (L.) Rchb. f.	Ccp			+							11
Fumaria officinalis L.	Fo			+							11
Pistacia lentiscus L.	Ple			+							11
Stellaria media (L.) Vill.	Smd			+							11
Ziziphus lotus (L.) Lam.	Zl			+							11
Dodonaea viscosa Jacq.	Dvs							+			11
Ceratonia siliqua L.	Csq								+		11
Convolvulus scammonia L.	Ccm								+		11
Crataegus x *monogyna* Jacq.	Cmo								+		11
Cymbopogon schoenanthus (L.) Spreng.	Ssch								+		11
Ecballium elaterium (L.) A. Rich.	Eel								+		11
Ferula communis L.	Fco								+		11
Rhus coriaria L.	Rco								+		11
Viola odorata L.	Vod								+		11
Viola tricolor L.	Vt								+		11

The Spearman's correlation coefficients presented in Table 3 revealed several significant relationships between different OGUs of Egypt. The Nile region (N) showed a significant positive correlation with the Oases (O) at the 0.01 level (0.51**), indicating a strong association between these two regions, possibly due to shared environmental conditions or species interactions. However, the Nile region (N) has a significant negative correlation with Sinai (S) at the 0.05 level (-0.22*), suggesting contrasting ecological or environmental characteristics between these regions. The Sinai region (S) also showed significant positive correlations with the Eastern Desert (De) at the 0.01 level (0.25**) and with the Red Sea (R) at the 0.01 level (0.33**), indicating ecological similarities or shared species between these regions. The Red Sea (R) further demonstrated a significant positive correlation with Gebel Elba (GE) at the 0.01 level (0.62**), highlighting a strong ecological connection between these two regions, likely due to their proximity and similar climatic conditions. Interestingly, Gebel Uweinat (Uw) showed a significant negative correlation with the Nile region (N) at the 0.05 level (-0.20*), suggesting ecological differences between these regions. Additionally, Gebel Uweinat (Uw) has a significant positive correlation with the Red Sea (R) at the 0.05 level (0.19*), indicating some level of ecological similarity or interaction. Overall, the correlations suggested that while some regions share significant ecological connections (e.g., Nile and Oases, Red Sea and Gebel Elba), others exhibit distinct ecological characteristics (e.g., Nile and Sinai). These relationships could be influenced by factors such as geographical proximity, climate, and species distribution patterns. The non-significant correlations (NS) between many regions imply that they may have unique ecological dynamics with little interaction or overlap.

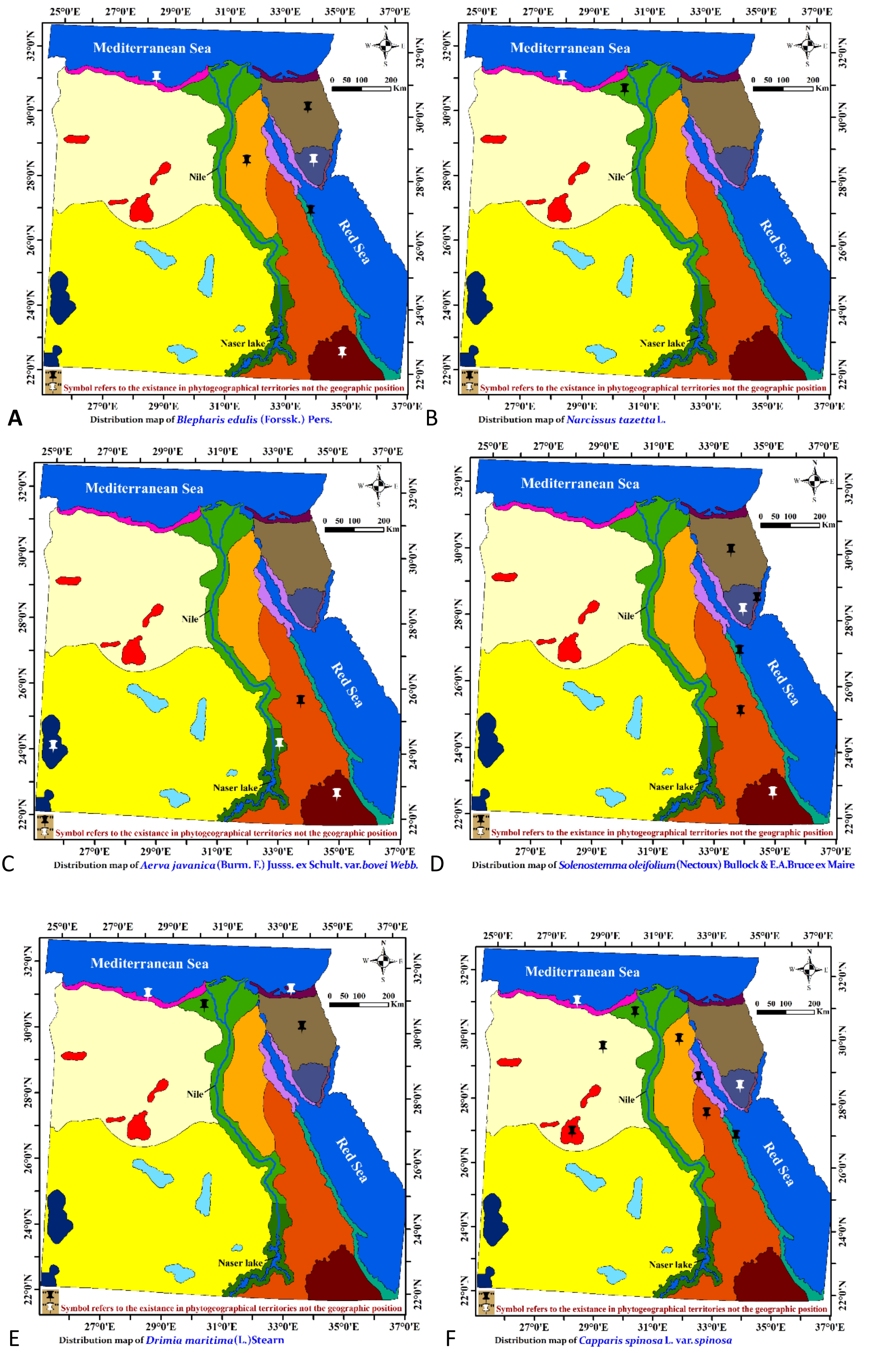

Figure 5. Species distribution maps in the different OGUs. A : *Blepharis edulis*, B : *Narcissus tazetta*, C : *Aerva javanica*, D : *Solenostema arghel*, E : *Drimia maritima*, and F: *Capparis spinosa*

To test the significant differences in the distribution of life form categories across different OGUs, ANOVA results indicated that the Nile biogeographic region showed strong significance at p<0.01 (F-ratio=4.031, p=0.001). In contrast, the Mediterranean (F-ratio=2.461, p=0.029), the Oases (F-ratio=2.762, p=0.16), and the Red Sea region exhibited significant differences at p<0.05 (F-ratio= 2.974, p=0.010).

Table 3. Pearson's correlation coefficients between the medicinal plant species recorded in different OGUs. ** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level. M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat

OGUs	N	O	M	De	Dw	R	GE	S
N								
O	0.51**							
M	NS	NS						
De	NS	NS	NS					
Dw	NS	NS	NS	NS				
R	NS	NS	NS	NS	NS			
GE	NS	NS	NS	NS	NS	0.62**		
S	-0.22*	NS	NS	0.25**	NS	0.33**	NS	
Uw	-0.20*	NS	NS	NS	NS	0.19*	NS	NS

Nativity and endemism of medicinal plants

Analysis based on Plants of the World Online (POWO; http://www.plantsoftheworldonline.org) revealed that the flora comprises 113 species, categorized as follows: 81 native species (71.7%, Figure 6), 20 introduced species, and 12 unidentified species. Regarding life forms of medicinal plants, therophytes were dominant, with 24 species in the native group and 12 in the introduced group. Additionally, native species exhibited significant numbers of chamaephytes (18), hemicryptophytes (15), and phanerophytes (14).

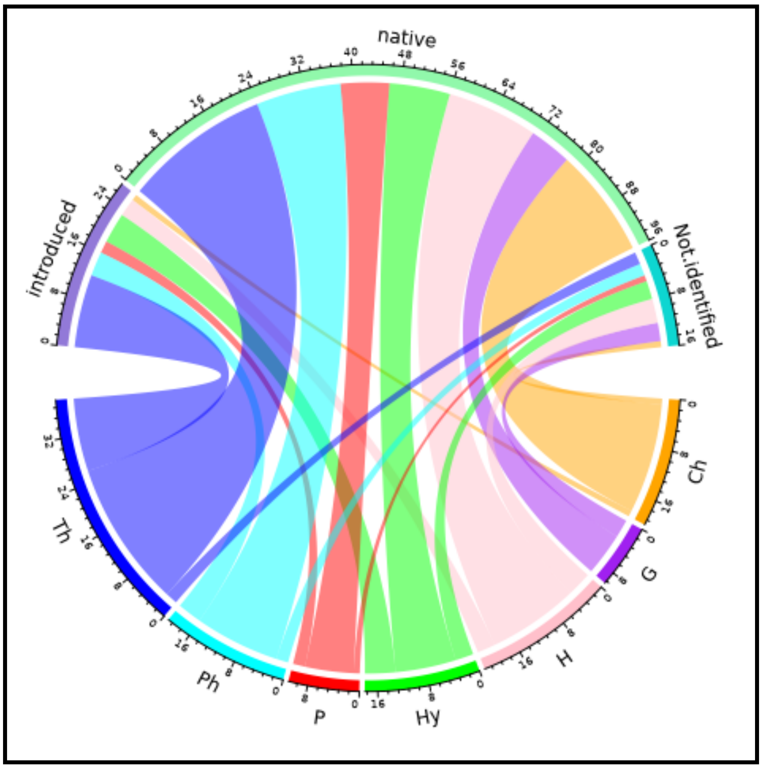

Figure 6. Distribution of categories of nativity within life forms (Th=Therophytes, Ch=Chamaephytes, Ph=Phanerophytes, G=Geophytes, Hy=Hydrophytes, P=Parasites, H=Hemicryptophytes)

The Egyptian endemic plants and their conservation status along the Mediterranean coastal region were evaluated by El-Khalafy *et al.* (2024). On the other hand, Abd El-Ghani *et al.* (2024) assessed the recent situation of endemic and near-endemic taxa in different biogeographic regions of Egypt. Taxa occurring exclusively within the political borders of Egypt are classified as "endemic", whereas those that also occur globally outside Egyptian borders are categorized as "near-endemic". Taxa lacking identification were referred to as "not identified". The latter investigation enumerated 21 taxa as endemic taxa recorded in the Mediterranean region, whereas the former study focused on 15 Mediterranean endemic taxa. It is worthy to note that neither endemic nor near-endemic taxa were included in this study.

Parts of medicinal plants used

As depicted in Figure 7, leaves, aerial parts, and seeds were the predominant plant components used in Egyptian medicinal flora within this study, with usage rates of 26.55%, 25.66%, and 24.78%, respectively. A moderate utilization was observed for fruits (23.89%), inflorescence (21.24%), and underground parts (15.04%). Notably, bark, plant secretions, and wood exhibited significantly lower usage rates, representing only 4.42%, 2.65%, and 1.77% of reported applications, highlighting a clear trend of preference for above-ground, readily accessible plant parts.

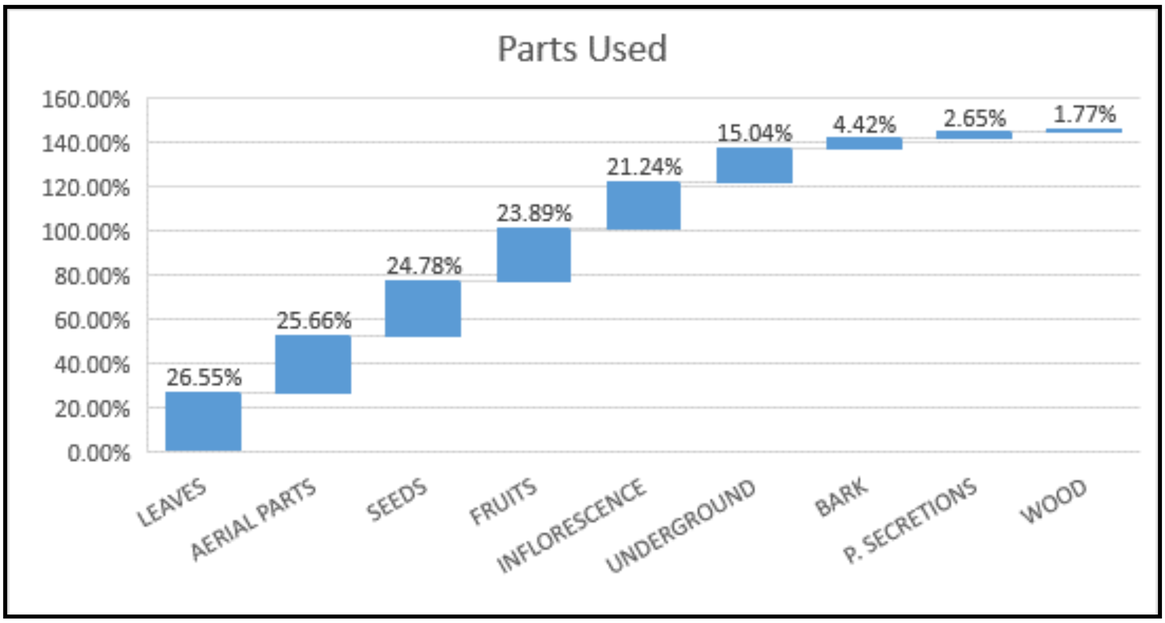

Figure 7. Percentages of plant parts used of the reported medicinal plant species

In terms of OGUs, the distribution of plant parts used varied across the OGUs (Nile, Oases, Mediterranean, Eastern Desert, Red Sea, Gebel Elba, and Sinai), with leaves and fruits generally being prominent (Figure 8). While leaves were among the most frequently used plant parts in most OGUs, fruits are also important across many regions. Specific trends include fruits being most used in the Nile, fruits and leaves in Oases (with relatively high underground part usage), leaves and aerial parts in the Mediterranean (also with relatively high underground part usage), relatively higher seed usage in the Eastern Desert (though overall usage is low), aerial parts in the Red Sea (though numbers are low), fruits and aerial parts in Gebel Elba (though numbers are low), and aerial parts in Sinai. Overall, while leaves and fruits are commonly utilized, the specific patterns of plant part usage differ across OGUs, likely reflecting ecological and cultural variations.

Figure 9 showed the relationships between the commonly used parts of the medicinal plants and the most important life forms. The used underground parts (UG) were mainly from geophytes (G) such as *Cyperus esculentus* L., *Cyperus rotundus* L., *Drimia maritima* (L.) Stearn, and *Narcissus tazetta* L. The majority of used seeds were from therophytes (annuals) such as *Datura stramonium* L., *Linum usitatissimum* L., *Nigella sativa* L., *Urtica pilulifera* L., and *Lupinus albus* L. The the mostly used fruits from (phanerophytes (trees) included, amongst others, *Vachellia nilotica* (L.) Delile, *Ceratonia siliqua* L., *Hyphaene thebaica* (L.) Mart., Phoenix dactylifera L., *Olea europaea* L., and *Ziziphus spina-christi* (L.) Desf. The common used barks were mainly from trees of *Vachellia seyal* Delile, *Capparis spinosa* L., and *Salix subserrata* Willd. Leaves from many annuals were used from plant species such as *Apium graveolens* L., *Coriandrum sativum* L., *Eruca vesicaria* subsp. *sativa* (Mill.) Thell., *Cichorium intybus* L., and *Sisymbrium officinale* (L.) Scop., and sometimes from other chamaephytes (shrubs) such as *Senna alexandrina* Mill., *Solenostemma arghel* (Del.) Hayne, *Coridothymus capitatus* (L.) Rchb. f., and *Withania somnifera* (L.) Dunal.

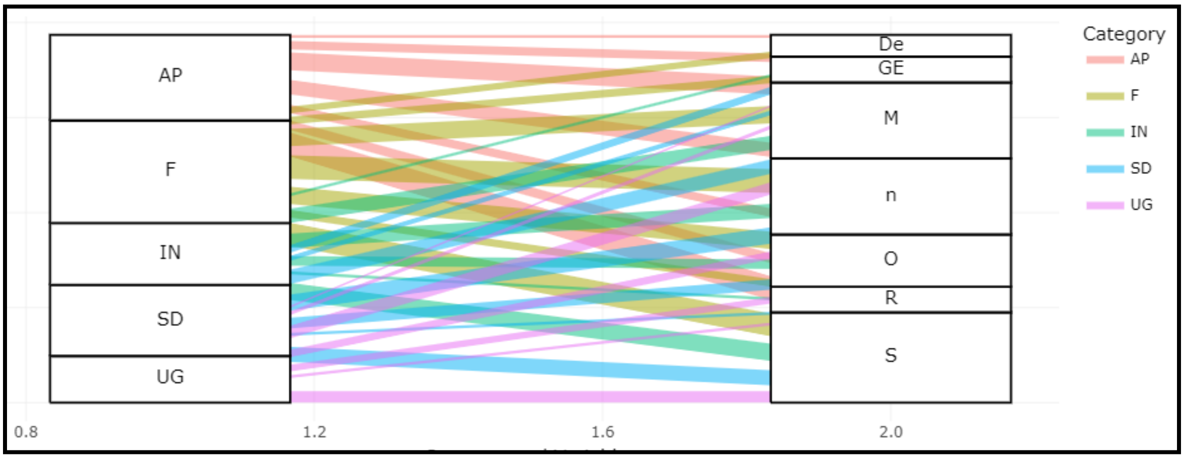

Figure 8. Distribution of the most important parts utilized of the medicinal plants across OGUs. Abbreviations of part used: AP=aerial parts, F=fruits, IN=inflorescences, SD=seeds, UG=underground. Abbreviations of OGUs: M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat

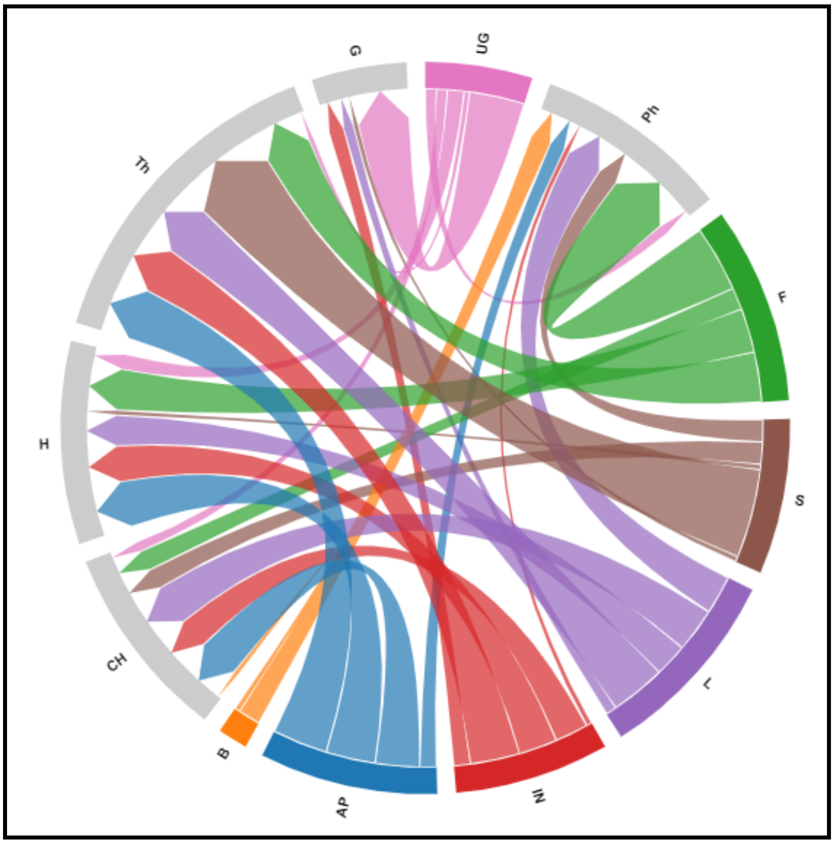

Figure 9. Distribution of the most important parts utilized of the medicinal plants across most important life forms. Abbreviations of part used: AP=aerial parts, F=fruits, IN=inflorescences, SD=seeds, UG=underground. Abbreviations of life forms: Th=Therophytes, Ch=Chamaephytes, Ph=Phanerophytes, G=Geophytes, Hy=Hydrophytes, P=Parasites, H=Hemicryptophytes

IUCN conservation status

The medicinal plant species recorded in this review were assessed using the IUCN Red List of Threatened Species (Version 2024, https://www.iucnredlist.org). The IUCN Red List Categories and Criteria provided a widely accepted system for categorizing species at high risk of global extinction. Results in Table 4 indicated that 61 species, approximately 54% of the total recorded in this review, were included in the IUCN Red List (IUCN 2025). Of these 61 species, 57 (93%) were classified as Least Concern (LC), three as Data Deficient (DD), and one as Near Threatened (NT). The LC designation signified that a taxon had been evaluated and does not qualify for the Near Threatened or Threatened categories, and this category may include abundant and widespread taxa. A taxon is classified as DD when there is inadequate information to directly or indirectly assess its extinction risk based on distribution and/or population status. Three species in this review were in this category: *Brassica rapa*, *Olea europaea*, and *Withania somnifera*.

Marrubium vulgare (white horehound) was listed as Near Threatened (NT) in Europe in 2013, according to the IUCN Red List of Threatened Species. The number of mature individuals of *M. vulgare* is decreasing, and populations were severely fragmented, contributing to the continued decline of mature individuals (IUCN 2025). The IUCN Red List Categories and Criteria were intended for global taxon assessments. A global category for a specific taxon may differ from a regional or national category. Notably, 50% (31 species) of the species were globally assessed by the IUCN, but some require updating, such as *Ephedra alata* and *Juniperus communis*. It is also noteworthy that almost all plant species assessed in Europe or the Mediterranean need to be updated.

Current population trends were decreasing for seven species: *Ceratonia siliqua*, *Marrubium vulgare*, *Moringa peregrina*, *Olea europaea*, *Posidonia oceanica*, *Urtica urens*, and *Zea mays*. *Posidonia oceanica*, an aquatic plant species endemic to the Mediterranean Sea, has a declining population trend that is a concerning indication of potential biodiversity loss, unless conservation measures are implemented. The decreasing populations of *Zea mays* (LC) and *Olea europaea* (DD) are also particularly worrisome due to their significance as crops. Populations of 16 species were globally stable, five were increasing, and the population trend was unknown for 12 species (Table 4).

Table 4. Status of globally threatened taxa as checked with The IUCN Red List of Threatened Species. LC=Least concern, DD=Data deficit, NT=Near threatened

Species	**Family**	**Status**	**Population Trend**	**Scope of Assessment**
Adiantum capillus-veneris L.	Pteridaceae	LC	Stable	Global
Ammi majus L.	Apiaceae	LC	Unknown	Europe
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	LC	Stable	Global
Bistorta officinalis Delarbre	Polygonaceae	LC	Increasing	Europe
Brassica rapa L.	Brassicaceae	DD	Unknown	Europe
Capparis spinosa L.	Capparaceae	LC	Stable	Global
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	LC	Stable	Europe
Ceratonia siliqua L.	Fabaceae	LC	Decreasing	Global
Cichorium intybus L.	Asteraceae	LC	Stable	Europe
Coridothymus capitatus (L.) Rchb.f. *Thymbra capitata* (L.) Cav.	Lamiaceae	LC	Stable	Europe
Crataegus monogyna Jacq.	Rosaceae	LC	Unknown	Global
Cyperus esculentus L.	Cyperaceae	LC	Increasing	Mediterranean
Cyperus rotundus L.	Cyperaceae	LC	Stable	Global
Dodonaea viscosa Jacq.	Sapindaceae	LC	Stable	Global
Drimia maritima (L.) Stearn	Asparagaceae	LC	Unknown	Global & Mediterranean
Ephedra alata Decne.	Ephedraceae	LC	Stable	Global
Ferula communis L.	Apiaceae	LC	Stable	Global
Ficus carica L.	Moraceae	LC	Increasing	Global
Foeniculum vulgare Mill.	Apiaceae	LC	Increasing	Europe
Hypericum perforatum L.	Hypericaceae	LC	Stable	Europe
Hyphaene thebaica (L.) Mart.	Palmae	LC	Unknown	Global
Juncus acutus L.	Juncaceae	LC	Stable	Mediterranean
Juniperus communis L.	Cupressaceae	LC	Increasing	Global
Lepidium latifolium L.	Brassicaceae	LC	Stable	Europe
Lupinus albus L.	Fabaceae	LC	Stable	Global
Malva sylvestris L.	Malvaceae	LC	Stable	Europe

Marrubium vulgare L.	Lamiaceae	NT	Decreasing	Europe
Matricaria chamomilla L.	Asteraceae	LC	Stable	Europe
Mentha pulegium L.	Lamiaceae	LC	Stable	Global
Mentha spicata L.	Lamiaceae	LC	Stable	Global
Moringa peregrina (Forssk.) Fiori	Moringaceae	LC	Decreasing	Global
Mutarda nigra (L.) Bernh.	Brassicaceae	LC	Stable	Global
Nymphaea lotus L.	Nymphaeaceae	LC	Unknown	Global
Olea europaea L.	Oleaceae	DD	Decreasing	Europe
Papaver rhoeas L.	Papaveraceae	LC	Stable	Europe
Pistacia lentiscus L.	Anacardiaceae	LC	Stable	Europe
Plantago afra L.	Plantaginaceae	LC	Unknown	Europe
Plantago major L.	Plantaginaceae	LC	Unknown	Global
Plantago ovata Forssk.	Plantaginaceae	LC	Stable	Europe
Pluchea dioscoridis (L.) DC.	Asteraceae	LC	Stable	Pan-Africa
Polygonum aviculare L.	Polygonaceae	LC	Stable	Europe
Portulaca oleracea L.	Portulacaceae	LC	Unknown	Global
Posidonia oceanica (L.) Delile	Posidoniaceae	LC	Decreasing	Global & Mediterranean
Rhus coriaria L.	Anacardiaceae	LC	Unknown	Global
Salix mucronata Thunb.	Salicaceae	LC	Stable	Global
Salvadora persica L.	Salvadoraceae	LC	Stable	Global
Senna alexandrina Mill.	Fabaceae	LC	Stable	Global
Silybum marianum (L.) Gaertn.	Asteraceae	LC	Stable	Global
Sinapis alba L.	Brassicaceae	LC	Stable	Europe
Sisymbrium officinale (L.) Scop.	Brassicaceae	LC	Stable	Europe
Stellaria media (L.) Vill.	Caryophyllaceae	LC	Stable	Europe
Tribulus terrestris L.	Zygophyllaceae	LC	Stable	Global
Urtica urens L.	Urticaceae	LC	Decreasing	Europe
Vachellia nilotica (L.) P.J.H. Hurter & Mabb.	Fabaceae	LC	Unknown	Global
Verbena officinalis L.	Verbenaceae	LC	Stable	Mediterranean
Viola odorata L.	Violaceae	LC	Stable	Europe
Viola tricolor L.	Violaceae	LC	Stable	Europe
Visnaga daucoides Gaertn.	Apiaceae	LC	Unknown	Europe
Withania somnifera (L.) Dunal	Solanaceae	DD	Unknown	Europe
Zea mays L.	Poaceae	LC	Decreasing	Global
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	LC	Stable	Global

Classification and ordination of medicinal plants within OGUs

Based on a presence/absence data matrix consisting of 9 Operational Geographical Units (OGUs) × 68 plant species (after removing species that occurred in only 1 or 2 OGUs to avoid distortion), classification and ordination analyses were performed. At the first hierarchical level of classification (Figure 10), the 9 OGUs were divided into two major clusters : the first cluster included 4 OGUs (N, O, M, and S), and the second cluster included the remaining 5 OGUs (R, GE, De, Dw, and Uw). At the second hierarchical level, the first cluster was further divided into 2 distinct species groups on the left side of the heatmap, based on their floristic similarity: Group (1) included the Nile (N) and Oases (O) regions, and Group (2) included the Mediterranean (M) and Sinai (S) regions. Most species in these two groups showed strong positive relations (indicated by deep red color in the heatmap), with Group (2) (Mediterranean and Sinai regions) exhibiting strong associations with Colchicum autumnale L., Marrubium alysson L., and Teucrium polium L.

On the right side of the heatmap (Figure 10), the second cluster was separated into 3 groups : Group (3) included the Red Sea (R) and Gebel Elba (GE) regions, Group (4) included the Eastern Desert (De) region, and Group (5) included the Western Desert (Dw) and Gebel Uweinat (Uw) regions. In these groups, a few species showed strong positive relations (varying shades of red), while the majority of species were not related (indicated by varying shades of blue). For example, the Western Desert-Gebel Uweinat group (Group 5) was characterized by strong positive relations with Anastatica hierochuntica L. and Cleome droserifolia (Forssk.) Delile in the Gebel Uweinat region, and with Capparis spinosa L., Vachellia nilotica (L.) P.J.H.Hurter & Mabb., and Zilla spinosa (L.) Prantl in the Western Desert region, while the Eastern

Desert species group (Group 4) showed strong positive relations with Solenostemma arghel (Del.) Hayne, Peganum harmala L., Alhagi graecorum Boiss., and Plantago afra L.

Six species (indicated by dark blue color, representing negative relations) were either absent or rarely found in Groups 4 and 5 (Figure 10): Adiantum capillus-veneris L., Citrullus colocynthis (L.) Schrad., Cyperus rotundus L., Hyoscyamus muticus L., Pluchea dioscoridis (L.) DC., and Ziziphus spina-christi (L.) Desf. In the Nile and Oases regions group (Group 1), Zilla spinosa (L.) Prantl (indicated by dark blue color, representing a negative relation) was absent from these regions. Simiar other comments can be made from other groups.

The separated five groups were separated along the first and second PCA axes (Figure 11). Groups 1 (Nile and Oases OGUs) and 2 (Mediterranean and Sinai OGUs) occupied the negative end of PCA axis 1 which captured 47.6% of the species variace, whhile the other 3 groups occupied the positive end of this axis. Gebel Elba and Red Sea group (group 3) occupied a lower position along PCA axis 1.

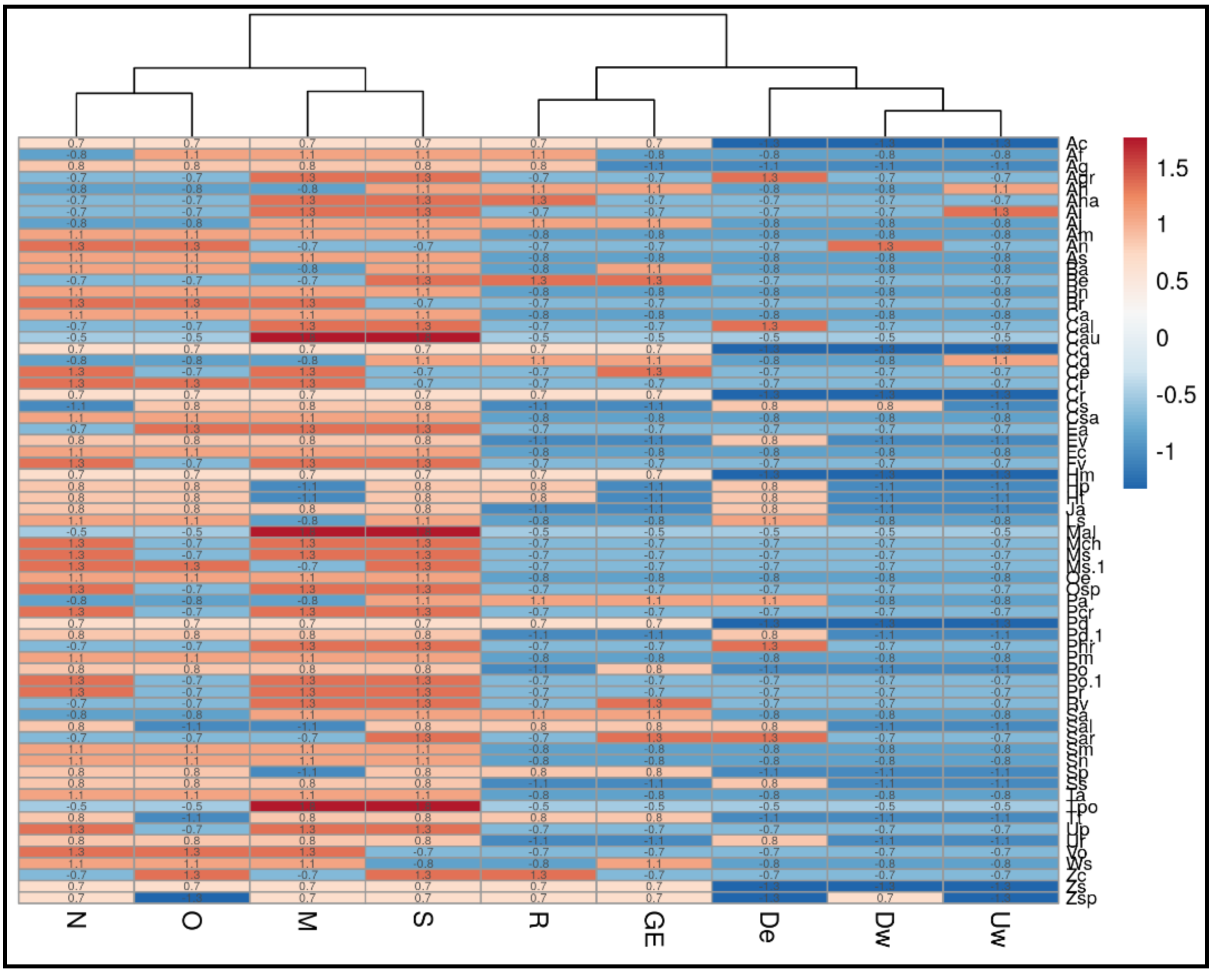

Figure 10. A heatmap showing the cluster analysis based on 68 species and 9 OGUs. Abbreviations of OGUs: M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat. For full species names, see Table 2.

Species diversity

Table 5 summarized the medicinal plant species diversity in the different OGUs. Sinai Peninsula (S) was the most diversified as shown by its highest number of species (77), followed by the Mediterranean region (70 species), and the Nile region (68 species). Shannon-Wiener diversity index showed similar trend. The least diversified OGUs with the lowest number of species were Gebel Uweinat (Uw) and the Western Desert (Dw) with 3 and 2 species, respectively. Similarly, Shannon-wiener index showed the lowest indices.

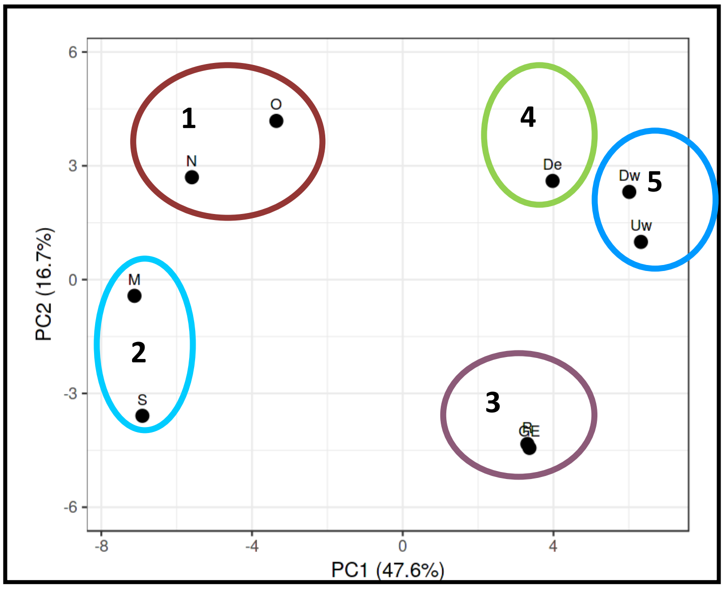

Figure 11. A Principal Components Analysis (PCA) scatterplot showing the separation of the 5 groups along axes 1 and 2. Abbreviations of OGUs: M=Mediterranean, N=Nile, O=Oases, S=Sinai, R=Red Sea, GE=Gebel Elba, De=Eastern Desert, Dw=Western Desert, UW=Gebel Uweinat

Table 5. Summary of species diversity measurements of the used medicinal plants across the 9 OGUs

OGUs	Species richness (SR)	Shannon-Wiener index (H')
N	68	4.22
O	45	3.81
M	70	4.25
De	19	2.94
Dw	02	0.69
R	23	3.13
GE	24	3.18
S	77	4.34
Uw	03	1.09

The Chao-Jaccard similarity index (C-J) and the shared plant species among the 5 cluster groups (1 – 5; Table 7) indicated that the high plant species similarity (0.518) was between the groups (1) and (2), where the similarity index was 0.554. In general, the dissimilarity between other groups was high and ranged between 0.017 and 0.289.

Table 6. Chao-Jaccard similarity index (C-J), and the shared species among the five cluster groups (1 - 5) in the 9 OGUs

Species cluster groups	Shared species	Chao-Jaccard similarity index
1 × 2	58	0.554
1 × 3	21	0.259
1 × 4	11	0.14
1 × 5	3	0.017
2 × 3	29	0.289
2 × 4	19	0.182
2 × 5	6	0.055
3 × 4	7	0.127
3 × 5	4	0.121
4 × 5	2	0.046

Medicinal uses

Table (7) demonstrated the medicinal uses of the studied plants, together with their references. It has been shown that they possess substantial antidiabetic, antioxidant, antitussive, anti-inflammatory, antitumor, antiulcer, antibacterial, hepatoprotective, neuroprotective, cardio protective, and wound healing properties. The ethnomedicinal uses of the identified plant species were analyzed to contribute to the broader understanding of traditional healing practices in the region.

Table 7. Medicinal uses of the plant species recorded in the present review

Species	Family	Medicinal Use	References
Achillea fragrantissima (Forssk.) Sch.Bip.	Asteraceae	Anti-inflammatory, antimicrobial, anti-diabetic, sedative	Egyptian Herbal Monograph (2023)
Adiantum capillus-veneris L.	Pteridaceae	Respiratory disorders, gastrointestinal disorders, diuretic and urinary disorders, menstrual problems, hair loss, and for treatment of snake and spider bites	Egyptian Herbal Monograph (2023)
Ajuga iva (L.) Schreb.	Lamiaceae	Antioxidants, antidiabetic, antimicrobial, and anti-inflammatory activities	Lahrizi *et al.* (2024)
Alhagi graecorum Boiss.	Fabaceae	Antioxidant, cardiovascular, anti-ulcer, hepatoprotective, antispasmodic, antidiarrheal, antinociceptive, antipyretic, anti-inflammatory, anti-rheumatic, antibacterial and antifungal activities	Muhammad *et al.* (2015)
Ammi majus L.	Apiaceae	For hypertension, depression, leucoderma, allergic rhinitis and rash, chronic asthma, diaphoretic, carminative, antispasmodic, and antiseptic	Hossain & Al Touby (2020)
Anastatica hierochuntica L.	Brassicaceae	Hypolipidemic activity, antidiabetic, hepatoprotective, antioxidant, antiproliferative, gastroprotective, antiinflammation, and cytotoxic activities	Rostan and Manshoor (2024)
Apium graveolens L.	Apiaceae	Prevention of cardiovascular disease, lowering blood glucose and serum lipid, decrease blood pressure and strengthen the heart, anti- bacterial, anti-fungal and anti- inflammatory Also, has a powerful antioxidant property.	Kooti et al., (2014)
Artemisia herba-alba Asso	Asteraceae	Antioxidants, anti-venom, antifungal, nematicidal, antibacterial, antispasmodic, anthelmintic, antileishmanial, neurological, hypoglycemic, and pesticidal activities	Mohamed *et al.* (2010)
Artemisia judaica L.	Asteraceae	Anti-inflammatory, analgesic, antioxidant activity and high potential antiangiogenic activity	Awad *et al.* (2022)
Avena sativa L.	Poaceae	Antioxidants, anti-inflammatory, dermatological, immunomodulatory, antidiabetic, gastrointestinal, hypolipidemic, neurological, cardiovascular and many other biological activities.	Al-Snafi (2015)
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	Good for jaundice, intestinal worm infection, wounds, malaria, syphilis, epilepsy, dysentery, constipation, diarrhea, hemorrhoid, stomach aches, asthma, and	Saboo *et al.* (2014), Chothani & Vaghasiya

		fever	(2011)
Blepharis edulis (Forssk.) Pers.	Acanthaceae	Antioxidant capacity and antimicrobial activity	Mahboubi *et al.* (2013)
Bistorta officinalis Delarbre	Polygonaceae	Antimicrobial activity against skin pathogens, and anti-inflammatory activity	Pawłowska *et al.* (2020)
Brassica rapa L.	Brassicaceae	Antibacterial activity and successfully lower hypertension	Serrano *et al.* (2024), Abid *et al.* (2022)
Bryonia cretica L.	Cucurbitaceae	Antimicrobial, antioxidant, antidiabetic, antinociceptive, and anti-inflammatory functions, along with an anticancer efficiency	Benarba & Belhouala (2024)
Capparis spinosa L.	Capparaceae	Used for rheumatism and gout, as diuretic, astringent, tonic, as appetizer, anti-diarrheic, treat hemorrhoids and spleen disease, and as expectorant, and for chest diseases, used in sciatica, dropsy, backache, and to relieve toothache, for ulcers, scrofula, and ganglions.	Rahnavard & Razavi (2017)
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	Anti-inflammatory, antioxidant, antibacterial, antifungal, acetylcholinesterase and anticancer properties and supportive action in the treatment of gynecological diseases.	Łukaszyk *et al.* (2024)
Ceratonia siliqua L.	Fabaceae	Antihypertensive, antidepressant, anti-obesity, and antihyperglycemic activities.	Dahmani *et al.* (2023)
Cichorium intybus L.	Asteraceae	Antimicrobial, anthelmintic, antimalarial, hepatoprotective, gastroprotective, anti-Inflammatory, analgesic, antidiabetic, antioxidant, tumor-Inhibitory, and antiallergic	Street *et al.* (2013)
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	Fruit is used to treat colds, diarrhea, parasitic worms, the expulsion of wind, tumors, ascites, leukoplakia, ulcers, asthma, bronchitis, diabetes insipidus, jaundice, splenomegaly, neck tuberculosis, constipation, anemia, throat diseases, lephantiasis, and joint pain; it is also used as an antipyretic	Li *et al.* (2022)
Cleome droserifolia (Forssk.) Delile	Cleomaceae	Treatment of hyperglycemia, accelerate wound healing especially for diabetes mellitus patients, open sores, allergy, dermatitis, inflammation, scabies, as antimicrobial agent and antibiotic for wounds and burns.	Egyptian Herbal Monograph (2022)
Colchicum autumnale L.	Colchicaceae	Healer of internal injuries, a treatment for gout	Akram *et al.* (2012)
Convolvulus althaeoides L.	Convolvulaceae	Cytotoxic activity against various tumor cell lines	Hassine *et al.* (2014)
Convolvulus arvensis L.	Convolvulaceae	Antioxidant and antibacterial	Salamatullah (2022)
Convolvulus scammonia L.	Convolvulaceae	Treatment of skin diseases, chronic headache, bilious fever, conjunctivitis, and	Ansari *et al.* (2022)

		jaundice	
Coriandrum sativum L.	Apiaceae	Anti-inflammatory, analgesic, antioxidant, antidiabetic, hepatoprotective, antibacterial, and antifungal	Asgarpanah and Kazemivash (2012)
Crataegus monogyna Jacq.	Rosaceae	Adjunct therapy for heart failure stage ll, relieve symptoms of temporary nervous cardiac complaints, relief of mild symptoms of mental stress and to aid sleep	Egyptian Herbal Monograph (2023)
Cuscuta epilinum Weihe	Convolvulaceae	Anti-microbial, cytotoxic, anticonvulsant, anti-urease, immune stimulatory, hepatoprotective effect, and antioxidant activity	Chabra *et al.* (2019)
Cymbopogon citratus (DC.) Stapf	Poaceae	Treatment of the nervous condition, gastrointestinal disturbances, fever, cardiovascular disease, coughs, hypertrophy,flu, gingivitis, headache, leprosy, malaria, ophthalmic, respiratory disease, and vascular disorders	Kassahun *et al.* (2020)
Cymbopogon nardus (L.) Rendle	Poaceae	Antifungal, antibacterial, antioxidant, insecticidal, antiparasitic, and food preservation	Pandey (2024)
Cymbopogon schoenanthus (L.) Spreng.	Poaceae	Antioxidant, antimicrobial, anthelmintic, insecticidal, protective, and acetylcholinesterase inhibitory activity	Al-Snafi (2016)
Cymbopogon schoenanthus subsp. *proximus* (Hochst. ex A.Rich.) Maire & Weiller	Poaceae	Cardiovascular depressant, antidopaminergic and antiglutamic-aspartic acids in the antiemetic and anticonvulsant effects	El-Tahir & Abdel-Kader (2008)
Cyperus esculentus L.	Cyperaceae	Antibacterial, antioxidant and insecticidal activities	Zhang *et al.* (2022)
Cyperus rotundus L.	Cyperaceae	Rhizomes are considered astringent, diaphoretic, diuretic, analgesic, antispasmodic, aromatic, carminative, antitussive, emmenagogue, litholytic, sedative, stimulant, stomachic, vermifuge, tonic and antibacterial	Sivapalan (2013)
Datura stramonium L.	Solanaceae	Spasmolytic, anti-asthmatic, anticholinergic, antioxidant, anticancer, analgesic, anti-inflammatory, and wound healing activity	Egyptian Drug Authority (2022)
Dodonaea viscosa Jacq.	Sapindaceae	Antidiabetic, antimicrobial, insecticidal, antioxidant, cytotoxic, antifertility, wound, anti-inflammatory, analgesic, anti-ulcer, antispasmodic, anti-diarrheal and detoxification effects.	Al-Snafi (2017)
Drimia maritima (L.) Stearn	Asparagaceae	Anti-asthmatic, and expectorant	Egyptian Herbal Monograph (2023)
Ecballium elaterium (L.) A.Rich.	Cucurbitaceae	Cytotoxic, anti-inflammatory, and anti-cancer	Anzano *et al.* (2024)
Ephedra alata Decne.	Ephedraceae	Anti-cancer,anti- asthmatic, also for arthritis, and rheumatoid	Chroho *et al.* (2024)

Eruca sativa Mill.	Brassicaceae	Leaves and seeds are used as antimicrobial, anticarcinogenic, diuretic, laxatives, to improve digestion and kidney functions, antiulcer, and aphrodisiac	Rozan & Boriy (2022)
Ferula communis L.	Apiaceae	Anti-microbial, anti-fungal, antinociceptive, anti-inflammatory, anti-convulsant, antioxidant, anti-mycobacterial, anti-spasmodic, and hypotensive activities	Sahebkar & Iranshahi (2010)
Ficus carica L.	Moraceae	Treatment of various ailments such as anemia, cancer, diabetes, leprosy, liver diseases, paralysis, skin diseases, and ulcers	Badgujar *et al.* (2014)
Foeniculum vulgare Mill.	Apiaceae	Antifungal, antibacterial, antioxidant, antithrombotic and hepatoprotective activities	Rather *et al.* (2016)
Fumaria officinalis L.	Papaveraceae	Anti-diabetic, analgesic, anti-inflammatory, antimicrobial, anticancer, diuretic and skin protective effects. It has potential against Alzheimer's disease.	Aguiar (2023)
Hibiscus sabdariffa L.	Malvaceae	Medications for high blood pressure, and antihypertensive.	Jalalyazdi *et al.* (2019)
Hyoscyamus muticus L.	Solanaceae	Antioxidant, and antimicrobial	Elsharkawy *et al.* (2018)
Hypericum perforatum L.	Hypericaceae	Antidepressant, antioxidant, anticonvulsant, analgesic, anti-inflammatory, cytotoxic and antidiabetic activities	Asgarpanah (2012)
Hyphaene thebaica (L.) Mart.	Arecaceae	Anti-inlammatory, antioxidant, antimicrobial, anticancer, and in the treatment of hypertension, bilharzias and as a hematinic agent. Fruits can reduce hyperlipidemia	El-Beltagi *et al.* (2018)
Juncus acutus L.	Juncaceae	Antidiabetic, antibacterial, and antifungal activities	Hammouti *et al.* (2023)
Juniperus communis L.	Cupressaceae	Antidiarrhoeal, anti-inflammatory, astringent, and antiseptic and in the treatment of various abdominal disorders	Bais *et al.* (2014)
Leontice leontopetalum L.	Berberidaceae	Anti-oxidant, anti-diabetic, cytotoxic and smooth muscle contractile effect	Al-Snafi (2019)
Lepidium latifolium L.	Brassicaceae	Antioxidant, as stomach tonics, diuretic , hypertension, diabetes and anti-tumor.	Verma *et al.* (2019)
Lepidium sativum L.	Brassicaceae	Effective in asthma, cough, gastrointestinal track disorders, cardiac disease, diabetes, hepatic function, infections	Shah *et al.* (2021)
Linum usitatissimum L.	Linaceae	Reduce blood pressure, improve digestion, and prevent certain types of cancer	Siddiquee *et al.* (2023)
Lupinus albus L.	Fabaceae	Anti-diabetic, anti-convulsant, antioxidant, antimicrobial and antihyperlipidemic activities. It shows efficiency in controlling serum glucose and dyslipidaemia.	Abdul Qaiyyum & Nawab (2020)
Malva sylvestris L.	Malvaceae	Antioxidant, anti-inflammatory, anticancer, wound-healing, hepatoprotective, antinociceptive, and antimicrobial	Mousavi et aol. (2021)

Marrubium alysson L.	Lamiaceae	Lipid lowering, anti-inflammation and anti-oxidation activities, managing Alzheimer's disease	Essawy *et al.* (2014), Eltahawy *et al.* (2023)
Marrubium vulgare L.	Lamiaceae	Anti-inflammatory, wound-healing, antihypertensive, hypolipidemic, and sedative potential antioxidant, hepatoprotective, antiproliferative, anti-inflammatory, antidiabetic, and antimicrobial activity	Aćimović *et al.* (2020)
Matricaria chamomilla L.	Asteraceae	For treatment of atopic dermatitis, colic, and diarrhea	Zadeh *et al.* (2014)
Mentha pulegium L.	Lamiaceae	Antioxidant and anti-tumor properties	Abood & Humadi (2023)
Mentha spicata L.	Lamiaceae	Antimicrobial, antioxidant, anticancer, anti-inflammatory and hepatoprotective activities.	Mahendran *et al.* (2021)
Moringa peregrina (Forssk.) Fiori	Moringaceae	Treatment of a wide range of conditions, such as inflammation, gastrointestinal, hematological, cardiovascular, hepato and renal disorders. Also, it has been used for diabetes and hypertension as well as liver protection	Said-Al Ahl *et al.* (2017)
Mutarda nigra (L.) Bernh.	Brassicaceae	Cytotoxic, mutagenic, hepato-protective, nephroprotective, lung protective, antiobesity, antidiabetic, antioxidant, immunological, anti-inflammatory, cardiovascular and hypolipidemic effects	Al-Snafi (2015)
Narcissus tazetta L.	Amaryllidaceae	Antibacterial and antifungal, antiviral, antimalerial, anticancer, antioxidant, dermatological, cardiovascular, immunomodulatory and acetylcholinesterase inhibitory effects	Al-Snafi (2020)
Nigella sativa L.	Ranunculaceae	Antidiabetic, antioxidant capacity, hypolipidemic, antiatherosclerotic, or antihypertensive properties, treat various gastrointestinal disorders, used in treating respiratory and allergic disorders, plays a role in cancer prevention and treatment, and has neuroprotective effects and memory improvement	Alberts *et al.* (2024)
Nymphaea lotus L.	Nymphaeaceae	Management of inflammation and diabetes, beside its nutritional value	Abelti *et al.* (2024)
Olea europaea L.	Oleaceae	Antidiabetic, antibacterial, antifungal, antioxidant, anticancer, and wound-healing properties.	Elhrech *et al.* (2024)
Orobanche crenata Forssk.	Orobanchaceae	For tonifying the kidney, against impotence and spermatorrhea, dermatological problems and wounds, as well as infantile diarrhoea.	Shi *et al.* (2020)
Papaver rhoeas L.	Papaveraceae	Treat nervousness, insomnia, digestive and respiratory disorders, baldness, eye	Grauso *et al.* (2021)

		infections, as well as measles treatment.	
Peganum harmala L.	Nitrariaceae	Anti-inflammatory, analgesic, antibacterial, and possibly psychoactive effects	Akramova (2024)
Petroselinum crispum (Mill.) Fuss	Apiaceae	Carminative, gastro tonic, diuretic, antiseptic of urinary tract, anti-urolithiasis, anti-dote and anti-inflammatory and for the treatment of amenorrhea, dysmenorrhea, gastrointestinal disorder, hypertension, cardiac disease, urinary disease, otitis, sniffle, diabetes and also various dermal diseases .	Farzaei *et al.* (2013)
Phoenix dactylifera L.	Arecaceae	The fruits were used traditionally as general tonic, for the treatment of liver diseases, memory disturbances, fever, inflammation, paralysis, loss of consciousness, nervous disorders and consumed by pregnant women before and after delivery. However, all parts of the plant were used for some purpose. Dates fruits were considered a complete diet and a very important item of food, possessed many pharmacological effects including anticancer, antidiabetic, anti-inflammatory, antimicrobial, antiparasitic, antioxidant, anti-toxin, cardiovascular, hypolipidemic, gastrointestinal, immunomodullatory, neural, hepato and reno-protective, reproductive and wound healing effects	Al-Snafi &Thuwaini (2023)
Pistacia lentiscus L.	Anacardiaceae	Anti-inflammatory, antioxidative and antimicrobial activities.	Milia *et al.* (2021)
Plantago afra L.	Plantaginaceae	Emollient, laxative for chronic constipation	Egyptian Herbal Monograph (2023)
Plantago major L.	Plantaginaceae	For respiratory complications and digestive system affections, wound healing and as an anti-inflammatory, anti-microbial and anti-tumor agent.	Nazarizadeh *et al.* (2013)
Plantago ovata Forssk.	Plantaginaceae	Lowering cholesterol, prevent constipation, improving cancer cells and reduce obesity	Khan *et al.* (2021)
Pluchea dioscoridis (L.) DC.	Asteraceae	Antifungal, and anticancer activity against a colon carcinoma cell line	Madboly *et al.* (2023)
Polygonum aviculare L.	Polygonaceae	Antioxidant, anti-inflammatory, antidiabetic, anti-cancer, and dermato-protective activities	Benrahou *et al.* (2023)
Portulaca oleracea L.	Portulacaceae	Neuroprotective, antimicrobial, antidiabetic, antioxidant, anti-inflammatory, antiulcerogenic, and anticancer activities	Zhou *et al.* (2015)
Posidonia oceanica (L.) Delile	Posidoniaceae	Antioxidant, anti-inflammatory, antidiabetic, and anti-glycation properties	Vasarri et al (2021)
Rhus coriaria L.	Anacardiaceae	Antioxidant capacities that have ameliorative and therapeutic benefits for	Alsamri *et al.* (2021)

		many common diseases including cardiovascular disease, diabetes, and cancer	
Ricinus communis L.	Euphorbiaceae	Anticancer, anti-diabetic, antioxidant, leishamicidial, insecticidal, hepatoprotective, acaricidal, lipolytic activity, larvicidal and mosquitocidal activity, laxative and uterine contracting, anticonvulsant activity, anti-asthmatic activity, bone regeneration, antimicrobial and anti-inflammatory properties, ophthalmic properties, and antiulcer	Chouhan *et al.* (2021)
Rumex vesicarius L.	Polygonaceae	Antioxidant, antiproliferative and anti-microbial potential	Gomaa & Saleh (2014)
Salix mucronata Thunb.	Salicaceae	Analgesic, anti-inflammatory, antioxidant, anticancer, cytotoxic, antidiabetic, antimicrobial, antiobesity, neuroprotective and hepatoprotective activities	Tawfeek *et al.* (2021)
Salvadora persica L.	Salvadoraceae	Antibacterial, antiviral, antifungal, antioxidant, and even antiulcer effects, promising for dental and fields	Aljarbou *et al.* (2022)
Salvia aegyptiaca L.	Lamiaceae	Antiseptic, carminative, digestive, analgesic, antioxidant, anticancer, and antiproliferative effect	Singh (2021), Hosseini *et al.* (2024)
Senna alexandrina Mill.	Fabaceae	Remedies for waterborne diseases including typhoid, also joint, tendon ligaments and bone related diseases, pneumonia, reducing fever, bacterial, viral and fungal long-term infections, leukemia, jaundice, intestinal worms and use as healer for splenic enlargement	Abbas & Rani (2020)
Silybum marianum (L.) Gaertn.	Asteraceae	Renal protection, hypolipidemic and anti-atherosclerosis activities, cardiovascular protection, prevention of insulin resistance, especially in cirrhotic patients, cancer, and Alzheimer prevention	Bahman *et al.* (2015)
Sinapis alba L.	Brassicaceae	Used in the treatment of common cold, bronchitis, rheumatism and in the treatment of inflammation of the respiratory tract and the gastrointestinal tract in homeopathy	Khatib & Al-Makky (2021)
Sisymbrium officinale (L.) Scop.	Brassicaceae	Strong antimutagenic effect suggesting anticancer properties	Di Sotto *et al.* (2010)
Solanum nigrum L.	Solanaceae	Larvicidal, anti-inflammatory, antioxidant, antitumor promoting, and hepatoprotective agent	Saleem *et al.* (2009)
Solenostemma arghel (Delile) Hayne	Apocynaceae	Anti-inflammatory, antioxidant, hypoglycemic, hypolipidemic, and anti-obesity activities	Abdel-Sattar & El-Shiekh (2024)
Stellaria media (L.) Vill.	Caryophyllaceae	Antiobesity, antifungal, antibacterial, antioxidant, anti-proliferative, anti-	Oladeji & Oyebamiji

		inflammatory, analgesic, antidiabetic and anxiolytic activities.	(2020)
Teucrium polium L.	Lamiaceae	Antioxidant, antibacterial, and antiinflammatory activity	Sharifi-Rad *et al.* (2022)
Thymbra capitata (L.) Cav.	Lamiaceae	Anti-Inflammatory, wound Healing, and anti-aging	Alves-Silva *et al.* (2023)
Tribulus terrestris L.	Zygophyllaceae	It has analgesic, diuretic and uricosuric effects, anti-hyperglycaemic, anti-inflammatory, antioxidant, and antibacterial.	Akram *et al.* (2011), Ştefănescu *et al.* (2020)
Trifolium alexandrinum L.	Fabaceae	Antioxidant, anti-inflammatory, and antidiabetic effects.	Abdou & Abd Elkader (2022)
Triticum aestivum L.	Poaceae	Anticancer, antimicrobial, antidiabetic, hypolipemic, antioxidant, laxative, and moisturizing effects	Moshawih *et al.* (2022)
Urtica pilulifera L.	Urticaceae	Antioxidant activity against various oxidative systems	Mahmoud *et al.* (2005)
Urtica urens L.	Urticaceae	Significant antioxidant activity	Elsherif *et al.* (2023)
Vachellia nilotica (L.) P.J.H.Hurter & Mabb.	Fabaceae	Anti-cancer, antimutagenic, spasmogenic, vasoconstrictor, anti-pyretic, anti-asthamatic, cytotoxic, anti-diabetic, anti-platelet agregatory, anti-plasmodial, molluscicidal, anti-fungal, inhibitory activity against Hepatitis C virus (HCV) and human immunodeficiency virus (HIV)-I, antioxidant, anti-bacterial, antihypertensive, anti-spasmodic activities	Ali (2012), Egyptian Herbal Monograph (2023)
Vachellia seyal (Delile) P.J.H.Hurter	Fabaceae	Antibacterial, antimalarial, antimycobacterial, cyclooxygenase inhibition effect, molluscicidal activity, anticancer, hypoglycemic, antidiabetic, antioxidant, immunomodulatory, cytoprotective antiulcer, prebiotic properties	Ashour *et al.* (2022)
Verbena officinalis L.	Verbenaceae	Treating cryptosporidiosis with a possible reduction of inflammatory changes in the small intestine.	El-Wakil *et al.* (2022)
Vicia faba L.	Fabaceae	Hypocholesterolemia, antioxidants, and anti-cancer properties, also improved blood sugar, cholesterol levels, and gut health, contributing to health advantage for cardiovascular diseases and other chronic conditions.	Feng *et al.* (2024)
Viola odorata L.	Violaceae	It is used for stress, fatigue, insomnia symptoms of menopause, depression, common cold, and influenza. Chewed Leaves are used for anticancer, diaphoretic, febrifuge, infantile disorder, and lung troubles, and leaves and flowers are used for respiratory disorders	Abdullah & Akram Khan (2023), Batiha *et al.* (2023)
Viola tricolor L.	Violaceae	The stem, leaves, flowers, fruits, and seeds	Batiha *et al.*

		are used against skin conditions, cystitis, rheumatism, bronchitis and against inflammation, cough, and diuretic.	(2023)
Visnaga daucoides Gaertn.	Apiaceae	Kidney diseases, antispasmodic and vasodilating, antidiabetic, anti-inflammatory, antimicrobial, antioxidant, hair Loss, antimutagenic, cardiovascular, and immunostimulatory	Khalil *et al.* (2020)
Withania somnifera (L.) Dunal	Solanaceae	It treats ulcers, emaciation, colds, coughs, diabetes, conjunctivitis, insomnia, senile dementia, epilepsy, leprosy, Parkinson's disease, nervous disorders, rheumatism, arthritis, intestinal infections, bronchitis and asthma	Sharma *et al.* (2024)
Zea mays L.	Poaceae	It possesses diuretic effects, hepatoprotective, anti-diabetic, antioxidant, neuroprotective, anti-inflammatory, anti-cancer, plant protection activity, and other activities.	Zhang *et al.* (2023)
Zilla spinosa (L.) Prantl	Brassicaceae	Treatment of gall bladder and kidney stones and/or ailments, antifungal, anticancer, and antirheumatic	Alsamahy et al (2025)
Ziziphus lotus (L.) Lam.	Rhamnaceae	Teating diabetes, obesity, dyslipidemia, ulcers, and spasms. Additionally, it was found to have an anti-urolithic effect, preventing the formation of kidney stones.	Bencheikh *et al.* (2023)
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	Antihyperglycemic, antibacterial, antifungal, antioxidant and antinociceptive activities	Asgarpanah & Haghighat (2012)
Zygophyllum coccineum L.	Zygophyllaceae	The plant extract has efficient and safe anti-inflammatory potential, with promising antifungal and insecticidal actions. It was also reported to control elevated blood pressure and heart rate in induced rats	Yosri *et al.* (2022)

Figure 12. *Datura innoxia* (left), *Schouwia thebaica* (right), Wadi El-Assiuty, Eastern Desert

Figure 13. *Limonium axillare* (left), *Cleome droserifolia* (right), Red Sea coast

Figure 14. *Lycium shawii* (left), *Anabasis articulata* (right), Gebel Musa, South Sinai

Figure 15. *Hyphaene thebaica* (left), *Gossypium arboreum* (right), Dakhla Oasis

Conclusion and recommendations

Extreme drought conditions, scarcity of water and high temperature were among the harsh environmental conditions in the hyper arid desert of Egypt. Besides, it is subjected to severe disturbances such as urbanization, overgrazing, disposal of waste products, over-collection of economic plants, road construction and others have their negative impacts on the vegetation and species diversity.

Medicinal plants are one of the most important elements of biodiversity around the world (Klein *et al.* 2008; Okigbo *et al.* 2008) because of their role in ecosystem services such as healthcare, cultural value and heritage, local economics and human wellbeing, especially in poor areas. Conserving and protecting these kinds of species is vital, including improving knowledge about the important ecological requirements of medicinal plants, and raising awareness among all stakeholders to protect this heritage. Consequently, conservation planning and effective management is important in protecting the most threatened species to avoid declines in the diversity of medicinal plants (Moustafa *et al.* 1999; Bidak *et al.* 2013).

Although Egypt has the potential for being an excellent source for aromatic and medicinal plants production, Egyptian exports of aromatic and medicinal plants is declining. The application of tissue culture micropropagation techniques among other measures might lead to new technologies for restoring the high brand production of medicinal plant products as well as maintenance of sustainable use for these valuable plants (El-Demerdash, 2001). Many activities aiming at the conservation of the aromatic and medicinal plants including in situ, ex situ conservation and micropropagation are recommended.

It is recommended to establish a national database for medicinal plants to integrate and enhance information management in the different related fields starting by field surveys and ending with market value of each species (El-Gazzar and El-Demerdash 1998). The implementation of marketing strategies which adopt the international codes for quality control measures, proper advertising policies, and coordinates between the different acting partners in medicinal plants (Fadl Allah 1998). The objective of the current review is to provide a comprehensive overview of medicinal plants in Egypt, diversity and distribution of these plants across Egypt's different biogeographical regions, as well as their current conservation status and nativity.

Declarations

Ethics approval and consent to participate: Not applicable
Consent for publication: All the authors agreed to publish the content. This paper does not include any individual person´s data and further permission for publication is not required.
Availability of data and materials: All the collected data are given in the manuscript itself.
Competing interests: The authors declare that they have no conflict of interest.
Funding: No funding was received from any organization.
Author contributions: Both authors conceived the idea, wrote the initial version of the manuscript, revised the manuscript and approved the final version of the manuscript.

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