Medicinal and Aromatic Plants of the World

Ákos Máthé
Kenan Turgut *Editors*

Medicinal and Aromatic Plants of Turkey

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Medicinal and Aromatic Plants (MAPs) have been utilized in various forms since the earliest days of mankind. They have maintained their traditional basic curative role even in our modern societies. Apart from their traditional culinary and food industry uses, MAPs are intensively consumed as food supplements (food additives) and in animal husbandry, where feed additives are used to replace synthetic chemicals and production-increasing hormones. Importantly medicinal plants and their chemical ingredients can serve as starting and/or model materials for pharmaceutical research and medicine production. Current areas of utilization constitute powerful drivers for the exploitation of these natural resources. Today's demands, coupled with the already rather limited availability and potential exhaustion of these natural resources, make it necessary to take stock both of them and enrich our knowledge regarding research and development, production, trade and utilization, and especially from the viewpoint of sustainability. The series Medicinal and Aromatic Plants of the World is aimed to look carefully at our present knowledge of this vast interdisciplinary domain, on a global scale. In the era of global climatic change, the series is expected to make an important contribution to the better knowledge and understanding of MAPs.

Budapest, Prof. Dr. Ákos Máthé.

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Preface

This book is the tenth volume of the series Medicinal and Aromatic Plants of the World (MAPW), with a focus on the medicinal and aromatic plants (MAPs) of Türkiye (formerly Turkey).

Türkiye (officially the Republic of Türkiye) is a so called transcontinental country bridging Europe with Asia. Located mainly on the Anatolian Peninsula (in Western Asia), with a small portion on the Balkan Peninsula (Southeast Europe) Türkiye covers an area of 783,562 square kilometers. The Aegean Sea, the Black Sea, and the Mediterranean Sea, as well as the Sea of Marmara contribute to Turkey's unique geographical position.

By lying at the crossroads of the land and sea routes and by containing a large variety of habitats across its geographical regions, Türkiye is home to a considerable species diversity and varied ecosystems.

With a forest area of *ca.* 220,643,600 hectares, Türkiye is an important exporter of medicinal and aromatic plants (close to 4500 species) to the world non-wood forest products market. While being an importer country of wood products, Turkey exports non-wood forest products.

Most of Turkey's land area is covered by one of three biodiversity hotspots (Caucasus, Irano-Anatolian, and Mediterranean). The flora of Türkiye comprises a remarkably high number of endemic species: out of the ca. 12,000 vascular plant taxa, about 32% are endemics. This high rate of endemism is reflected also in medicinal and aromatic plants numbering 1546 species. Currently 1280 plant taxa belonging to 458 genera and 114 plant families have been recorded as used in Türkish folk medicine. As such, traditional medicine can be regarded an important component of primary health care, although the negative impacts of modern age misinformation can also already be felt.

This scenario underlines the importance of pioneering initiatives by the Government of Türkiye to promote research aimed at exploring and utilizing the unique wealth of renewable Türkish MAP diversity. By creating a framework for sustainable sourcing of MAPs and by harmonizing their production chain with international standards, Türkish MAP production is an important component of international

MAP trade. In view of the dangers of overharvesting, special efforts are made to elaborate methods for environment friendly, sustainable sourcing (collection and wild-crafting) of MAPs with the ultimate aim of their conservation.

Initiatives to validate drugs from medicinal and aromatic plants will surely flourish their use in the millennia to come.

The 14 chapters included in present volume offer up-to-date and comprehensive information on a choice of important MAP related topics. Introduced by a review of the present and prospective role of ethnobotany, in Türkiye, chapters on selected pharmacologically important plant species (e.g., carob, laurel, oregano, sage, soap-root, St. John's Wort) and plant families (e.g., Apiaceae, Asteraceae, Umbelliferae) highlight their traditional uses in Türkiye. The chapters on anti-aging effect of Türkish MAPs and natural dye plants summarize important knowledge and information on the outcomes of recent studies.

A brief summary of threatened MAPs is complemented by informative chapters on the cultivation and breeding of MAPs in Türkiye, as well as selected aspects of traditional farming.

Several chapters of the present volume bear witness to above said.

Editors sincerely hope and anticipate that the 14 chapters compiled in the present volume will shed light and assist to obtain insight into the extreme wealth of Türkiye's medicinal plant diversity including their rich traditions and present achievements in the research and environment friendly, sustainable utilization.

Mosonmagyaróvár, Hungary Ákos Máthé

Antalya, Türkiye Kemal Turgut
June 2023

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About the Editors

Ákos Máthé Habil. Dr., Prof. Dr. MÁTHÉ, Ákos has 40 years' background of teaching and research in plant ecophysiology and agricultural botany. He is Professor Emeritus at the Albert Kázmér Faculty of Széchenyi István University, Mosonmagyaróvár, Hungary.

He was two times Fulbright Scholar (1986 and 1995), and visiting professor at University of Veterinary Medicine, Vienna (1995–1997).

Teaching/Research/Consulting and Publications activity of Professor Máthé focuses on ecophysiology, plant domestication/introduction, production of MAPs, as well as new crops, new uses of plants, including feed-additives.

Serving as president of ICMAP (2014–2019) and Chairman of ISHS Section MAPs (2006–2014), he was founding secretary of Hungarian Medicinal Plant Association.

Professor Máthé collaborated in international projects: FEED SEG, CEEPUS, ERASMUS+, HERBAID, GOOD HERBS, Herbs4Youth, EOHUB, etc.

He has also authored some 100 publications and was editor of Herba Hungarica, Acta Agronomica Hungarica. and convener/speaker at international scientific congresses, conferences, workshops, etc. Presently he is network co-ordinator of ESCORENA MAP (http://www.agrowebcee.net/map/).

Kenan Turgut Prof. Dr. Kenan Turgut is a full professor at the Department of Field Crops, Faculty of Agriculture, Akdeniz University in Antalya, Turkey. He received his PhD degree in Plant Biotechnology from the University of Leicester, UK, in 1994. He has been working on agronomy, biotechnology, and breeding of medicinal and aromatic plants for almost 25 years. He uses plant tissue culture methods for in vitro propagation and also for breeding studies. He has introduced *Stevia rebaudiana* to Türkiye successfully. He has seven commercial varieties registered in the national variety list of the Ministry of Agriculture of Forestry.

He has carried out number of research projects on MAPs. Consequently, he has authored about 70 research articles and participitated many international meetings on MAPs. Currently he carries out teaching, training, consultancy and research activities on MAPs.

He was awarded by British Council (1997) and TUBİTAK – Royal Society (1998) for scientific visiting of Leicester University, UK.

He was a co-convener of the First International Medicinal and Aromatic Plants on Culinary Herbs (ISHS) in Antalya in 2007. Also, he was co-editor of *Proceedings of Acta Horticulturae*, Number 826.

Chapter 1
Introduction to Medicinal and Aromatic Plants in Türkiye

Ákos Máthé and Kenan Turgut

Abstract Türkiye, officially the Republic of Türkiye, as of 2022 Türkiye, is a country located between Europe and Asia, at the crossroads of the Balkans, Caucasus, Middle East, and eastern Mediterranean. This huge territory of land surface is divided into seven geographical regions, with most varied topographic characteristics, though Türkiye is predominantly a mountainous country. The extremely rich flora of the country abounds in endemic plant species: one third of some 9,000 medicinal and aromatic plants species is endemic. The present chapter presents various aspects of MAP production and utilization in Türkiye. These are, including geographic characters and vegetation of Türkiye, biodiversity, wild-crafting, natural conservation, cultivation. Aspects of MAP trade as well as their role in the healthcare system are also introduced. Despite its rich natural flora, MAPs in Türkiye generate only 250–300 million USD worth of export revenue, annually. Although a limited number is already cultivated, still most of the MAP species are sourced from wildcrafting. Natural conservation, therefore, is an important issue. Intensive R&D studies that are essential for such patented products with high added values have already been started to ameliorate this situation.

Keywords Türkiye · Medicinal and aromatic plants · Natural Flora · Biodiversity · Natural conservation

Abbreviations

ASU	Ayurveda, Siddha and Unani
BÜGEM	General Directorate of Plant Production

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CCRAS	Central Council for Research in Ayurveda and Siddha Medicines
CCRH	Central Council for Research in Homeopathy
CCRIMH	Central Council for Research on Turkish Medicine and Homoeopathy
CCRUM	Central Council for Research in Unani Medicines
CCRYN	Central Council for Research in Yoga and Naturopathy
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CKS	Farmer Registration System
CMD	Chiang Mai Declaration
GAP	Good Agricultural Practices
GMP	Good Manufacturing Practices
GRevP	Good Review Practice
ISM & H	Türkiyen System of Medicine and Homeopathy
ISM	Türkiye system of medicines
ISO	International Organization for Standardization
IUCN	International Union of Nature Conservation
NAM	National Ayush Mission
NCEs	New Chemical Entities
NMPB	National Medicinal Plant Board
TAGEM	General Directorate of Agricultural Research and Policies
THMP	Traditional Herbal Medicinal Products
TMMDA (TITCK)	Turkish Medicines and Medical Devices Agency
TPRLA	Turkish Plant Red List Authority
TSE	Turkish Standards Institute
UNCOMTRADE	United Nations Comtrade
VCSMPP	Voluntary Certification for Medicinal Plant Produce
WHO	World Health Organization

1.1 Introduction

Türkiye, officially the Republic of Türkiye, as of 2022, is a country located between Europe and Asia. Owing to its unique geographic position, Türkiye is situated at the crossroads of the Balkans, Caucasus, Middle East, and eastern Mediterranean.

According to some information sources, it is one of the largest countries of the region, in terms of territory and population. Its land area is greater than that of any European states.

Most of the country's territory lies in Asia that comprises the oblong peninsula, the so called "Asia Minor" (also known as Anatolia- Anadolu). The remainder – Turkish Thrace (Trakya) – lies in the extreme southeastern part of Europe. Türkiye is still looked upon as a tiny remnant of an ancient empire that once extended over much of the Balkans.

The country has a north-south extent ranging between 480 and 640 km, and it measures about 1600 km from west to east. Türkiye is bounded by several seas: on the north it has a coastline on the Black Sea, while on the southwest and west it is bordered by the Mediterranean Sea and the Aegean Sea.

The narrows linking the Black and Aegean seas (which include the so-called Turkish straits Bosporus, the Sea of Marmara, and the Dardanelles) play a decisive role in the geopolitical importance of the country.

The capital is Ankara, while its largest city and seaport is Istanbul. According to the World Bank, Türkiye is the world's 19th largest economy (World Bank 2013) that has achieved the 172 place in a ranking by the Environmental Performance Index (Wolf et al. 2022).

Using 40 performance indicators across 11 issue categories, the 2022 Environmental Performance Index (EPI) provides a data-driven summary of the state of sustainability around the world. It ranks 180 countries on climate change performance, environmental health, and ecosystem vitality. These indicators provide a gauge at a national scale of how close countries are to established environmental policy targets. 26.3 EPI Score and in a 10 years' change perspective −05.

According to the EPI 2022 index, Turkey, has insufficiently protected its biodiversity and habitat (the third lowest-scoring country and the worst performing Eastern European nation). Less than 7% of land area and 2% of marine territory is covered by protected areas, although Turkey is home to several biodiversity hotspots and unique species (Şekercioğlu et al. 2011). It is also claimed that Turkey's immense infrastructure projects, like the Ilisu Dam, jeopardize important habitats of several threatened species, and also restrict water (Hockenos 2019).

Türkiye covers an area of 783,562 km^2; the country is more than twice the size of Germany or slightly smaller than the U.S. states of Texas and Louisiana combined.

The present Türkiye is home to 19 UNESCO World Heritage Sites. It is also among the most visited countries in the world.

1.1.1 Geographic Characters Versus Vegetation of Türkiye

Türkiye is divided into seven geographical regions: Marmara, Aegean, Black Sea, Central Anatolia, Eastern Anatolia, Southeastern Anatolia and the Mediterranean (Fig. 1.1a, b).

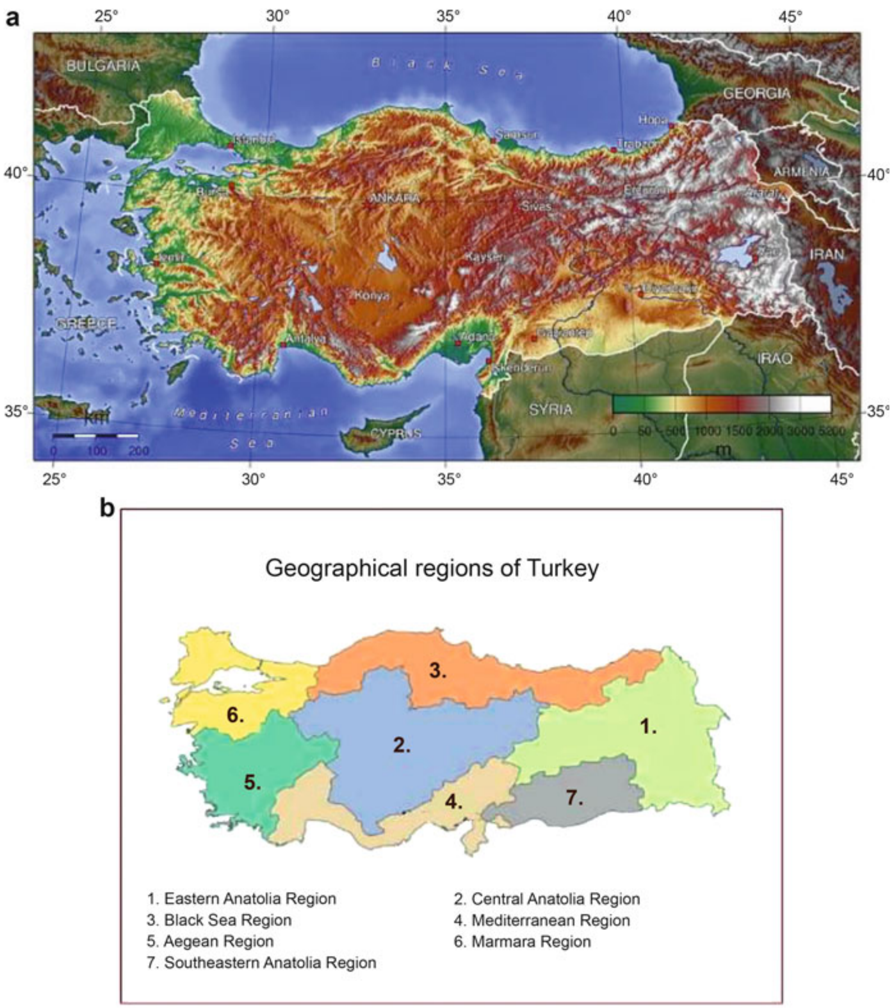

Fig. 1.1 Topographic map (**a**) and geographic regions (**b**) of Türkiye (Wikipedia)

Türkiye is predominantly a mountainous country, where the true lowland areas are situated mostly along the coastal fringes. The special relief conditions created by high mountains and peaks, like Mount Ararat (5165 m), Uludoruk Peak (4744 m), Demirkazik Peak (3755 m), etc. produce climates that are often harsher and not characteristic of a basically Mediterranean country like Türkiye.

Regarding medicinal and aromatic plants, it is important that these conditions have strongly contributed to the evolution of a unique vegetation containing a high/significant number of endemic species.

Table 1.1 Main characteristics of Turkish climatic regions

Region	Main climatic characteristics
Black Sea coastlands	Wettest region with rain throughout the year (813–2438 mm), winter generally mild
Thrace and Marmara region	Dry summers, annual precipitation (610–914 mm) with a pronounced winter maximum
Aegean coastlands	Mediterranean climate regime, with rare winter frosts
Mediterranean coastlands	Mediterranean climate regime, with rare winter. July mean temperatures above 28 °C, and moderate annual rainfall (500–1000 mm)
Southeast region	Dry and hot during the summer, winters cold (near freezing)
Anatolian interior	Semi continental climate, with large temperature range

1.1.2 Climate and Ecological Conditions of Türkiye

The generally dry semi-continental Mediterranean climate of Türkiye is strongly influenced by the vicinity of the seas (to the north, south and west) and the large territories covered by forests.

The seas and the mountains create contrasts between the climates of the interior territories and the coastal fringes. Remarkably, several areas experience winter rainfalls which is mostly typical of the Mediterranean climate. As a contrast, summer droughts are also widespread. Remarkably, due to the elevation of the country winters are often much colder than it would be common in Mediterranean climates. Significant contrasts between winter and summer temperatures are also frequent and are regarded as characteristic Table 1.1.

1.2 Vegetation Types of Türkiye

Normally, there are 3 types of climates in Türkiye, i.e.: Mediterranean, Continental and Oceanic (Akman and Ketenoğlu 1986) that regulate the vegetation formations in Turkey. Being one of the richest floristic regions in the world, the number of herbaceous and woody species has been estimated over 10,000.

The greatest part of the country, including much of the montane area, stands under the influence of various types of Mediterranean climate, while the Continental climate prevails in two distinct areas: in North and North-Eastern Anatolia. In the regions boarding the Black Sea the Oceanic climate is dominant.

According to Atalay (Atalay 1986) the following vegetation formations can be distinguished:

I. The vegetation formations of northern Anatolia and Thrace phytogeographical region.
II. Vegetation formations of Mediterranean phytogeographical region.
III. Vegetation formations of central and eastern Anatolia.

IV. Vegetation formation of southeast Anatolia.
V. Oro and pedobioms of Turkey.

Within the above-mentioned vegetation formations various sub-regions have been described.

In Türkiye, also desertification has been recently recognized as an environmental problem. According to Cetin et al. (2007) it is generally caused by incorrect land use, excessive grazing, forest fires, urbanization, industry, genetic erosion, soil erosion, salinization, and uncontrolled wild type plants picking (Camci Çetin et al. 2007). The anthropogenic destruction of forests, steppe flora has gradually become dominant in Anatolia.

In terms of **biodiversity**, Turkey has a significant importance in Europe and Middle East, as out of the some nine thousand plant species native to Turkey, one third of the species are endemic. Alone from this viewpoint, Turkey is a country of global concern in terms of desertification.

1.3 Biodiversity Hotspots in Türkiye

According to the original concept by Myers et al. (2000) biodiversity hotspots are areas that feature extreme concentrations of endemic species and experience extreme loss of habitats. Most of Türkiye's land area has been described as covered by one of the following biodiversity hotspots: Caucasus, Irano-Anatolian, and Mediterranean.

1.4 Flora of Türkiye

Due to its unique geographic location, Türkiye has a relatively wide range of flowering plant biodiversity that is reflected in its Flora. From the scientific point of view, the first Turkish comprehensive flora work, a survey of the Flora of Türkiye and the East Aegean Islands, was published in the form of a 10-volume set of books edited by the British botanist, Prof. P. H. Davis (Edinburgh University). This monumental work was started in 1965 and the last, 10th volume, was completed in 1985 (Güner et al. 2000).

The scientific exploration of the Turkish flora has been going on ever since the publication of this basic work. New observations/ developments have been continuously incorporated into the subsequent volumes, so that – as a result – 12 years after the publication of the first supplement to the Flora of Türkiye and East Aegean Island, a second supplement (Vol. 11) was published in April 2001 (Özhatay et al. 2022). This contains the latest information on the flora of Türkiye and the East Aegean Islands.

Until 2014, a total of 10 "checklists" were published (Özhatay et al. 2022). Just to characterize the scope of this work: the 10th publication contains 225 taxa from

Table 1.2 Statistical table of summary data of additional taxa for the checklists

	Check-list III (2006)		Check-list IV (2009)		Check-list V (2011)		Check-list VI (2013)		Check-list VII (2015)		Check-list VIII (2017)		Check-list IX (2019)		Check-list X	
	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R
Species	154	75	85	40	158	53	141	32	76	19	110	21	102	33	153	33
Subsp.	12	16	23	13	20	4	29	5	1	2	12	2	10	7	8	8
Variety	15	13	9	1	9	3	8	4	-	-	3	-	2	2	9	2
Hybrid	8	2	3	-	1	-	8	1	1	-	2	2	3	-	10	2
Total	189	106	120	54	188	60	186	42	78	21	127	25	117	42	180	45

↓ **Vol. II (2000) based onCheck-list I & II** (Check-list III)

↓ **Güner *et al.* (2012)** (Check-list V)

N: new taxa for science; **R:** new record for Turkish flora

Source: Özhatay et al. (2022)

193 manuscripts published between January 2019 and December 2021. The taxa described herein are found neither in the previous 11 volumes of 'Flora of Türkiye', nor in the nine previously published checklists. Remarkably, 180 taxa, new to science, as well as 45 taxa with new records for the Turkish flora have been added. A statistical overview of the "evolution" of checklists is contained in Table 1.2.

Surveys by Özhatay and co-authors (2016, 2022) attempted to present all the published taxa added to the Turkish flora since the publication of the second supplement to Davis' work (published before the end of 2004).

As explained in these reviews, the 11 volumes of the Flora of Türkiye collectively describe 8796 species from Türkiye (excluding an additional 192 species confined to the East Aegean Islands lying within Greece). However, the flora of Türkiye has continued to grow following publication of the 11th volume, and an additional 1040 new species were added, either as a new species or new records, in the periods up to December 2014. These check lists have been published in a series papers by N. Özhatay et al. as Check list III, IV, V, VI and VII (Özhatay and Kültür 2006; Özhatay et al. 2009, 2011, 2013).

The 10th review, in the checklist series, contains 225 taxa from 193 manuscripts published between January 2019 and December 2021. These taxa are not found in the previous 11 volumes of 'Flora of Türkiye' nor in the nine formerly published checklists.

Despite all the imposing figures indicating the richness of the Flora, Türkiye seems to face a significant challenge with regard to biodiversity and associated conservation (Şekercioğlu et al. 2011). Despite a reported 5.9% increase in Türkiye's total forest area, since 1973, the endemic-rich Mediterranean maquis, grasslands, coastal areas, wetlands, and rivers are disappearing. The current "developmentalist obsession", particularly regarding water use, seems to threaten with eliminating much of what remains, while forcing large-scale migration from rural areas to the cities.

1.4.1 Floristic Biodiversity as Contributing Factor to Rural Economy

The importance of biodiversity as an important contributing factor to Türkiye's rural economy has been raised by Şekercioĝlu et al. (2011), in one of the scarce reports on medicinal and aromatic plants as non-wood forest products. According to Hüsnü Can Baser (2002) aromatic plants constitute one third of the Turkish flora. Baser also mentions that the chemical diversity among the flowering plants is well documented in the volume 11 of the Flora of Türkiye and the East Aegean Islands. Aromatic diversity is illustrated with examples from genera such as *Sideritis, Salvia, Thymus, Origanum, Satureja, Thymbra, Mentha, Micromeria, Ziziphora, Calamintha, Cyclotrichium, Acinos, Echinophora, Ferulago, Heracleum, Pimpinella, Tanacetum, and Betula*.

At least 123 plant species are used as dyes, especially for carpets (Dogan 2004), while at least 346 taxa of wild medicinal plants are commercially traded (Atay 2000). Other plants are used as pesticides, detergents, musical instruments, furniture, ornaments, or domestic animal feed (Kizmaz 2000). Most geophytes and bulbous plants exported for use in medicine and cosmetics (Kizmaz 2000) are endemic and threatened (Ekim & Güner 2000), often by poaching. Additionally, tuberous orchids have been used to obtain sahlep, an ingredient used in ice cream and in a traditional Turkish beverage (Sezik 2002). Botanists frequently report that orchids have been dramatically overharvested, causing some species to decline to critical levels (Ece Tamer et al. 2006). The data presented in Table 1.3 well represent the diversity of from the botanical viewpoint (Table 1.3).

Table 1.3 Statistical data on the Flora of Türkiye (Güner et al. 2000)

	Native	Endemic	%	Alien	Cultivated	Total
Families	163	0	0	2	8	174
Genera	1168	16	1.4	31	52	1251
Species	8988	2991	33.3	96	138	9222
Subspecies	1683	497	29.5	6	8	1702
Varieties	1074	390	36.3	1	11	1086
Hybrids	298	160	53.7	1	8	307
Total infrageneric taxa	10,754	3708	34.5	101	159	11014[a]

[a]532 new taxa have been included in Vol. 11

1.4.2 Alien Flora of Türkiye vs. Naturalized Species

Turkey is endowed with a wealth of endemic species therefore, it can be postulated that its ecological conditions are favorable also for alien/naturalizing species, as well. Remarkably, there is only limited information in this respect. According to a recent research by Uludağ et al. (2017) there are 340 taxa (among them 68% naturalized and 32% casual). As compared to the total plant diversity of ca. 12,000 species in the Turkish flora, the contribution of alien taxa is ca. 2.8% and that of naturalized taxa ca. 1.9%.

There are 275 neophytes (i.e.: species not native to this geographical region) that have been introduced in recent history (172 naturalized and 103 casual). The number of archaeophytes (non-native plants, long-established in a given area) amounts to 61 (52 taxa of these are naturalized and 9 casual). Remarkably, 47 frequently planted taxa have been described with a potential to escape. The richest in species plant families are Asteraceae (38 taxa), Poaceae (30), Fabaceae (23) and Solanaceae (22).

1.5 Natural Conservation of MAPs in Türkiye

A general overview on the conservation of medicinal plants in Türkiye was published recently by Akalin et al. (2020).

These authors emphasize the importance of plant conservation that should support both the sustainable uses and the protection of the biological resources of MAPs. Based on the main components/forms of good management processes for MAPs elaborated by Kathe (Kathe 2006), authors carried out the evaluation of Turkish medicinal plants. The major criteria used in the evaluation included:

- the study traditional knowledge on the use of plants in health care
- identification of medicinal plants, outline their distributions and assess their abundance
- cultivation, wherever possible, the medicinal plants at the source of supply
- ensurance that collection from the wild is sustainable
- improvement of techniques for harvesting, storage and production
- *ex situ* and *in situ* conservation of populations of medicinal plant species
- building public support for the conservation of medicinal plants through communication and cooperation

Further details of MAP conservation in Türkiye are discussed in Chap. 6. of this volume.

1.5.1 Evolution of MAP Conservation in Türkiye as Reflected by the Database SCOPUS

In view of the fact that the conservation of MAPs has gained an universal recognition and is widely implemented in Türkiye, a brief analysis of relevant activities, as reflected by the database SCOPUS, was carried out (Table 1.4). As a first approach, the keywords "*Native flora*" of Turkey has returned 53 documents, since 1990. The notion of "*Endangered plants* / *Endangered Medicinal Plant Conservation*" appears with 134 and 14 documents, since 1988 and 2000, respectively. It should be noted that the year 1988 coincides with the date of publishing of the **Chiang Mai Declaration** (CMD) on the conservation of Medicinal Plants (Máthé 2015). It was at this international conference/consultation of medicinal plant experts that the imminent threats to MAP global resources was first given due attention, recognized and the call for their conservation was first worded. In view of the widespread and increasing use, i.e.: the exploitation of medicinal plants by various industries inherently implies the notion that Saving Plants means Saving Human Lives. Consequently, the first Turkey related documents on "*Medicinal Plant Conservation*" appeared in SCOPUS for the first time in 1993.

The widespread use of MAPs in Turkey seems to be verified by the fact that 721 documents on "*Traditional medicine*" have been published since 1965. Remarkably high is the number of documents (219) on the scientifically founded use of medicinal plants in various walks of therapy. The 219 documents in SCOPUS,

Table 1.4 Turkish medicinal and aromatic plants represented in the Elsevier Database SCOPUS

Turkey		
Search term (*title. Abstracts, keywords*)	No. of documents	Data available since
Turkey *(total no. of documents)*	**192,032**	**1828**
Medicinal plant	1185	1960
Aromatic plant	249	1974
Medicinal and aromatic plant	114	1990
Native Flora	53	1990
Endangered plants	134	1988
Endangered medicinal plants	14	2000
Medicinal plant conservation	37	1993
Medicinal plant cultivation	44	1974
Medicinal pant domestication	1	2021
Medicinal plant introduction	21	1999
Medicinal plant collection	28	2000
Aromatic plant collection	5	2003
Medicinal plant research	172	1960
Herbal medicine	354	1985
Traditional medicine	721	1965
Phytotherapy	219	1979

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seems to be an indication that Turkish scientists have recognized this, at an early stage of the life of the science of Phytotherapy.

1.5.2 IUCN SSC Turkey Plant Red List Authority

In regard of MAP protection and conservation in Türkiye, the activity of Turkish Plant Red List Authority (TPRLA) is of importance. Within the International Union of Nature Conservation (IUCN) TPRLA is engaged in evaluating Turkish endemic plant species and filling knowledge gaps about the condition of Turkish plants. (https://www.iucn.org/our-union/commissions/group/iucn-ssc-turkey-plant-red-list-authority.)

Since 1964, the IUCN's Red List of Threatened Species and within this the TPRLA has been functioning as the world's most comprehensive information source on the global conservation status of species, including Medicinal and Aromatic Plants. The Red List serves as a critical indicator of the health of global biodiversity. It provides information about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions.

1.6 MAP Research in Türkiye, as Reflected by the Database SCOPUS

To briefly assess the medicinal plant related research activities in Türkiye, the expertly curated abstract & citation database SCOPUS has been used. By covering 240 disciplines, SCOPUS is recognized to deliver the broadest coverage of interdisciplinary abstracts and citation databases.

In this extensive database, the query term "*Turkey*" has returned 192,032 documents for the period 1828–2022. The term "*Medicinal plant*" refers to 1185 entries that have been recorded since 1960, whereas the number of entries on "*Medicinal and Aromatic Plants*" (114 documents since 1990) is significantly less.

"*Medicinal plant research*" has returned 172 documents for Turkey, in the period 1960–2023 (Fig. 1.2a). It should be noted that although this figure cannot be regarded as all exhaustive, still it can be regarded useful for obtaining an insight into to the **research domains** related to MAPs.

As demonstrated by Fig. 1.2b the three foremost active scientific research domains related to MAPs were *pharmacology* (28.3%), *medicine* (23.6%) and *agriculture* (16.3%). Regarding the frequency distribution of the total number of accessible records, a notable upsurge of activities can be observed starting with the year 2005 (3 publications) Fig. 1.2c. For the sake of comparison, on a global basis, 22,411 documents were found for the same period (Fig. 1.2d). Similarly, to Turkey,

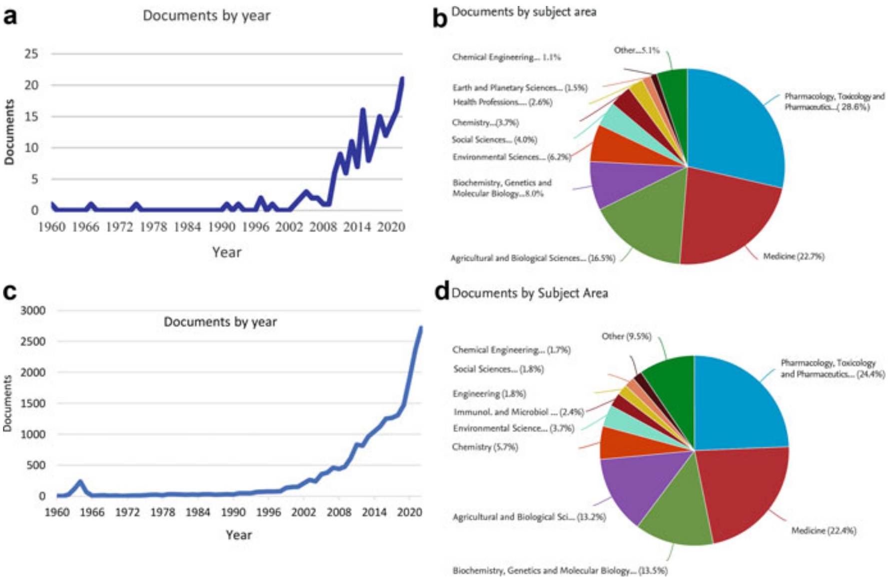

Fig. 1.2 (**a**–**d**) Documents on "Medicinal Plant Research" found in the SCOPUS database

the most frequently studied disciplines were *pharmacology* (24,4%) and *medicine* (22.4%) while in difference to Turkey, the domain *biochemistry* (13.6%) ranked as third. This comparison seems to indicate the agricultural character of Turkey.

1.7 Collection of MAPs in Türkiye vs. Non-wood Forest Products

Medicinal and aromatic plant collection (wildcrafting) from nature is implemented in areas where they grow spontaneously (e.g.: in forests, pastures, unused agricultural lands, in or around used agricultural lands). According to the latest records, there are 11,707 plant taxa in the flora of Turkey, out of which 3649 taxon is endemic. 347 species are collected from nature for commercial purposes and sold in domestic and foreign markets: 10% of these species are endemic (TAGEM 2021).

As a common practice among the people living in rural areas, it serves as an additional source of income for the people living there, including women. The majority of "wildcrafters" belong to social groups that lack basic social amenities (e.g.: children, women and elderly people). Since there are no official records in Turkey, the number of collectors is principally unknown (BÜGEM 2018).

Information can be obtained from the database maintained by the General Directorate of Forestry under the Ministry of Agriculture and Forestry, a quasi comprehensive database of official statistical figures on medicinal and aromatic plants collected from nature (Table 1.5). These data are also related to the so-called

Table 1.5 Production of Non Wood Forest Products in Türkiye between 2010 and 2021, in tons

Non-wood forest products	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Anemone blanda	7	10	15	6	54	2	1	–	–	–	1	–
Arum italicum	–	0,07	2	3	3	3	–	–	–	–	–	–
Ballota cristata, B. saxatilis	114	27	9	31	81	110	123	29	–	–	–	–
Buxus (faggot and shoot)	51	12	32	1	3	2	18	224	14	1	51	–
Dracunculus vulgaris	8	–	3	4	4	2	–	–	–	–	–	–
Chestnut	56	41	27	158	315	336	1908	6461	7019	5910	6200	6585
Carob (*Ceratonia siliqua*)	322	23	24	522	539	614	1492	669	933	642	1170	1962
Cistus sp.	332	204	130	204	307	758	353	258	144	177	244	338
Cyclamen cilicium, C. coum, C. hederefolum	67	65	29	26	28	31	10	8	29	40	11	42
Dryopteris sp.	49	47	33	30	24	19	16	9	12	19	1	–
Eranthis hyemalis	5	3	3	4	51	3	1	2	3	3	1	2
Erica arborea (briar-root)	–	39	39	10	30	44	1	3	30	–	17	–
Fir faggot (*Abies* sp.)	–	–	–	50	–	–	–	–	–	–	–	–
Folium myrtillin (*Myrtus communis)*	416	440	533	390	458	490	618	447	710	570	580	765
Galanthus elwesii, Galanthus woronowii	19	39	37	34	34	24	33	24	29	36	28	33
Geranium tuberosum	2	2	2	0,39	1	1	–	–	–	–	–	–
Hedera sp.	186	12	6	4	8	21	24	–	–	–	–	–
Hypericum ~~montana~~ perforatum	–	–	–	–	–	–	–	1	–	1	1	0,2
Laurus nobilis	15,418	12,329	12,351	15,178	15,581	21,634	21,788	27,678	28,582	32,537	44,350	45,225
Lavandula officinalis Cultivated!!!	1	–	–	–	–	–	–	–	–	10	9	48
Lavandula stoechas	–	–	1	–	–	–	–	–	–	–	–	–
Cone of semen pine	6091	6266	2560	1871	3501	5457	2083	758	1085	1432	1703	1308
Lichen	–	0,50	–	2	1	–	–	25	22	35	2	0,7

(continued)

Table 1.5 (continued)

Non-wood forest products	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Leucojum aestivum	6	–	–	–	–	70	–	73	180	194	181	–
Matricaria chamomilla	–	3	1	1	–	1	–	–	1	–	–	20
Melissa officinalis	–	–	–	1	–	2	–	–	–	–	–	–
Moss	117	129	174	143	74	238	122	237	394	306	197	172
Natural mushroom	–	–	101	50	146	147	803	88	243	73	50	25
Other flower bulbs	–	–	–	–	–	–	–	–	–	–	–	–
Rhododendron sp.	86	76	27	55	51	65	36	68	28	22	19	30
Rosmarinus officinalis	–	50	133	121	172	278	174	264	61	283	218	228
Salvia sp.	702	410	341	324	342	578	279	229	281	261	342	283
Urtica sp.	51	5	1	1	9	–	1	–	1	–	10	–
Resin	–	13	156	26	3	3	21	43	175	190	420	630
Scotch broom (*Spartium junceum*)	3	–	–	–	–	–	–	–	–	–	–	–
Sideritis sp.	–	–	–	–	–	–	–	–	–	–	–	–
Sweetgum oil *Liquidambar orientalis*	3	–	–	1	–	–	–	1	–	–	–	–
Tilia sp.	194	3	56	29	50	48	65	208	35	76	30	45
~~*Thymus* sp.~~ *Origanum* sp.	1412	972	1786	1874	2493	2159	1256	1511	1977	1834	2195	1598
Tragacanth *Astragalus* sp.	–	–	7	1	–	–	–	–	–	–	4	–
Urginea maritima	2	–	0,24	0,19	–	0,47	1	–	1	1	–	2
Underbrush	11,299	12,759	5655	1524	8324	218	1819	1177	2010	1638	200	503
White mistletoe (*Viscum album*)	18	–	1	10	–	–	–	1	–	–	–	–

OGM (2020)
Strikethrough text: unavailable data

Non-Wood Forest Products collected in afforested areas. Among the most important non-wood products collected from forest areas, laurel ranks first with 32.5 thousand tons. Chestnut ranks second with 5.9 thousand tons and oregano ranks third with 1.8 thousand tons.

While in the case of certain products, like *Laurus nobilis, Rosmarinus officinalis* or Folium myrtilli a constant and significant increase can be observed, the figures for other crude drugs (e.g.: White mistletoe, *Dryopteris* sp., or *Geranium tuberosum*) indicate a steady recess that is possibly also due to the overexploitation of natural resources.

Collection of wild growing medicinal and aromatic plants is closely related to the conservation of their habitats. Moreover, any success in conserving medicinal plants has the potential to benefit other types of plants and animals too. In Türkiye, several types of conservation measures have been applied to medicinal plants, including the protection of their areas and other forms of legal control. Ultimately, the domestication (i.e.: *ex situ* conservation) of these species is also aimed at reducing the collection pressure on wild growing medicinal plants (Akalin et al. 2020).

1.8 Cultivation of Medicinal and Aromatic Plants in Türkiye

In Türkiye, like in several other countries of the world, the notion of "Medicinal and Aromatic Plants" covers a wide range of plants used not only for medicinal, aromatic purposes, but also as natural spices, condiments, natural dyes, etc. Due to their diverse utilization, there exist no comprehensive (all inclusive) statistics regarding their production or trade.

In Turkey, Medicinal plant production is supervised and regulated by the Ministry of Agriculture and Forestry (Karik and Tunçtürk 2019). With the aim of rationalizing the production and relevant research of this special group of crops, in 1990, the Ministry launched the National Research Project of Medicinal and Aromatic Plants, a series of studies.

The ultimate goal of these studies was to develop registered varieties for the cultivation of standard and high-quality raw materials required by different medicinal, aromatic and dye plants industries, in Turkey. In some cases, it meant the domestication/introduction of new plant species. Participating research institutes were located in the different regions of the country. Research started by breeding (selection and variety development) appropriate genotypes suitable to the given ecological conditions. As of today, this R + D work has yielded 41 registered cultivars of 15 medicinal and aromatic plant species.

In terms of official statistics, it should be noted that it is difficult to establish clear and all including, comprehensive statistics. The figures contained in Table 1.6 (source: the Ministry of Agriculture and Forestry of the Republic of Türkiye) well

Table 1.6 Medicinal and aromatic plants production area in Turkey (da)

Product/Year of Production	2000	2005	2010	2015	2016	2017	2018	2019
Tea leaves	767.500	766.250	758.641	762.073	763.609	821.079	781.334	785.693
Poppy (Capsules)	275.550	253.350	518.970	615.919	299.217	237.314	451.226	677.369
Cumin	135.300	258.000	171.242	270.247	268.849	267.358	361.761	321.889
Aniseed	360.000	165.000	186.450	138.118	136.552	121.833	124.455	239.171
~~*Thyme*~~ Oregano		47.000	85.351	104.863	121.127	121.472	139.061	157.074
Red Pepper	80.940	78.000	104.049	112.887	122.415	101.710	119.865	119.409
Rose (for oil)				28.243	29.753	33.277	34.205	38.457
Nigella				4.681	23.160	32.560	33.864	37.085
Fennel				15.512	17.503	16.525	23.400	33.859
Mint	6.960	8.710	11.733	10.577	10,921	10.520	10.134	12.650
Lavender				3.218	5.700	6.606	8.684	11.903
Broom wort				15.035	13.850	10.339	10.199	7.468
Buy (fenugreek)	7.000	8.000	1.651	4.825	8.234	14.499	7.188	6.040
Sage				536	3.681	4.123	3.951	5.602
Hops	3.180	2.530	3.550	3.500	3.415	3.300	3.300	3.307
Son Herb (lemon balm)				512	213	207	172	209
Coriander				150	503	410	405	155
Flax Fiber	3.200	1.760	100	15	25	50	50	25
Capers (gebere herb)				15	3	0	20	25
Stinging nettle				0	5	5	5	5
Total	872.130 1.639.630	822.350 1.588.600	1.083.096 1.841.737	1.328.853 2.090.926	1.065.126 1.828.735	982.108 1.803.187	1.331.945 2.113.279	1.671.702 2.457.395

TÜİK (2020)
Strikethrough text: unavailable data

represent the main cultivated crops and their recent production trends, over the period of the last decade.

In terms of the registered production area of medicinal and aromatic plants cultivated in Turkey, an increase by 50% reaching a total production area of 245.7 thousand hectares was recorded for the period 2019 through 2000.

In addition to plants like poppy, cumin, aniseed, fennel, hops, fenugreek, mint, flax that have a rather long record of production, recent years have seen the increasing production of species like oregano, sage, rose, black cumin, fennel, lavender, lemon balm, coriander, capers, nettle that are expected to meet the increasing demands by the market (see: Table 1.6).

According to Karik and Tunçtürk (Karik and Tunçtürk 2019), also in view of the breeding of new varieties, Türkiye should carry on with increasing the culture and usage areas of MAPs. This should contribute to increase Türkiye's shares from the world herbal medicine market which is expected to reach 5 trillion USD in 2050. In this process the export of processed products should be given priority over raw materials (Karik and Tunçtürk 2019).

Further aspects of MAP production will be described in Chap. 7 of this volume.

1.8.1 Production Structure of MAPs in Türkiye

Official records of the General Directorate of Agricultural Reform, under the Ministry of Agriculture and Forestry, mention 26.587 registered producers in the Farmer Registration System (CKS) with an indication to medicinal and aromatic plant production. Among these 575 producers indicated that they produce medicinal and aromatic plants according to organic agriculture principles. 4.393 producers declared themselves as followers of GAP. The products produced and the number of producers are given in Table 1.7.

1.8.2 Good Agricultural Practices

In Türkiye, like in many other countries of the world, Good Agricultural Practices (GAP) cover the entire production chain, from agricultural production to marketing of produce. In order to implement these practices, producers should acquire a good knowledge about the origin of plant material (varieties) and should assess the possible effects on human health and environment. In cases of possible risks GAP should not be implemented. Implementing GAP is based on voluntariness and producers must comply with the Regulation on Good Agricultural Practices dated December 7, 2010 and numbered 27,778 and the relevant legislation (Republic of Türkiye n.d.).

The Web-site of the Turkish Ministry of Agriculture and Forestry contains updated information on the 26 companies presently authorized for GAP Certification.

Table 1.7 Number of farmers producing medicinal and aromatic plants registered in the Farmer Registration System (2019)

Product	Number of producers	Product	Number of producers	Product	Number of producers	Product	Number of producers	Product	Number of producers
Oregano	5608	Stinging nettle	35	Aniseed	5314	Saffron	30	Rose	3411
St John's wort	25	Poppy capsule	3059	Bitter melon	25	Cumin	3046	Stevia	22
Nigella (Black cumin)	933	Holy thistle	22	Lavender	812	Hibiscus	20	Fennel	754
Echinacea	20	Carob	713	Capers	17	Jujube (Unnap)	364	Daisy	17
Sage	267	Mahlep Mahaleb cherry	15	Laurel	257	Radika Dandelion	15	Hops	224
Chicory	13	Coriander	194	Mustard herb	11	Buckwheat	187	Tarragon plant	11
Rosehip	166	Buy (fenugreek)	9	Blueberry	140	Passiflora	8	Rosemary	128
Gum tree	8	Sumac	111	Yarrow	7	Goji berry	93	Marshmallow flower	6
Quinoa	88	Spanish lavender	6	Linden	83	Çöven Soaproot	5	Basil	68
Marjoram	4	Hawthorn	65	Common myrtle	4	Salep Orchids	62	Primrose	3
Melissa	41	Ginger	2	Guelder rose	38	Comfrey	1		

TAGEM (2021)

Recognizing the importance of GAP, as an agricultural production method that allows to observe traceability, sustainability and food safety in agriculture, without harming the human health, animal health and environment, the Ministry has started projects aimed at the expansion and control of good agricultural practices (GAP) in Turkey. Products which are subject to international trade and which are certified with Good Agricultural Practices are preferred by consumers, especially in the European Union Countries. By expanding the implementation of GAP, and by increasing the production of agricultural (incl. MAP) products it is hoped that exports can be farther increased. The "Project on the Expansion and Control of Good Agricultural Practices and Organic Farming" is meant to be a certain kind of pilot project on fruits and vegetables, and the experiences gained thereof, will be used to expand good agricultural practices throughout Turkey.

1.9 Trade of MAPs in Türkiye

It is hard to give an exact statistics of the quantities of MAPs that are traded by Türkiye, as there seems to be no official statistics, there are no relevant databases (Akbulut and Bayramoglu 2013). According to information sources (United Nations Comtrade database), trade data for 2011, reveal that the total global import value was $3.05 billion US dollars and total exports was $2.86 billion US dollars (SITC 3, 292.2 "Natural gums, resins, etc." and 292.4 "Plants, Pharmaceutical plants, etc."). Turkey's total exports for 2011 were almost $13.4 million US dollars, corresponding to approximately 3760 tons of plants. Total Turkish imports in 2011 were $7.5 million US dollars, corresponding to approximately 2398 tons of plants (UNCOMTRADE 2012).

Turkey is exporting to approximately 100 countries worldwide. An important part of these foreign sales is directed to North America, European Union, Latin America, Far East and North Africa. US, Germany, Vietnam, Netherlands, Poland, Brazil, Canada, Italy, Belgium, Greece, France and Japan are listed in the list. Major pharmaceutical and spice plants include oregano, bay leaf together with cumin and anise, fennel seeds, juniper bark, mahlep, fenugreek, rosemary, licorice, mint, sumac, sage and lime. The most exported products are oregano and laurel. In 2018, a total of 80 thousand tons of medicinal and aromatic plants were exported and a total of USD 265 million in revenue recorded (Table 1.8).

1.10 Medicinal Plants in the Turkish Healthcare System

A detailed study by Ozkan et al. (Ozkan et al. 2016) summarizes the potential use of Turkish medicinal plants in the treatment of various diseases. The review refers to studies that indicate that medicinal plants have been used to treat human diseases for thousands of years. Considering their beneficial health effects, some of the

Table 1.8 Medicinal and aromatic plants exports of Türkiye in 2018 (Anonymous 2019b)

Product	Amount (tons)	Value (1000 USD)
Poppy seed	25.286	73.736
Oregano	16.212	52.331
Laurel leaf	13.253	36.716
Cumin	6.455	19.500
Carob	2.421	18.433
Tea	3.321	12.035
Anis seed	2.418	9.637
Morphine	25	8.434
Other spices	2.985	8.233
Sage	1.824	6.695
Sumac	2.108	4.491
Licorice	1.069	3.102
Spice mix	300	2.006
Mahaleb	123	1.242
Spearmint	620	1.876
Linden	116	1.521
Rosemary	493	1.477
Thyme	48	1.287
Black cumin	404	983
Fenugreek	168	298
Cinnamon	38	234
Turmeric	45	201
Coriander	142	187
Ginger	26	116
Clove	5	99
Saffron	4	89
Curry	24	78
Nutmeg	10	55
Cardamom	3	54
Total	**79.960**	**265.162**

medicinally important plants grown in Turkey are covered in this review with respect to their antioxidant potential and phytochemical profiles.

The Traditional and Complementary Medicine (T&CM) Department, the main regulator of the T&CM practices in Türkiye, was established by the Ministry of Health, in 2012. The Directorate General for Health Services is responsible for certification, authorization and supervision. "Traditional and Complementary Medicine Practices Regulation" was implemented on 27 October 2014. The purpose of this Regulation is to determine the traditional and complementary medicine application methods for human health, to train and authorize the people who will apply these methods, and to regulate the working procedures and principles of the health institutions where these methods will be applied.

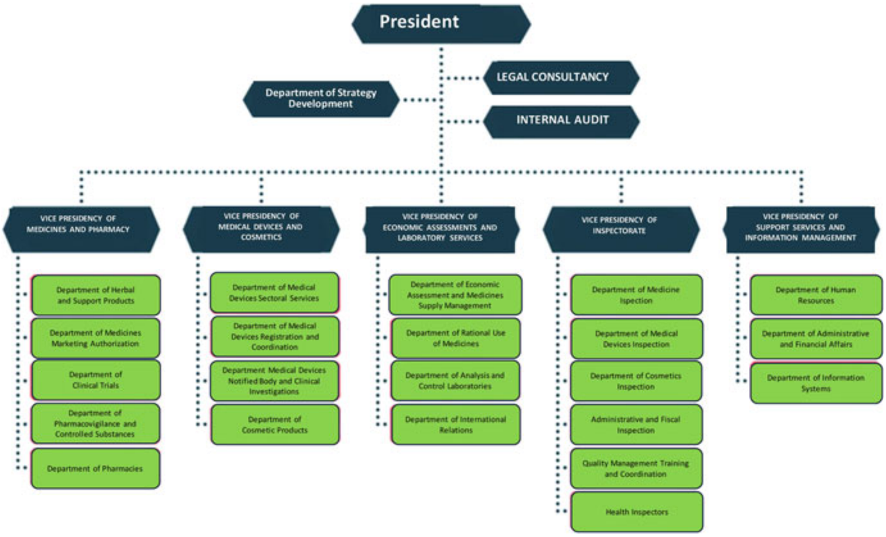

Fig. 1.3 Organization Chart of Turkish Medicine and Medical Devices Agency. (Source: https://www.titck.gov.tr/Dosyalar/Erisim/TMMDABrochure.pdf)

The Turkish Medicines and Medical Devices Agency serves as supervisory agency for several MAP related activities and their products: e.g.: medicines, cosmetics and traditional herbal medicinal products, including medicinal nutrition products. Within the umbrella of the Agency, it is the Vice President of Medicines and Pharmacy whose responsibilities include Pharmacovigilance and Controlled Substances, whereas a separate Presidency "Vice Presidency of Inspectorate" is supervising, among others the Department of Quality Management, Training and Coordination, Department of Medicine Inspection, etc. (Fig. 1.3).

The calendar year of 2022 witnessed a number of significant developments in the pharmaceuticals and healthcare sector in Turkey. The Turkish Medicine and Medical Devices Authority ("Authority") issued guidelines and announcements with a view to align with the international standards and addressing the commonly encountered procedural issues. Below is a summary of the recent developments in the sector (Table 1.9).

1.11 Medicinal Plants in the Turkish Folk Medicine (Traditional Medicine)

It seems to be common knowledge that the vast territory of Turkey, a country bridging over from Europe to Asia, has a rich flora, with more than 9000 flowering plant species (Sezik et al. 1991), which is quite imposing when compared to 12,000 species, reported for the whole of Europe. In the past, due to its strategic position,

Table 1.9 Latest developments in the Turkish Pharmaceuticals and Healthcare Sector

Guideline on GPP – Module X.
Guideline on GPP – Module XI.
Amendments to the Medical Device Legislation.
Guideline on Risk-Based Inspections for Good Clinical Practice (GCP).
Guideline on Good Distribution Practices (GDP).
Reliance Guideline on GMP.
Guideline on Good Pharmacovigilance Practices (GPP) – Module VI.
Guideline on Batch Release.
Guideline on Scientific and Product Promotional Meetings.
Guideline on Pharmacovigilance Indicators.
New Requirements for Medical Device Manufacturers on Exports to the United Kingdom.
Amendments to Module III – Periodic Benefits / Risk Assessment Report.
New Guideline on Import Applications and Market Release Permit.
Reliance Guideline on Clinical Research Applications.
New Guideline on Crisis and Emergency Management for Human Medicinal Products Where Routine Regulatory Operations Cannot Be Followed.
New Reliance Practices Guide on Pharmacovigilance Activities.

Anatolia (Asiatic Turkey, Anadolu) was occupied by various ethnic races and tribes. These had frequently different cultures, religions and customs and settled down in Turkey, for many centuries. As a result of both cultural and floristic diversity and richness, an extremely rich amount of knowledge of traditional medicine has accumulated in this region.

As it was rightly stated by Sezik et al. (1991), in the modern times (with the modernization of society, especially by the development of road communication, the migration of people from villages to cities, and the influx of modern medicine) this accumulated knowledge is rapidly being lost.

Despite of this important recognition, there seems to be a need for comprehensive, rigorous surveys on traditional medicine, even today, as most available studies deal with various regions only, presenting their findings in the form of data collections (list of plants and their uses).

1.12 Herbal Medicines in Turkey

Herbal Medicines (HMs) are generally considered safe due to their natural origin and long-standing use. Although the use of HMs is common in Turkey, no detailed studies on their use or knowledge-attitudes towards HMs have been performed.

The results of face-to-face surveys on the use of herbal medicines by hospital patients is therefore of importance. As an example, a study based on questionnaires completed by both out- and in-patients admitted to the Meram Faculty of Medicine Hospital in Konya (Türkiye) has revealed that 48.8% of the surveyed population, mostly the female patients, used this type of traditional therapy (53.4% of the 927 patients). It was also found that patients with a higher education level and a higher family income were similarly more likely to use HMs. The most frequently used herbal medicines were *Camellia sinensis* (14.2%), *Rosmarinus officinalis* (10.2%) and *Zingiber officinale* (9.1%).

Similarly informative are the semi-structured interviews by Fakir et al. (2009) that were aimed at acquiring information on traditional plant use, particularly medicinal plants, in the Western Mediterranean Region of Türkiye. As a result, a simplified list was created containing information on scientific names, vernacular names and medicinal usage of 187 plant taxa belonging to 135 genera, and 67 families. The dominant families were Lamiaceae, Asteraceae, and the Rosaceae. It was found that *Sideritis* sp., *Verbascum* sp., *Origanum* sp., *Salvia* sp. and *Hypericum* sp. were the most commonly used species. It was also stated that several plant species are commonly consumed for the same purposes, in traditional medicine around the Mediterranean area.

As Turkey is divided into seven geographic regions with different physical and climatic features, even today, ethnobotanical studies seem to have been focusing on some selected regions, only. In this regard, an important series of publications ("Traditional Medicine in Turkey") was started by Sezik et al., in 1991, in the Journal of Ethnopharmacology (Sezik et al. 1991). As such, the ten publications listed in Table 1.10 provide an insight into the ethnobotanical knowledge of different Turkish regions.

1.13 Actors and Marketing Structure of Türkiye Medicinal and Aromatic Plants Sector

In Türkiye, similarly to other countries, medicinal and aromatic plants are used in most varied areas: some of the products are available in the market under the name of "Herbal Product", others as food supplements with the permission of the Ministry of Agriculture and Forestry. Traditional Herbal Medicinal Products (THMP) are regulated with the permission of the Ministry of Health and as medicines. Due to the high number of products and the variety of usage areas, a different supply chain (structure) emerges for each product.

Local intermediaries buy the raw material (raw crude drug) from the producers or collectors. As a next step, they deliver it either to so called general intermediaries, or directly to the wholesalers. Processed according to different areas of use, the wholesalers distribute the produce to reach the consumer. The most frequently applied forms of processing include distillation, extraction and drying and transformation into products such as aromatic water, essential oil, extract, oleoresin and processed drugs. On the other hand, the marketing chain of plants such as hops, poppy, cannabis, etc., which have developed artisanship and have been produced in

Table 1.10 Traditional medicine in Turkey: publications by E. Sezik

No	Geographic area	Citation
1	Traditional medicine in Turkey I. Folk medicine in northeast Anatolia	Sezik, E., Tabata, M., Yesilada, E., Honda, G., Goto, K., & Ikeshiro, Y. (1991). Traditional medicine in Turkey I. folk medicine in northeast Anatolia. *Journal of Ethnopharmacology*, *35*(2), 191–196.
2	Traditional medicine in Turkey II. Folk medicine in Kastamonu	Sezik, E., Zor, M., & Yesilada, E. (1992). Traditional medicine in Turkey II. Folk medicine in Kastamonu. *International journal of Pharmacognosy*, *30*(3), 233–239.
3	Traditional medicine in Turkey III. Folk medicine in East Anatolia, van and Bitlis provinces	Tabata, M., Sezik, E., Honda, G., Yeşilada, E., Fukui, H., Goto, K., & Ikeshiro, Y. (1994). Traditional medicine in Turkey III. Folk medicine in East Anatolia, van and Bitlis provinces. *International journal of pharmacognosy*, *32*(1), 3–12.
4	Traditional medicine in Turkey IV. Folk medicine in the Mediterranean subdivision	Yeşilada, E., Honda, G., Sezik, E., Tabata, M., Goto, K., & Ikeshiro, Y. (1993). Traditional medicine in Turkey IV. Folk medicine in the Mediterranean subdivision. *Journal of ethnopharmacology*, *39*(1), 31–38.
5	Traditional medicine in Turkey. V. Folk medicine in the inner Taurus Mountains	Yeşilada, E., Honda, G., Sezik, E., Tabata, M., Fujita, T., Tanaka, T., . . . & Takaishi, Y. (1995). Traditional medicine in Turkey. V. Folk medicine in the inner Taurus Mountains. *Journal of ethnopharmacology*, *46*(3), 133–152.
6	Traditional medicine in Turkey VI. Folk medicine in West Anatolia: Afyon, Kutahya, Denizli, Mugla, Aydin provinces	Honda, G., Yeşilada, E., Tabata, M., Sezik, E., Fujita, T., Takeda, Y., . . . & Tanaka, T. (1996). Traditional medicine in Turkey VI. Folk medicine in West Anatolia: Afyon, Kütahya, Denizli, Muğla, Aydin provinces. *Journal of Ethnopharmacology*, *53*(2), 75–87.
7	Traditional medicine in Turkey VII. Folk medicine in middle and west Black Sea regions	Sezik, A. E. (1995). Traditional medicine in Turkey VII. Economic Botany, 49(4), 406–422.
8	Traditional medicine in Turkey VIII. Folk medicine in East Anatolia; Erzurum, Erzincan, Ağri, Kars, Iğdir Provinces	Sezik, E., Yeşİlada, E., Tabata, M., Honda, G., Takaishi, Y., Fujita, T., . . . & Takeda, Y. (1997). Traditional medicine in Turkey VIII. Folk medicine in East Anatolia; Erzurum, Erzincan, Ağri, Kars, Iğdir provinces. *Economic botany*, 195–211.
9	Traditional medicine in Turkey IX: Folk medicine in north-west Anatolia	Yeşilada, E., Sezik, E., Honda, G., Takaishi, Y., Takeda, Y., & Tanaka, T. (1999). Traditional medicine in Turkey IX: Folk medicine in north-west Anatolia. *Journal of ethnopharmacology*, *64*(3), 195–210.
10	Traditional medicine in Turkey X. Folk medicine in Central Anatolia	Sezik, E., Yeşilada, E., Honda, G., Takaishi, Y., Takeda, Y., & Tanaka, T. (2001). Traditional medicine in Turkey X. Folk medicine in central Anatolia. *Journal of ethnopharmacology*, *75*(2–3), 95–115.

Source: https://scholar.google.com/citations?user=-aqKZTIAAAAJ&hl=en

a controlled manner for a long time, differs from this general distribution network (Temel et al. 2018).

Public institutions in the medicinal and aromatic plants sector are the Ministry of Agriculture and Forestry, General Directorate of Crop Production and Departments, General Directorate of Food Control and Departments, General Directorate of Agricultural Research and Policies, General Directorate of Forestry, Ministry of Health, Pharmaceuticals and Medical Devices Agency. The Ministry of Trade, Ministry of Industry and Technology as well as universities, are also among the internal stakeholders.

There are numerous laws, regulations and communiques on medicinal and aromatic plants issued by the Ministry of Agriculture and Forestry, Ministry of Health and other public institutions. The first codex was the Law on Turkish Codex (Law Number: 767) in its 324th issue dated 17 March 1926 and five codexes were published until our membership to the European Pharmacopoeia Commission in 1994. Finally, Turkish Pharmacopoeia I-European Pharmacopoeia Adaptation was put into force in 2004 (BÜGEM 2018).

In addition, there are also legislations on important areas of use of medicinal and aromatic plants. Law on the ratification of Turkey's accession to the "1961 Single Convention on Narcotic Drugs" (Poppy Law), Turkish Food Codex Communiqué on Spices, Turkish Food Codex Communiqué on Diet Foods for Special Medical Purposes, Regulation on Certification and Marketing of Oil, Fibre, Medicinal and Aromatic Plant Seeds, Regulation on Traditional Herbal Medicinal Products, Turkish Food Codex Regulation, Regulation on Flavourings and Flavouring Food Ingredients, Regulation on Cannabis Cultivation and Control, Turkish Food Codex Regulation on Common Authorisation Procedure for Food Additives, Food Enzymes and Food Flavourings are some of them.

There is no legal regulation on the collection of medicinal and aromatic plants from nature and the issue is handled within the framework of the "Environmental Law" and different regulations. With the "Communiqué No. 302 on Inventory and Planning of Non-wood Forest Products and Production and Sales Principles" implemented by the Ministry of Agriculture and Forestry, the inventory, sales and production procedures and principles of non-forest products including medicinal and aromatic plants are carried out under the authority and responsibility of the Department of Non-wood Products and Services (BÜGEM 2018).

The issuance of business registration certificates and inspections of herbalists, which have an important place in the marketing structure of medicinal and aromatic plants, are carried out by the Ministry of Agriculture and Forestry and some activities are carried out by the Ministry of Health.

The Turkish Standards Institute (TSE) became a full member of the European standardization organizations CEN and CENELEC on 1 January 2012. In accordance with the membership obligations, the standards published by these organizations are adapted by TSE and accepted as Turkish Standards. European Standards are accepted instead of Turkish Standards prepared on the same subject.

In addition, international standards published by International Standard Organizations (ISO, IEC etc.) are closely monitored and those deemed necessary in line with Turkey's needs and priorities are published as Turkish Standards as a result of harmonization studies.

In Turkey, there are 68 Turkish Standards on medicinal and aromatic plants. Of these 68 standards, 41 are related to product properties, 22 to test methods, 3 to terms, definitions and labelling and 2 to sampling and preparation. The distribution of these 68 standards in terms of their sources; 31 of them are synthesis, 25 of them are ISO standards and 11 of them are ISO standards accepted by CEN.

ISO (International Organisation for Standardisation) has a sub-technical committee "ISO/TC 34/SC 7 Spices, culinary herbs and condiments" to prepare standards on Medicinal and Aromatic Plants. India is the secretariat of this technical committee. So far, 72 standards including amendments have been prepared in this committee and 6 drafts are being worked on in work programmes. Turkey is a participating member of this committee. There is no technical committee in CEN (European Organisation for Standardisation) to prepare standards on Medicinal and Aromatic Plants. The standards prepared by ISO are accepted and published as EN standards by the CEN/SS C01 "Food Products" technical committee.

Turkey became a member of the Codex Alimentarius Commission on 01 October 1963. Turkey is represented by the Ministry of Agriculture and Forestry in the Commission and the Codex contact point is the General Directorate of Food and Control. A "Committee on Spices and Culinary Plants" was established within the Codex Alimentarius Commission in 2013. The Committee has held 4 meetings so far and 3 meetings have been attended on behalf of our country. Codex Alimentarius spices and culinary herbs standards are being prepared in the committee and black pepper, cumin, thyme standards have been published so far and the draft garlic standard is ready for publication. Countries are not obliged to comply with the published standards. However, since it is the most comprehensive standard as international legislation, countries that do not have national legislation take Codex Standards as a basis at the import stage and it is accepted as an important criterion in the preparation of national legislation. In addition, these standards are also important in international commercial disputes. For this reason, in order not to adversely affect our exports, these standards should not contain criteria that are not suitable for the products in our country.

1.13.1 Turkish Food Codex Regulation on Food Additives

This Regulation sets forth the rules and conditions of usage of food additives in foodstuffs, food enzymes and flavorings, labelling of food additives and list of food additives in Annex II and III. The aim of this Regulation is to protect consumer rights, consumer health and human health and also to protect environment. This Regulation does not cover food enzymes and flavorings covered by Turkish Food Codex Regulation on flavorings and certain food ingredients with flavoring properties. This Regulation is drafted in accordance with Regulation (EC) No 1333/2008 of the European Parliament and of the Council on food additives.

1.13.2 Pharmacopoeia of Türkiye

A comprehensive historical survey of pharmacopeia in Turkey was presented at the 38th International Congress for the History of Pharmacy, in Sevilla, by Halil et al. in 2007. According to this, as of 2007, twelve different pharmacopœias had been published and used by pharmacists in Turkey. Six of these books belong to the period of the Ottoman Empire and were mostly written in languages other than Turkish, such as French, Italian, Greek and Latin. Recently, the Turkish Ministry of Health authorities have officially approved the use of the European Pharmacopeia, since the Turkey's EU membership is underway (Tekiner et al. 2007). Nonetheless, in 2018, the Turkish Medicines and Medical Devices Agency (TITCK) published on its website the Preparation Guidelines for the Turkish Pharmacopeia ("Guidelines") (Mashaki Ceyhan et al. 2018).

With the aim of evaluating and improving TITCK activities, Mashaki et al. (2018) published an open access questionnaire based study comparing similar registration processes in Australia, Canada Saudi Arabia and Singapore (Mashaki Ceyhan et al. 2018). As a general outcome of the research, it was stated that the TITCK performs a full review for all new active substance (NAS) applications. Whereas a submission of a Certificate of Pharmaceutical product (CPP) with an application is not a precondition, evidence of approval in another country is required for final authorization by the TITCK. As a rule, approval times at the TITCK exceeded the agency's overall target time suggesting room for improved performance, consistency, and process predictability. Measures of GRevP (Good Review Practice) are in place, but the implementation by the TITCK is not currently formalized.

1.13.3 Spices Board of Türkiye

Türkiye, as a member of the European Spice Association, is represented by the Aegean Exporters Association, located in Izmir. In compliance with the objectives of this European Association, Türkiye has been engaged in the realizing the following main goals:

- represent the interests of its members vis-à-vis the competent bodies and departments of the European Union, as well as international institutions and organizations.
- promote the interests of members in respect of the products concerned and to protect the image of the products and the sector;
- study subjects of common interest to the members in the scientific, legislative, technological and economic fields.

1.14 Conclusions

Türkiye, officially the Republic of Türkiye, as of 2022 Türkiye, is a country located between Europe and Asia. Owing to its unique geographic position, Türkiye is situated at the crossroads of the Balkans, Caucasus, Middle East, and eastern Mediterranean.

This huge territory of land surface is divided into seven geographical regions, with most varied topographic characteristics, though Türkiye is predominantly a mountainous country.

In terms of **biodiversity**, the extremely rich flora of the country abounds in endemic plant species: this is valid of the native medicinal and aromatic plant flora (out of the nine thousand plant species native to Turkey, one third of the species are endemic).

Work on the systematic scientific exploration of the Turkish flora has been going on with already 11 volumes of the “Flora of Türkiye” published. This means an extraordinary wealth of potential medicinal and aromatic plants that are already utilized or await utilization. In this sense, biodiversity of MAPs is an important contributor also to rural economy.

MAPs in Türkiye play an important role in the Turkish Healthcare System. The agency “Turkish Medicines and Medical Devices Agency” takes in key-role in supervising related activities with a focus on quality management, training and coordination. The guidelines and announcements issued by the Agency comply with the main international standards and address the commonly encountered procedural issues.

Regarding the sourcing of crude drugs, the collection of wild growing medicinal and aromatic plants, is closely related to environment conservation and the sustainable utilization of habitats. Although presently there exists no official statistics of MAP wildcrafting, activities in Türkiye imply that any success in conserving medicinal plants has the potential to benefit other types of plants and animals too.

The various types of conservation measures applied to medicinal plants, including the protection of their areas and ultimately, their domestication (i.e.: *ex situ* conservation) are also aimed at reducing the collection pressure on wild medicinal plants.

Türkiye has embarked on a road of systematic, as well as sustainable production (sourcing) of MAPs. This activity combined with intensive scientific research will contribute to the further development of best practices in production and utilization of this unique wealth of natural resources.

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Chapter 2
Ethnobotany in Turkey: Retrospect and Prospect

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Abstract Turkey has a deep-rooted ethnobotanical knowledge due to its rich flora and cultural and historical background. In this review, the historical course of ethnobotanical studies in Turkey is briefly addressed and highlights from ethnobotanical records belonging to seven geographical regions of the country are compiled. In addition, the richness of Turkey's ethnobotanical accumulation and its potential for future issues has been revealed through some striking examples and bioactivity studies conducted under the guidance of traditional knowledge.

Keywords Ethnobotany · Turkey · Anatolian folklore · Turkish culture · Traditional medicine · Folk remedy · Medicinal plants

2.1 Introduction

Ethnobotany is the study of the human-plant relationship on a historical and geographical basis. While carrying out this job, it calls for understanding how plants are perceived, defined, classified and used by people belonging to a particular culture. Considering the importance of plants in different practices of human life, the complex relationships between human societies, and the approximately 400,000 plant species in the world, it can be understood that ethnobotany is a highly comprehensive, diverse, multidimensional and dynamic field of study (Alexiades 2018).

Defining the history of the human-plant relationship is a part of a general effort to determine the relationship between archeology and history. Apart from these two study areas, an essential part of human history is not included in written records and cannot be deciphered in the context of any remains (Diamandopoulos 2014).

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Throughout history, stories about plants have emerged in the oral traditions of humankind. It is widely accepted in local and academic communities that these stories contain valuable ethnobotanical information and have been transmitted from generation to generation (Sugiyama et al. 2020). They can also fill the gaps between the data coming from archeology and history. Ethnobotany, defined by Prance et al. as the science of human survival (Prance et al. 2007), uses bibliographic and field methods. These two methods can often be advantageously intertwined (Schultes 1960).

Turkey, with a total surface area of 814,578 km^2, is located on two peninsulas at the junction of the continents of Asia and Europe in the Northern Hemisphere. The part of Turkey in the European continent is known as Thrace, while the larger part in the Asian continent is Anatolia or Asia Minor. It has different geographical, geological, edaphic, geomorphological and climatic features that determine the structure of its unique flora. Turkey, one of the countries with the richest plant diversity in the Mediterranean basin and hosted many tribes and cultures throughout history due to its location as an intercontinental bridge, has a significant ethnobotanical accumulation (Kandemir et al. 2014).

2.2 Foundations of Turkish Ethnobotany

Turkey has been host to many influential, world-renowned personalities and historical events: Julius Caesar made his famous “Veni, Vidi, Vici” declaration here in Anatolia, in Tokat Zile; the Trojan War was fought here; the universal phrase “rich as Croesus” was inspired by the Lydian King Croesus, who ruled a large part of Western Anatolia; Gordium, the place where Alexander the Great split the legendary Gordian knot, is about 60 kilometers southwest of modern-day Ankara. In many ways, Turkey’s history is that of humanity. Beginning with the world’s first known human settlements, many great civilizations—the Hittites, Phrygians, Urartians, Lycians, Ionians, Lydians, Romans, Byzantines, Seljuks, and Ottomans—were ruled in these extraordinary lands. It is clear that Turkey, which has a legacy of countless cultures, plays a vital role in the development of society (Arda 2009). This deep-rooted background has also enriched the human-plant relationship and related archaeological finds, historical sources and the oral information transmitted from generation to generation providing rich research material for people who do ethnobotanical research in Turkey.

2.2.1 Historical Highlights

There is some evidence that the picking of some wild fruits is quite common in the pre-agricultural settlements Hallan Çemi and Göbeklitepe and the agricultural settlements Aşıklı Höyük and Çatalhöyük. Archaeological data show that wild plant collection has been a regular part of living, as well as agricultural production. There are also recornd showing how diverse the various plant use practices were in Anatolia, in the past (Rosenberg et al. 1995; Hauptmann 1999; Fairbairn et al. 2007).

Çatalhöyük, one of the most important archaeological sites in the world, located near Konya in central Turkey, has unearthed a dense Neolithic settlement dating back 9000 years as a result of excavations since the 1960s. Çatalhöyük provides an archaeological example of the collection and storage of seeds of wild plants from an extraordinary range of plants. For instance, *Capsella bursa-pastoris* (L.) Medik. and *Erysimum sisymbrioides* C.A. Mey. from the Brassicaceae family, *Eremopyrum* (Ledeb.) Jaub. & Spach and *Taeniatherum caput-medusae* (L.) Nevski from the Poaceae family, *Helianthemum* Mill. from Cistaceae, *Vicia noeana* Boiss., wild vetch from Fabaceae, and some unidentified seeds were found and examined at this site. Seed finds stored in burnt buildings showed that Cruciferous tiny seeds were an essential and valuable resource at Çatalhöyük (Fairbairn et al. 2007). The most obvious use of seeds was in the form, as a source, of oil, but they may also have been used also as a flavoring (Rosenberg et al. 1995). The study of non-food plant uses also conveys essential information about the human-plant and human-natural environment relationship. Detailed analyses of silicified plant traces, frequently found in houses and tombs at Çatalhöyük, show the routine use of wild plants, particularly from wetlands, for basketry (mats, baskets and ropes) and construction (Ryan 2011).

Most of the 20 tons of material found in the Ulu Burun Late Bronze Age shipwreck discovered on the Turkish coast, which is the oldest shipwreck ever found, has remained intact until today. Among them, the remains of some plants traded in the eastern Mediterranean and used as food on the ship, were examined. These include almond (*Amygdalus communis* Poit. & Turpin), olive (*Olea europaea* L.), pomegranate (*Punica granatum* L.), fig (*Ficus carica* L.), grape (*Vitis vinifera* L.), coriander (*Coriandrum sativum* L.) and the spiny burnet (*Sarcopoterium spinosum* (L.) Spach), which is used as a filler to stabilize the cargo in the ship's hold were determined. The resin obtained from *Pistacia* L. species found in Canaanite jars was most likely for aromatic uses (Haldane 1993).

A study conducted in 2009 (Salih et al. 2009) showed that a flask from the Old Hittite Period level of Boyalı Höyük from 1650 BC in north-central Anatolia, contained pure black cumin seeds mixed with bee products, beeswax and propolis. So far, no direct archaeological evidence has been found to suggest that the inhabitants of Boyalı Höyük or the Hittites used black cumin seeds mixed with bee products medicinally. However, considering the folkloric use of black cumin seeds for the treatment of diseases and health promotion together with bee products, it is thought that the Boyalı Höyük material represents a medicine used by the Hittites in Anatolia about 3600 years ago.

Historically, human knowledge of medical theories and practices feeds materia medica and pharmacopeias quantitatively. Dioscorides, born in *Anazarbos*, near the province of Adana in what is now Turkey, in the first century AD, is the author of *De Materia Medica*, one of the pioneers of modern pharmacopeias. It is also the most detailed guide to medicinal plants ever transferred from the ancient Mediterranean. This book is a landmark in the development of pharmacy and botany and has profoundly impacted these disciplines over the centuries. In this book, Dioscorides monographed over 600 different plants, 35 animals, and 90 minerals. He not only described the drugs of his time and explained their effects but also systematically organized their definitions. To compile the information, Dioscorides drew on previously written sources, his experience as a physician and local therapeutic traditions. This book is the oldest and most important source known about medicinal plants used in Anatolia (Baytop 1999; Staub et al. 2016).

As a tertiary relict endemic, *Liquidambar orientalis* Mill. a medicinal plant known as "Sığla ağacı" in Turkey, grows naturally in the southwestern coastal regions of Turkey, particularly in Köyceğiz, Fethiye, Marmaris and Ula. Its exudate obtained from the injured body, locally called "Sığla yağı" has been used in Anatolian folk medicine for centuries since the time of Hippocrates. Hippocrates says it can be used as a pill to strengthen the body, to relieve constipation, menstrual and rheumatic pains, and increase diuresis. He also states that this drug is used as incense in sacred areas. It is known that Emperor Caracalla, who lived in the third century and had a stomach ulcer, healed and recovered from a kind of medicine made by mixing sweetgum oil and pine resin with honey in the Bergama Asclepion. Therefore he donated to the city and the doctors to pay his debt of gratitude (Aydıngöz and Bulut 2014; Kahya 2015).

2.3 Overview of the Flora of Turkey

Turkey is known as one of the countries with the richest flora in the temperate zone. The land is at the intersection of three phytogeographical regions that differ from each other in terms of both climate and vegetation. These are the Euro-Siberian region in Northern Anatolia, the Mediterranean in Western and Southern Anatolia, and the Irano-Turanian region in Central and Eastern Anatolia. Anatolia's position as a bridge between the European and Asian continents and the mutual plant migrations between the two continents contributed to the richness of the flora (Erik and Hacıoğlu 2004). The number of plant species has been determined as 9753 (when naturalized, exotic, cultured species and infraspecific taxa are included, the number of existing taxa reaches 11,707) according to the most recent work on the flora of Turkey "A Checklist of the Flora of Turkey (Vascular Plants)". The number of endemic species grow in Turkey is 3035 and the endemism rate is 31.12% (Güner et al. 2012). In addition to many wild species, Anatolia is the natural gene center of many cereals, fruit and ornamental plants cultivated worldwide (Erik and Hacıoğlu 2004).

The three plant families richest in terms of the number of species are: Asteraceae (485 endemic/1311 species), Fabaceae (322 endemic/1059 species) and Brassicaceae (228 endemic/602 species). Lamiaceae (239 endemic/586 species), which was in the third rank before, dropped to the fourth. The first three genera richest in the number of species are, respectively, *Astragalus* (194 endemic/440 species), *Verbascum* (165 endemic/341 species), and *Allium* (67 endemic/179 species) (Güner et al. 2012; Kandemir et al. 2014).

2.4 Ethnobotany in Modern Turkey

Considering the thousands of plant species growing in Turkey, ethnobotanical knowledge specific to particular regions and cultures reveals a great biocultural diversity. In Turkey, as in the rest of the world, people use plants for their most basic needs such as nutrition, shelter, clothing, heating, personal care, healthcare practices, making tools and equipment, and rituals (Ertuğ 2014).

The use of folk remedies is especially widespread in rural areas. Rural people try to treat their everyday ailments with medicines they prepare by collecting plants that grow nearby. Everyday ailments should be considered as diarrhea, stomachache, indigestion, colds, aches, injuries, and inflammations the symptoms of which are recognizable without the need for professional observation and analysis. Simple drug forms such as tea (infusion/decoction), poultice or ointment are prepared with herbs. Knowledge about the use of medicinal plants is folkloric; learned from parents or other elders. During the fieldwork, in almost every village, it is mentioned that an old woman knew the plants well and was knowledgeable about their medicinal properties. Semi-religious persons and traditional practitioners are other important sources of information and practice. In Anatolian Folk Medicine, "Ocak" is the family believed to have cured a particular complaint or disease using the information handed down from the previous generation. It is accepted that the concept of "ocak" emerged due to the shamans' compliance with Islamic rules. It is believed that the person who is a member of an "ocak" has a mystical power from his ancestors and can cure diseases. In addition to the unique treatment methods, they also use simple drug forms prepared with some local herbs (Sezik and Yeşilada 2001; Şar 2008).

In ethnobotanical studies, it is essential to compile all local knowledge from people who live close to nature in rural areas and have traditional knowledge. While 30 years ago, the rural population in Turkey was more than those living in cities, it has decreased to less than a quarter of the total population today. Depending on this change, ethnobotanical knowledge is gradually reducing and evolving. Although the information has been partially lost and changed, there is still much more data than a limited number of researchers can go through. In each new field study, information about food and medical use of at least a few new taxa emerges. Sometimes, this number can be quite high, depending on the work done in the chosen field. There is always the possibility that original information may be retained even in a single individual or a small community. Just for the sake of this, it is an essential responsibility for those working in this field to continue ethnobotanical studies and record this precious human heritage. Multidisciplinary teams are needed to understand and convey this multifaceted relationship. Especially in recent years, efforts to record the ethnobotanical heritage of the Turkish people without being completely lost have continued with increasing momentum, and folk medicine practices are the most researched subject in this field (Ertuğ 2014).

2.4.1 Ethnobotanical Studies Conducted in Turkey

Considering the studies in which ethnobotanical records are compiled (Sadıkoğlu 1998; Ospankulava 2005; Kendir and Güvenç 2010; Bellikci Koyu 2020), it is understood that ethnobotanical data in Turkey started to be recorded in 1929 (since the alphabet revolution was made in Turkey in 1928, the Ottoman or Arabic sources in previous years are excluded). In Sadıkoğlu's (1998) research, which is the oldest of these compilation studies, 765 ethnobotanical studies conducted in Turkey were identified (Sadıkoğlu 1998). In a thesis, which was published in 2005 and aimed to create a database for ethnobotanical research in Turkey, 658 ethnobotanical sources were evaluated (Ospankulava 2005). Similarly, in another more recent thesis, which aimed to create an ethnobotanical database of Turkey, 1758 sources were identified and assessed (Bellikci Koyu 2020).

When the ethnobotanical sources published in the period until the end of the 1980s are examined, it is seen that these investigations were published in local journals and include topics such as regional traditions and beliefs rather than folk medicine knowledge (Sadıkoğlu 1998; Ospankulava 2005; Kendir and Güvenç 2010; Bellikci Koyu 2020). To scientifically record an ethnobotanical study, it is essential to prepare herbarium voucher specimens and place them in a registered herbarium where they will be available indefinitely to verify the identity of these plants included in the compiled ethnobotanical data (Nesbitt 2014). The first systematic studies published in international journals and in which plants were recorded by quality vouchers in the form of herbarium specimens in the field of ethnobotany in Turkey started with the serial investigations carried out by Erdem Yeşilada and Ekrem Sezik with a Japanese team (Sezik et al. 1991, 1992, 1997, 2001; Yeşilada et al. 1993a, 1995, 1999; Tabata et al. 1994; Fujita et al. 1995; Honda et al. 1996). It could be said that the ethnobotanical studies in Turkey have reached a scientific standard and quality to be published in international journals with these studies.

In this section, which we have prepared to provide an overview of ethnobotanical studies in Turkey, online publications were surveyed by respecting the following criteria; (1) All papers published in English or have English abstract. (2) The scientific names of the plants in the publication should be determined and herbarium records should be available. (3) Used keywords are "Ethnobotany and Turkey," "Folk medicine and Turkey", "Traditional medicine and Turkey", "Ethnopharmacology and Turkey", and "Ethnomedicine and Turkey." (4) Literature research was performed using PUBMED, SCOPUS and Web of Science. As a result of the literature research, 138 publications were obtained. The distribution of these publications by cities is given in Fig. 2.1.

Fig. 2.1 Geographical regions of Turkey and the number of ethnobotanical studies in each city

2.4.1.1 General Demographic Characteristics of Informants

When the demographic characteristics of the informants in the folk medicine inventory collection studies are examined, it is seen that women are in the majority (about 60%). When the age range of the participants was evaluated, it was understood that most of them were 50 years and over (approximately 68%). About 80% of participants are primary school graduates or just literate. Because the research is conducted in villages and the number of female participants is high, people who have folk medicine knowledge are primarily housewives and farmers (Akaydın et al. 2013; Bulut and Tuzlacı 2013, 2015; Günbatan et al. 2016; Bulut et al. 2017b; Karcı et al. 2017; Akgül et al. 2018; Arı et al. 2018; Gürbüz et al. 2019; Akbulut and Yılmaz 2022).

2.4.1.2 Geographical Regions of Turkey, General and Ethnobotanical Features

After the first geography congress convened in 1941, Turkey was divided into seven geographical regions, taking into account its physical, social and economic characteristics; Black Sea, Mediterranean, Marmara, Aegean, Central Anatolia, Southeastern Anatolia and Eastern Anatolia regions (Avcı 2011). It would be appropriate to evaluate Turkish ethnobotany based on these geographical regions. However, when ethnobotanical studies in Turkey are examined, it is seen that plants are generally used as medicines. It would not be wrong to say that ethnobotanical information consists mainly of folk medicine information. Therefore, for each region, first of all, common and interesting folk remedies and their applications, as well as some prominent non-medical ethnobotanical data, will be summarized below.

2.4.1.2.1 Eastern Anatolia Region

Eastern Anatolia Region is the most rugged and highest region of Turkey. The average altitude of the area is over 1500 m. There are some volcanic masses in the Eastern Anatolia Region whose altitude exceeds 5000 m (E.g., Ağrı mountain) (Avcı 2014). Ağrı, Palandöken, Munzur and Esence mountains are the significant elevations of the region. The altitude of the plains in the area is also high. Turkey's largest lake, Lake Van, is within the borders of the Eastern Anatolia Region. Aras, Dicle, Fırat, and Zap Rivers are the important rivers of the area (Avcı 2014). Reaching an average altitude of 2000 m in the region leads to low-temperature values, long-term snow cover and frost events. The effect of the continental climate increases due to the inaccessibility of the impact of the sea and the high altitude. While the annual average temperature drops below 5 °C in high plateaus (Kars, Sarıkamış), it is higher in some plains such as Iğdır (12.8 °C). Snowy days approach two months in some provinces, such as Kars, and the rain is in the range of 380–410 mm, although it varies according to the provinces (Avcı and Avcı 2014a). In the region, continental (in Ardahan, Kars provinces), little rainy Mediterranean (in Bingöl) and the semi-arid Mediterranean (in Erzincan, Elazığ, Malatya provinces) climates are observed (Kurt 2014).

According to the 1970 census results, the city population (1,110,695), which was half of the village population (2,871,643), developed at the opposite rate by 2021 and reached almost four times the village population (1,460,478 village, 5,124,442 city population) (TUİK 2021). This indicates a significant migration from the village to the city. According to the 2017 Socio-Economic Development Ranking Research report of the Ministry of Industry and Technology of the Republic of Turkey, six provinces in the region (Bitlis, Van, Hakkari, Muş, Ağrı, Şırnak) are in the last place (STB 2017).

As a result of literature search we conducted within the criteria mentioned above, 36 ethnobotanical investigations were determined to be carried out in the Eastern Anatolia Region. According to the analysis of ethnobotanical studies, it is understood that the plants used in folk medicine in the area are mainly in the families of Asteraceae, Rosaceae and Lamiaceae. *Urtica dioica* L., *Malva neglecta* Wallr., *Rosa canina* L., *Plantago major* L., *Helichrysurn plicatum* DC, *Mentha longifolia* (L.) L., *Mentha spicata* L. subsp. *spicata, Hypericum perforatum* L., and *Tribulus terrestris* L. are the most frequently cited species. Dermatological, gastrointestinal, respiratory and urogenital system diseases are folk medicines' most frequently applied conditions (Tabata et al. 1994; Özgökçe and Özçelik 2004; Çakılcıoğlu et al. 2010, 2011; Çakılcıoğlu and Türkoğlu 2010; Özgen et al. 2012; Polat et al. 2013; Hayta et al. 2014; Kaval et al. 2014; Korkmaz and Karakuş 2015; Korkmaz et al. 2016; Nadiroğlu et al. 2019; Polat 2019; Karakaya et al. 2020; Kazancı et al. 2020). Among the ethnobotanical studies conducted in the region, it has been seen that folk remedies are used even in a serious disease affecting the central nervous system, such as epilepsy. The decoction prepared by boiling the roots of *Leontice leontopetalum* L. subsp, *ewersmannii* (Bunge) for 5 h is drunk on an empty stomach for three days to treat epilepsy (Özgökçe and Özçelik 2004). Another interesting folk remedy is the bath application for any internal disease that cannot be diagnosed. In this application, *Mentha longifolia* L., *Rumex* sp., *Plantago major* L., *Urtica pilulifera* L., and *Eryngium bilardieri* Delar. are boiled and a bath is taken with this mixture (Sezik et al. 1997). It is also quite surprising to encounter narcotic usages such as using *Hyoscyamus reticulatus* L. roots and seeds to get drunk (Tabata et al. 1994). As mentioned above, *Rosa canina* L. is one of the most cited species in the region. Interestingly, the fruits and roots of this plant are used for hemorrhoids treatment in the form of decoction or infusion in different cities of the Eastern Anatolia Region (Iğdır, Erzurum, Ağrı, Kars) (Sezik et al. 1997). Another common folk medicine in the area is *Ranunculus* species. In inflammatory joint diseases such as rheumatism, different *Ranunculus* species (e.g., *Ranunculus neopolitanus* Ten, *R. repens* L., *R. sericeus* Banks & Sol.) are crushed and wrapped around the affected area (Sezik et al. 1997). The local people unconsciously use different species from the Boraginaceae family for skin diseases such as wounds and burns. The ointment is prepared by roasting *Alkanna orientalis* Boiss., *Alkanna megacarpa* DC, *Echium italicum* L., *Echium vulgare* L., *Onosma armeniacum* Klokov or *Onosma microcarpum* Steven ex DC. roots in oil is applied in case of wound and burns (Tabata et al. 1994; Sezik et al. 1997). The plant parts from which folk remedies are obtained is also very important. The latex of *Euphorbia* species is consumed orally by dripping into sugar in case of constipation. However, it was stated that for this application, the latex should be obtained from the middle parts of the plant, the latex obtained from the upper parts is ineffective and the latex obtained from the lower parts is highly effective (Tabata et al. 1994). In the region, plants are also used for different ethnobotanical purposes. For example, *Artemisia austriaca* Jacq. is used to repel mosquitoes and fleas by being attached to a belt or placed under the bed (Sezik et al. 1997). Other examples of non-medical usages are; *Herniaria incana* Lam. which is used as soap, *Quercus cerris* L., which is used to make walking sticks, *Juncus inflexus* L., which is used for making hats, and viscous, sticky exudate of *Armeniaca vulgaris* Lam. is used as glue (Yeşil and Akalın 2016).

2.4.1.2.2 Southeastern Anatolia Region

Southeastern Anatolia Region is one of the flattest regions of Turkey. Karacadağ and Kartal Mountains are significant elevations in the region. There are Harran, Suruç, Ceylanpınar and Birecik plains in the west of Karacadağ. The Fırat and Dicle rivers and the Atatürk Dam, built on the Fırat River, are the essential water resources of the region. January temperature averages, which represent the winter season, are higher in Southeastern Anatolian than in the interior areas (Şanlıurfa 5.7 °C, Gaziantep 3.3°C). Cities in this area have the highest temperature values of the summer season in Turkey (Diyarbakır 34 °C, Şanlıurfa 31.5 °C) (Avcı and Avcı 2014a). Little rainy and semi-arid Mediterranean climates are observed in the region (Kurt 2014).

The village-city population, which was very close to each other in 1970 (1,075,566 city, 1,727,600 village population), has increased in the direction of the city due to migration and urbanization today. According to the results of the address-based census in 2021, 630,336 people live in the village and 8,580,108 people live in the city (TUİK 2021).

As a result of a literature research, we determined that 12 ethnobotanical studies were carried out in the region. According to the results of these studies, plants belonging to the Lamiaceae, Asteraceae and Fabaceae families are primarily used to prepare folk remedies. *Teucrium polium* L. has emerged as one of the most frequently cited plants. When the diseases, which folk remedies are used for, are evaluated, it is understood that the people of the region mostly use folk remedies for gastrointestinal, respiratory system diseases and diabetes (Bulut et al. 2017c, 2019; Akgül et al. 2018; Kılıç et al. 2020, 2021; Yeşil and Inal 2021). Interesting usages have been reported in ethnobotanical studies conducted in the region. For example, *Gundelia tournefortii* L. var. *tournefortii* seeds are prepared and consumed as coffee in vitiligo, a disease that is difficult to treat in modern medicine. The use of *Hyoscyamus niger* L. as an inhalation for toothache and tooth cavity is another example that can be given (Özgökçe and Özçelik 2004). It has been noted that some folk remedies in the area have poisonous effects. For example, *Teucrium polium* L. which is used for diabetes, hemorrhoids, abdominal pain and urinary problems, has been stated to cause stomach irritation if used in large quantities (Yeşil and Inal 2021). Some ethnobotanical uses of plants other than folk medicine have also been reported. For example, *Crupina crupinastrum* (Moris) Vis., *Polygonum bellardii* All., *Scabiosa argentea* L. are used as broom; while *Rubia tenuifolia* subsp. *doniettii* (Griseb.) Ehrend. & Schönb.-Tem. is used as toy, and *Peganum harmala* L. is used as amulet (Akgül et al. 2018). *Pistacia terebinthus* subsp. *palaestina* (Boiss.) Engler, an important agricultural product of the region, is used as food and in the treatment of sore throat (Akgül et al. 2018). Another *Pistacia* species, *Pistacia khinjuk* Stocks fruits are consumed as coffee and soap is made from its fixed oil (Bulut et al. 2019).

2.4.1.2.3 Black Sea Region

Black Sea Region has a very mountainous and rugged structure. Küre, Kaçkar, Köroğlu, Ilgaz, Canik, mountains are among the important high-altitude points of the region (Avcı and Avcı 2014b). Yeşilırmak, Kızılırmak, Sakarya and Çoruh rivers are the important water resources (Avcı 2014). The fact that the mountains extend parallel to the coast and the outer slopes prevent warm fronts causes the precipitation area's expansion, increasing the precipitation's duration and intensity. January temperatures are above 5 °C on the Black Sea coast, while in internal incisions, it drops below 0 °C. July temperatures are between 21 and 24 °C. Black Sea coastal areas have the highest rainfall in Turkey, usually more than 1000 mm (Avcı and Avcı 2014a). While the oceanic climate is observed in the coastal regions, the little rainy Mediterranean climate is observed in the inner parts of the region (Kurt 2014).

When the population data is evaluated, the situation in the Black Sea Region is similar to the other areas. According to the census results of 1970, while the village population (5,048,412) was about four times the city population (1,542,020), it decreased to one-fourth of the city population by 2021 (6,336,129 city, 1,633,073 village population) (TUİK 2021). These results show that there has also been significant migration from the village to the city in 51 years in the Black Sea Region.

As a result of our literature search, we determined that 16 ethnobotanical studies were carried out in the region. The analyses of the studies showed that Rosaceae, Asteraceae and Lamiaceae are the most preferred families for folk medicine preparation. At the same time, the most cited species in the region are *Urtica dioica* L., *Plantago major* L. and *Sambucus ebulus* L. Considering the illnesses that folk remedies are used, in most of the studies, gastrointestinal, respiratory and dermatological diseases take place in the top three ranks (Fujita et al. 1995; Yeşilada et al. 1999; Ezer and Arısan 2006; Polat et al. 2015; Karcı et al. 2017; Yeşilyurt et al. 2017a; Gürbüz et al. 2019; Karaköse et al. 2019; Kazancı et al. 2020; Gürdal and Öztürk 2022). In the Black Sea Region, usage of an ointment that is prepared by boiling *Abies bornmülleriana* Mattf. resin with *Salvia aethiopsis* L. root, soap, beeswax, and butter for wound healing is quite remarkable. The use of the phloem layer of the *Pinus nigra* Arn. subsp. *pallasiana* for stomachache, tuberculosis, bronchitis and as a panacea is another example of the usages we come across in the region. The usage of *Hyoscyamus niger* L. appears in the Black Sea Region as well. The vapor from roasting or boiling seeds in water is used for eye diseases. It is stated that with this application, maggots that cause disorders in the eye are dislodged (Fujita et al. 1995). Another interesting folk remedy application is the roots of *Helleborus orientalis* Lam. It is cut into small pieces and placed in the tooth cavity to treat toothache (Yeşilada et al. 1995). The use of *Allium cepa* L., a plant found in almost every kitchen, is also quite common as a folk remedy. Especially in the case of felon in the fingers, it is boiled with soap and liquid oil to prepare a poultice and applied to the affected area. *Petroselinum crispum* (Mill.) Nyman is used internally as a diuretic in many parts of Anatolia. However, in the ethnobotanical research carried out in Samsun, its external usage for sore throat by roasting it with sunflower oil was recorded for the first time. As in many regions of Turkey, the use of teas prepared with *Cydonia oblonga* Mill. leaves in respiratory tract diseases such as cough and cold has also appeared in this region (Karcı et al. 2017). The use of *Rubus* species is also widespread in the area. Folk medicines prepared from the leaves and roots of different *Rubus* species (e.g., *Rubus canescens* DC., *Rubus discolor* Weiher et Nees, *Rubus sanctus* Schreber) are used in cases such as infertility, hemorrhoids, stomachache, wound treatment, colds (Yeşilada et al. 1999). In this region, plants are also used for non-therapeutic purposes such as dye production (*Sambucus ebulus* L., *Juglans regia* L.), basket making (*Corylus maxima* Mill.), fishing (*Cornus mas* L., *Juglans regia* L.) (Gürbüz et al. 2019).

2.4.1.2.4 Central Anatolia Region

Central Anatolia Region generally has a plain appearance and few rough terrains. However, there are also mountains exceeding 2000 m, such as Erciyes and Hasan Mountains in the area (Avcı and Avcı 2014b). The most important streams of the

Central Anatolia Region are Kızılırmak, Sakarya Rivers and Porsuk Streams (Avcı 2014). Tuzgölü, Akşehir, Seyfe and Ilgın (Çavuşçu), are important lakes in the region. The annual average temperatures in the region vary between 8–12 °C. The area is surrounded by high mountain ranges in the north and south and is closed to humid air masses from the seas. Therefore, the amount of precipitation it receives is also low (<400 mm) (Avcı and Avcı 2014a). Arid and semi-arid Mediterranean climate is observed in the region (Kurt 2014).

The difference between the village and city population, which was close to each other 51 years ago (2,956,912 city, 3,733,946 village population), has widened day by day and the city population (12,627,639) has reached 14 times the village population (859,112) in the last census (TUİK 2021). Two of Turkey's most socio-economically developed cities are located in the region. While Ankara stands out for reasons such as being the capital city, high workforce potential, and the high level of education of the residents, Eskişehir stands out due to its high level of development in the field of education (STB 2017).

In a literature search, we determined that 21 ethnobotanical studies were carried out in the region. It has been determined that Asteraceae family members are primarily used in the preparation of folk remedies, followed by Lamiaceae and Rosaceae families. According to evaluation based on species, *Malva neglecta* Wallr., *Urtica dioica* L. and *Rosa canina* L. are the most used plants as folk medicines. Recorded folk medicines are primarily used in treating respiratory, gastrointestinal and urogenital system diseases and dermatological problems (Sezik et al. 2001; Sarper et al. 2009; Özüdoğru et al. 2011; Han and Bulut 2015; Özdemir and Alpınar 2015; Günbatan et al. 2016; Paksoy et al. 2016; Uzun and Kaya 2016; Gürbüz et al. 2019, 2021b). Interesting ethnobotanical usages have been found in this region as well. For instance, ashes obtained by burning the *Salix alba* L. root bark are mixed with water and then applied to the scratched scalp for headache and sinusitis (Günbatan et al. 2016). *Salix triandra* L. subsp. *bournmuelleri* is used as an antipyretic in sunstroke as follows; the fresh leaves are wetted with vinegar and applied to the patient's chest and back (Sezik et al. 2001). Folk remedies are also used in urogenital diseases such as infertility—for example, aerial parts of *Ballota larendana* Boiss. & Heldr., an endemic plant, is boiled with milk and applied as a sitz bath in case of infertility in women (Gürbüz et al. 2021b). The use of *Solanum tuberosum* L. in headache and eye pain is also quite common. Its tuber is sliced, rubbed with salt or coffee, and then wrapped on the forehead or eyes. Another common practice is drinking water in which *Cicer arietinum* L. seeds are kept for 2–4 days to expel intestinal parasites (Sezik et al. 2001). It has been determined that tar, obtained from coniferous plants and widely used in Turkey, is also used in this region. Tar obtained from *Juniperus oxycedrus* L. is used externally in eczema and psoriasis. The resin of coniferous plants is also highly utilized. The resin obtained from *Abies nordmanniana* Spach var. *bornmuelleriana* (Mattf.) Silba, *Pinus nigra* J. F. Arnold subsp. *pallasiana* (Lamb.) Holmboe and *Pinus sylvestris* L. is often used for wound healing and inflamed wounds (Günbatan et al. 2016). Usages other than folk medicine were also encountered, such as *Polygonum* spp. used as a broom, *Crataegus* *tanacetifolia* (Lam.) Pers. used to make a walking stick, *Quercus pubescens* Willd. fruit used as a dye, and *Astragalus compactus* Lam. used to obtain glue (Özüdoğru et al. 2011).

2.4.1.2.5 Mediterranean Region

Mediterranean Region, which stretches along the coast of south Anatolia, is generally rugged and mountainous. The mountain range extending parallel to the coastline in the Mediterranean Region is called the Taurus Mountains. The important rivers of the region are Asi, Seyhan, Ceyhan, Göksu, Manavgat, Aksu and Dalaman Streams. Acıgöl, Akgöl, Beyşehir, Burdur, Eğirdir, Kovada, Salda and Suğla are the important lakes of the region (Avcı 2014). The average temperature in July is 25–30 °C, while the average in January is above 10 °C. The Mediterranean region is the second region that receives the most rainfall after the Black Sea Region (1000–1200 mm) (Avcı and Avcı 2014a).

According to the results of the address-based census in 2021, the population of the Mediterranean Region is 10,888,766. 316,395 live in the village, and 10,572,371 live in the city (TUİK). Considering the 1970 census results, the village population was higher than the population of the city center (1,531,088 city, 2,302,976 village population) (TUİK 2021). Antalya, one of the important cities in the region, has become an international center of attraction due to its advanced tourism opportunities. The education level is also quite high and according to 2014 data, Antalya ranks first in terms of literate women rate (STB 2017). As a result of our literature search, we determined that 18 ethnobotanical studies were conducted in the region. Similar to the other regions, it has been recorded that most of the plants used in the preparation of folk remedies in this region are members of the Lamiaceae, Asteraceae and Rosaceae families, which are also dominant in Turkish flora. *Hypericum perforatum* L., *Achillea millefolium* L., *Achillea biebersteinii* Afan. and *Arum maculatum* L. are among the most cited plants. Gastrointestinal, respiratory and urogenital system diseases are the leading situations in which folk medicines are used (Yeşilada et al. 1993a; Everest and Öztürk 2005; Aslan et al. 2007; Fakir et al. 2009; Demirci and Özhatay 2012; Akaydın et al. 2013; Güzel et al. 2015; Güneş et al. 2017, 2018).

When the ethnobotanical records in the region were examined, interesting folk medicine uses were found. One example that can be given is *Aristolochia badamae* Dinger. This poisonous plant is used to treat sinusitis by sniffing the fruit juice into the nostrils. One of the other interesting folk medicine applications in the Mediterranean Region is the usage of *Citrullus lanatus* (Thunb.) Matsum et Nakai to remove worms in the stomach. Fruit of *C. lanatus* is cut into small pieces and lined up on a string. This string is swallowed and kept in the stomach for 8–10 min. A worm in the stomach is pulled out with this string (Yeşilada et al. 1995). It is pretty remarkable that latex of different *Euphorbia* species (*E. helioscopia* L., *E. kotschyana* Fenzl., *E. macrostegia* Boiss., *E. peplus* L. var. *minima* DC.) is used in the treatment of warts in the region. As in the different regions of Turkey, *Helichrysum* species

[*H. arenarium* (L.) Moench. subsp. *aucheri* (Boiss.) Davis et Kupicha, *H. armenium* DC. subsp. *armenium*, *H. plicatum* DC. subsp. *plicatum*] are frequently used in the treatment of kidney stones in the Mediterranean Region (Demirci and Özhatay 2012). *Pistacia lentiscus* L. used against the evil eye can be an example of ethnobotanical use other than folk medicine (Aslan et al. 2007). In addition, *Papaver macrostomum* Boiss. & Huet ex Boiss. aerial parts is used as ornamental in Hatay (Akaydın et al. 2013). Latex of *Erodium cedrorum* subsp. *salmoneum* (P. H. Davis & J. Roberts) P.H. Davis is used as yeast for making yogurt or cheese. Spoons are prepared from *Morus alba* L. and *Olea europaea* L., while the *Ferula elaeochytris* Korovin is utilized for making walking sticks (Sargın et al. 2015).

2.4.1.2.6 Aegean Region

In Aegean Region, a topography consisting of plains and mountains extending perpendicular to the Aegean Sea coast is dominant. Madra, Kozak, Yunt, Bozdaglari, Manisa, Aydın, Beşparmak, Babadağ, Honaz, Emirdağ, Şaphane, Murat, and Sandıklı Mountains are the significant elevations of the region. Bakırçay, Gediz, Küçük Menderes, Büyük Menderes and Susurluk are the important rivers of the region (Avcı and Avcı 2014b; Avcı 2014). While the average January temperature of the region is between 5 and 10 °C on the coasts line, it is between 0 and 5 °C in the interior. July temperatures range between 25 and 30 °C. The region receives 400–800 mm of precipitation annually (Avcı and Avcı 2014a). Little rainy Mediterranean climate (in İzmir, Aydın provinces), semi-arid Mediterranean climate (in Kütahya, Uşak provinces) and rainy Mediterranean climate (in Muğla) are observed in the region (Kurt 2014).

According to the results of the address-based census in 2021, the population of the Aegean Region is 10,784,645. About one nineteenth (536,334) of this population lives in the villages, the rest (10,248,311) in the cities (TUİK 2021). However, according to the results of the 1970 census, the population of the villages was close to twice the population of the provincial centers (1,781,917 city, 3,085,234 village population).

As a result of our literature search, we determined that 21 ethnobotanical studies were carried out in the region. In these studies, it is understood that Lamiaceae, Asteraceae and Rosaceae are the leading families of plants used in folk medicine. Unlike other regions, aromatic plants such as *Origanum onites* L. and *Salvia fruticosa* Miller have been determined to be used chiefly as folk medicine in the region and prepared folk medicines are frequently used for the treatment of gastrointestinal, respiratory system and dermatological diseases (Honda et al. 1996; Uğulu et al. 2009; Kargıoğlu et al. 2010; Doğan and Uğulu 2013; Gürdal and Kültür 2013; Bulut et al. 2017b; Güler et al. 2020; Akbulut and Yılmaz 2022). There are interesting folk medicine usages in the Aegean Region, as in other regions. For example, to treat paralysis, 20–30 kg *Allium cepa* L. bulb is pounded with 2 kg old vinegar and the patient's body is covered with this mixture. Similarly, *Urtica dioica* is also used in the treatment of paralysis. Aerial parts of *Urtica dioica* L. are boiled to obtain a poultice. This poultice is applied to patient's body and covered with a blanket (Honda et al. 1996). Another example of interesting usages is; a fire is lit in a hollow, and *Pinus brutia* Ten. resin is sprinkled on it. The person suffering from hemorrhoids sits on this hollow, and his/her anus is exposed to the smoke from the burned resin. In addition to higher plants, Fungi are also used as folk medicine in the region. For example, *Morchella esculenta* Fr. is used externally in scorpion bites. The usages of Asteraceae species (e.g., *Achillea millefolium* L. subsp. *millefolium*, *Anthemis cretica* L. subsp. *tenuiloba*, *Anthemis wildemanniana* Fisch et Mey., *Anthemis austriaca* Jacq.) in abdominal pain is also quite common (Honda et al. 1996). The usage of *Malva* L. species is also widespread in the region. *Malva neglecta* Wallr. and *Malva sylvestris* L. are used internally as infusions or externally as a poultice for the treatment of diseases such as stomachache, abdominal pain, wound treatment, goiter and bronchitis. The species members of the Lamiaceae family (e.g., *Mentha longifolia* (L.) Hudson subsp. *typhoides* (Briq.) Harley var. *typhoides*, *Mentha spicata* L. subsp. *spicata, Origanum majorana* L., *Origanum onites* L., *Salvia adenophylla* Hedge et Hub., *Salvia tomentosa* Miller) which is stated to be the most frequently used in the region above, are generally used in the treatment of abdominal pain, stomach pain and respiratory diseases (Bulut and Tuzlacı 2013). In addition to folk medicine, other ethnobotanical usages have also been found in the region. For example, *Centaurea solstitialis* L. subsp. *solstitialis* and *Centaurea virgata* Lam. are used to make brooms (Kargıoğlu et al. 2010). Other examples are *Herniaria hirsuta* L., used as soap, and *Peganum harmala* L. used as an amulet (Bulut et al. 2017a). Dried pedicels of *Daucus carota* L. are used as a toothpick, while the glue is prepared from *Drimia maritima* (L.) Stearn bulb (Akbulut and Yılmaz 2022).

2.4.1.2.7 Marmara Region

Marmara Region comprises the cost lands encircling the Sea of Marmara and the straits. There are Yıldız, Biga, Kapıdağ, Uludağ, Samanlı, Domaniç, Koru, Kaz Mountains in the area. There is a dense river network throughout the region, although they are small in scale. Sakarya, Ergene, Susurluk, Meriç and Biga are the main streams. There are many natural and artificial lakes of various sizes in the region. Büyükçekmece, Küçükçekmece, İznik, Sapanca and Manyas Lakes are the important ones. While the average temperature in January is between 0 and 10 °C, the average temperature in July is between 21 and 27 °C. The shores of the region facing the Black Sea receive more precipitation (800–1000 mm), while the annual rainfall decreases to 400 mm in other parts (Avcı and Avcı 2014a). While the oceanic and rainy Mediterranean climate is observed in regions with a coast to the Black Sea (in Istanbul, Izmit, Adapazarı and Tekirdağ provinces), a little rainy Mediterranean climate is observed in other parts (Kurt 2014). In 1970, the Marmara Region's population with the highest population density was 6,837,167 (3,692,903 city, 3,144,264 village population). Due to the region receiving the most immigration, its population has been significantly increasing until today. According to the results of the address-based census in 2021, the region's population is 26,302,134. 528,256 live in the village and 25,773,878 live in the city (TUİK 2021). It is obvious that the presence of the most socioeconomically developed cities such as Istanbul, Kocaeli, Bursa and Tekirdağ, which are Turkey's industrial and production centers, in this region also contributes to this situation. (STB 2017).

As a result of our literature search, we determined that 26 ethnobotanical studies were carried out in the region. According to these studies, plants from the Lamiaceae, Asteraceae and Rosaceae families are primarily used to prepare regional folk remedies. In addition, *Hypericum perforatum* L. and aromatic plants such as *Lavandula stoechas* L., *Origanum, Salvia, and Mentha* species are determined to be used frequently. Folk medicines in the region are mostly used in the treatment of gastrointestinal, respiratory system diseases and diabetes (Uzun et al. 2004; Koçyiğit and Özhatay 2006; Tuzlacı and Bulut 2007; Polat and Satıl 2012; Bulut and Tuzlacı 2015; Güler et al. 2015; Bulut 2016; Kartal and Güneş 2017; Yeşilyurt et al. 2017b). One of the interesting folk medicinal usages in this region is the application of *Prunus divaricata* Ledeb. subsp. *divaricata* for gallbladder stone. Its fruit is kept in a jar with the fruit of *Pyrus amygdaliformis* Vill. var. *amygdaliformis*, rosehip and pomegranate for one week, and this mixture is drunk (Yeşilyurt et al. 2016). Another interesting usage is as follows: bulb of *Allium sativum* L. is cooked in olive oil, then crushed and dropped into the ear for treatment of earache (Bulut and Tuzlacı 2015). The infusion prepared from the flowering branches of *Lavandula stoechas* L. subsp. *stoechas*, one of the region's most cited plants is used in stomachache, headache, embolism, heart diseases, shortness of breath and as a menstruation regulator. It is pretty surprising that *Silybum marianum* (L.) Gaertn., which is known to be effective in liver diseases such as cirrhosis, is used in liver diseases among the people in the region (Polat and Satıl 2012; Bulut and Tuzlacı 2015). *Morus alba* L. is one of the highly cited folk medicines that uses syrup from its fruit to treat aphthae (Genç and Özhatay 2006). In the region, plants are also used for different purposes besides folk medicine. For example, *Cornus mas* L., *Arbutus andrachne* L. fruits are consumed as a jam; pickle is prepared with *Prunus divaricata* Ledeb. subsp. *divaricata* (Ledeb.) Schneider (Özdemir and Kültür 2017), *Crocus sativus* L. and *Juglans regia* L. are used as a fabric dye, while *Prunus armeniaca* L. is used to make fishes dizzy during fishing (Güler et al. 2015).

2.5 Common Ethnobotanical Records from Turkey

As mentioned above, one of Turkey's most used folk remedies is *Plantago major* L. This plant is used in many regions of Turkey to mature abscesses. For this purpose, fresh leaves of the plant are wrapped on the abscess either directly or after crushing until the pus is discharged. It is also used in wound healing in a similar way (Fujita et al. 1995; Sezik et al. 1997; Günbatan et al. 2016; Karcı et al. 2017; Gürbüz et al. 2019).

Hypericum perforatum L., another of the most common medicinal plants, is used in wound treatment in many regions of Turkey. The flowering branches of the plant are placed in a jar of olive oil and kept in a sunny place for a long time (like six months). The obtained oily extract is externally applied to the affected area (Akaydın et al. 2013). Other *Hypericum* species (E.g., *Hypericum bithynicum* Boiss., *H. heterophyllum* Vent., *H. lydium*, *H. triquetrifolium* Turra) are similarly used as well (Yeşilada et al. 1995; Gürbüz et al. 2019; Kılıç et al. 2020).

Sambucus ebulus L. is also another plant that is frequently encountered in folk medicine inventory research in Turkey. Fresh or wilted (by holding over ember or stove) leaves are wrapped on the affected area for disorders such as joint pain and rheumatism (Fujita et al. 1995; Yeşilada et al. 1995; Bulut and Tuzlacı 2015; Badem et al. 2018; Gürbüz et al. 2019).

Crataegus species are used to treat cardiovascular diseases in Turkey and many parts of the world (Kumar et al. 2012). For example, the leaves of *Crataegus monogyna* Jacq. subsp. *monogyna* are used in heart failure in Edirne (Yeşilyurt et al. 2017b). In Malatya, *Crataegus* x *bornmuelleri* Zabel and *Crataegus orientalis* Palas ex Bieb. are used as anti-hypertensive agents (Yeşil and Akalın 2009). In another study conducted in Malatya, *Crataegus aronia* (L.) Bosc. ex DC. var. *aronia* (L.) Bosc. ex DC., *Crataegus monogyna* Jacq. subsp. *monogyna* Jacq. flower and mature fruits were determined to be used in cardiac diseases (Tetik et al. 2013). In Mersin, the leaves, flowers and fruits of *Crataegus azarolus* var. *aronia* L., *Crataegus monogyna* Jacq. and *Crataegus orientalis* Pall ex M. Bieb. are used in cardiovascular diseases (Sargın 2015).

Urtica dioica L. is one of the most cited plants as a folk medicine in Turkey. Although it is used in quite different ways for many other diseases, one of its remarkable usages is as follows: in Bafra (Samsun), before ear piercing to wear earrings, the aerial parts of the plant are applied to the ear. It was stated that this application anesthetized the area, and the ear was pierced painlessly (Karcı et al. 2017).

In most ethnobotanical research in Turkey, many plants have been used as "panacea". For instance; *Allium cepa* L., *Malus sylvestris* (L.) Mill., *Malva neglecta* Wallr., *Matricaria chamomilla* L. var. *recutita* (L.) Grierson, *Thymus longicaulis* C. Presl subsp. *longicaulis* var. *longicaulis*, *Rosa canina* L. *Plantago major* L., *Urtica dioica* L., *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe, *Pinus sylvestris* L., *Cichorium intybus* L., *Viscum album* L. subsp. *abietis* (Wiesb.) Abromeit (Sezik et al. 2001; Yeşilada et al. 1995; Karcı et al. 2017; Günbatan et al. 2016; Gürbüz et al. 2019; Sezik et al. 1997). People consider the plants a panacea when a plant is thought to be beneficial for many diseases or used to maintain health.

It has been understood that the public is also sensitive to issues such as the gathering places of the plants used to prepare folk medicines. For example, *Viscum album* L. lives as a parasite on the Rosaceae and Pinaceae family members. In a study in which Düzce folk remedies were compiled, it was determined that this plant was used in heart disease, diabetes, kidney stones and kidney inflammation. Interestingly, some informants do not care about the host tree, while those who recommend its usage for diabetes specifically stated that the plant should be collected from a pear, apple or cherry tree (Gürbüz et al. 2019).

As mentioned before, plants are also used in non-medical conditions in Turkey. One of the most prominent non-medical usages is the use of *Peganum harmala* L. Its seeds used against the evil eye in different parts of Turkey (e.g.: Afyon, Batman, Kırşehir, Mardin, Uşak) (Arı et al. 2015; Bulut et al. 2017a, 2019; Akgül et al. 2018; Çelik and Yeşil 2021). Fruit peel of *Juglans regia* L. is used as a fabric dye in Afyon, Bilecik and Ordu (Arı et al. 2015; Güler et al. 2015; Badem et al. 2018). *Helichrysum stoechas* (L.) Moench branches are hung on the wall to keep snakes out of the house (Akbulut and Yılmaz 2022). Different *Verbascum* species (*Verbascum sinuatum* L. var. *sinuatum*, *Verbascum insulare* Boiss. &Heldr.) are used for fishing by immersing in the water in Ankara and Manisa (Akyol and Altan 2013; Gürbüz et al. 2021a). Brooms are made from different species such as *Scabiosa argentea* L. and *Spartium junceum* L. (Çelik and Yeşil 2021; Akbulut and Yılmaz 2022).

2.6 Bioactivity Studies on Turkish Folk Remedies

Another issue that makes ethnobotanical studies (especially folk medicines) so important is their providing advantages on the way to medicines. Because folk medicines have been in use for centuries. By giving up the use of unuseful or toxic remedies, during this time, they could be considered as sources that have a therapeutic effect on humans and have been tested for toxicity (Sezik 1991). It should also be noted that folk remedies are an essential starting point on the road to medicine. For example, in the bioactivity study conducted on 23 folk remedies used in peptic ulcer symptoms in Turkey, it was determined that all of them showed powerful antiulcerogenic effects (Yeşilada et al. 1993b; Gürbüz et al. 2002, 2003, 2005b). The decoction of *Sideritis caesarea* H. Duman, Aytaç & Başer from these plants was recorded to be a calming herbal tea and folk medicine for stomachache and intestinal spasms in the Kayseri (Özkan and Koyuncu 2005). With ethnobotanical data-based bioactivity-guided fractionation studies, two flavonoid substances with strong antiulcerogenic effect were obtained from the plant (Gürbüz et al. 2005a; Günbatan et al. 2020). Likewise, *Equisetum palustre* L. is another species used to treat peptic ulcers in Turkey (Yeşilada et al. 1995). As a result of antiulcerogenic activity tests and bioactivity-guided fractionation studies, it was shown to have significant gastroprotective activity in rats and isolated flavonoid, kaempferol-3-*O*-1″-*β*-D-glucopyranosyl-3-*O*-1‴-*β*-D-glucopyranoside, were determined to contribute to this activity (Gürbüz et al. 2002, 2009). In another research, six plant species (*Hypericum bithynicum* Boiss., *Malva neglecta* Wallr., *Morus alba* L., *Rubus discolor* Weihe & Nees, *Sambucus ebulus* L. and *Smilax excelsa* L.) have folk medicinal utilization associated with dermal infections and wound healing in Düzce Province (Gürbüz et al. 2019). Their antibacterial, antifungal, antihyaluronidase, anti-collagenase and anti-elastase activity were investigated. All studied plant species were shown to have antibacterial and antifungal activity on investigated microorganisms (*Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Acinetobacter baumannii, Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus pneumoniae, Streptococcus pyogenes, Candida albicans, Candida parapsilosis* and *Candida krusei*) in different degrees, while *Malva neglecta* Wallr., *Rubus discolor* Weihe & Nees, and *Hypericum bithynicum* Boiss. were determined to have hyaluronidase and elastase inhibitory effects (Gürbüz et al. 2021c). The folk medicinal usage of *Hypericum perforatum* L. for wound treatment is quite common in Turkey (Yeşilada et al. 1993a, 1995). In a bioactivity study conducted to investigate the accuracy of its usage, its olive oil extract was determined to have significant wound healing and anti-inflammatory activity in animal test models (Süntar et al. 2010). These are a small portion of the examples that can be given to bioactivity studies based on folk medicine records in our country. Supporting folk medicinal usages with bioactivity research increases ethnobotanical studies' value and reliability.

2.7 Ethnobotany as an Indispensable Part of Turkish Folk Culture

As a result of our literature research and examination of databases in which ethnobotanical studies are compiled, ethnobotanical studies conducted in Turkey were found to be quite numerous. In this review, we discuss only publications that meet the criteria (in English, indexed in PUBMED, SCOPUS and Web of Science) specified in the introduction, regarding international accessibility are discussed.

In Bellikçi Koyu's thesis, which aims to create a database of ethnobotanical research conducted in Turkey, the highest number of taxa (1031) was recorded in the Eastern Anatolia Region; and the least number of taxa (664) was recorded in the Southeastern Anatolia Region. Determining the Eastern Anatolia Region as the most studied region and the Southeastern Anatolia Region, as the least studied region, is consistent with these data (Bellikci Koyu 2020). The families in which the most taxa were used in Turkey were determined as Asteraceae, Lamiaceae, Fabaceae and Rosaceae. *Urtica dioica* L., *Rosa canina* L., *Juglans regia* L., *Hypericum perforatum* L., *Plantago major* L., *Malva sylvestris* L. and *Malva neglecta* Wallr. are the most cited plants as folk medicine. When folk medicines were evaluated according to the diseases they were used, gastrointestinal system diseases took the first place and followed by dermatological, respiratory tract and urogenital system diseases (Bellikci Koyu 2020).

As an examination of ethnobotanical investigation conducted in Turkey, it is understood that plants are utilized for different ethnobotanical purposes besides their medicinal usages. While 1902 taxa are used for medical purposes, 965 taxa are used for various purposes such as dye, fuel and making items (Bellikci Koyu 2020). But we think that this number is much higher. Other ethnobotanical usages keep in the background and cannot be fully detected, as studies mostly focus on folk medicine.

2.8 Concluding Remarks

Ethnobotanical research should primarily aim at contributing to the solution of health, hunger and environmental problems. For this reason, studies should also include suggestions for using plants within the framework of sustainable development and evaluating the results for the benefit of society, in addition to listing the local names and ways of utilization of plants. Studies in which the folk knowledge of the plants used in the treatments are compiled and evaluated with current information can yield significant results. 74% of herbal medicines used today have emerged through such compilation studies (Alpınar 2010).

Scientific studies conducted in Turkey, in recent years, have taken incredible strides towards deciphering and elucidating phytochemicals with the unique ability to interact with therapeutic targets to prevent or treat diseases, guided by ethnobotanical knowledge. This is the story of traditional knowledge enriching the process of scientific discovery on one hand, and science, on the other hand, bringing this ancient wisdom to the level it deserves. This mutual interaction is a great source of hope for humanity in coping with the problems brought about by the modern lifestyle.

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Chapter 3
Natural Dye Plants in Turkey

Mustafa Genç, Muhammed Biyikli, and Hasan Baydar

Abstract The natural dyes obtained from the plants in Turkey have been used for centuries, in traditional textiles, carpets, rugs and woven products. The dyeing information brought from Turkistan was developed in Anatolia, and the Turkish dyeing tradition was created. As can be seen in the literature of the Turkish aesthetic world, very special colours such as "Turkish red" have been used to dye the fabrics made from cotton, linen, wool and silk. Turkish red painting has preserved its mystery and confidentiality for many years, based on the master-apprentice teaching. These very special colors have gradually lost their importance, especially due to the production of chemical dyes, in the nineteenth century. The findings about the allergic, toxic and carcinogenic effects of chemical or synthetic dyes on human health have renewed the interest in natural dyes, especially since the second half of the twentieth century. Turkey is one of the world's richest countries with regard to diversity of plant species and plant genetic resources. Flora of Turkey has a rich biodiversity of 9225 species and over 11,000 taxa. 123 plant species belonging to 50 families have been determined as a natural dye source in the flora of Turkey. Anatolia owes its success in natural dyeing culture to the rich presence of dye plants in its flora and to skilled weaving and dyeing masters. As in the past, the most commonly used species used in Anatolia for natural dyeing is madder (*Rubia tinctorum* L.) which has given the name of the dyeing tradition called "Root dyeing". Important species widely used are: acorn (*Quercus infectoria*), buckthorn (*Rhamnus petiolaris*), dyers' chamomile (*Anthemis tinctoria*), chasteberry (*Vitex agnus-castus*), euphorbia (*Euphorbia species*), onion (*Allium cepa*), sumac (*Rhus coronaria*), walnut (*Juglans nigra*), weld (*Reseda luteola*), and woad (*Isatis tinctoria*).

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3.1 Colorful World and Coloring Strategies of Plants

Plants are the most precious color sources because of the color pigments they have. "Dye plants" are used in herbal dyeing. Their organs or parts, such as roots, rhizomes, stems, barks, leaves, flowers and fruits are potential sources of natural dyes (Schetky 1982). Plants owe their appearance, in part, to the colorful substances consisting of biochromes, which either absorb or reflect light of varying wavelengths. The human eye is capable of seeing light within the range of 400–700 nm, which corresponds to the colors of the rainbow identified by Newton: violet, indigo, blue, green, yellow, orange and red (Heldt 2005).

Plants appear green because the chlorophyll pigments in their leaves reflect green light. But plants don't just have green leaves; underground organs such as roots and rhizomes, reproductive organs such as flowers, fruits and seeds are also very colorful. Plants color themselves by containing carotenoids such as carotene and lutein; flavonoids such as anthocyanin, flavone and flavanol; alkaloids such as betalain, betacyanin and betaxanthin (Młodzińska 2009). For example, the blue color of petunia flower is due to delphinidin, the red color of paprika fruit is due to lycopene, the orange color of carrot root is due to beta-carotene, the red color of madder root is due to alizarin, and the orange color of turmeric rhizome is due to curcumin (Baydar 2021). Plants rich in flavonoids such as quercetin, luteolin, and apigenin are commonly used to obtain the yellow color.

Why do plants color themselves? Because they need other living things, especially insects and birds, in order to pollinate, fertilize and spread their seeds (Menzel and Shmida 1993). The colors and odors of flowers and fruits, which are reproductive organs, are a clear call to the attention of living things that will be pollen/stigma pollinators and produce fruit/seeds (Trunschke et al. 2021); "Drink my sweet nectar, but carry my pollen to the stigmas of other flowers; eat of my juicy sweet fruits, but carry them together with their seeds as far away as possible.". This design is a wonderful procreative intelligence that generously rewards good deeds (Baydar 2021).

Plants have acquired their characteristic colors as a result of millions of years of evolutionary development (Griesbach 2005). It is no coincidence that the most common flower colors in the plant kingdom are red, white, yellow and blue. Because these colors are also the colors that most attract many living things, especially pollinating insects (Trunschke et al. 2021). For example, the cherry tree attracts honeybees with its white flowers and birds with its red berries. Thus, it carries its pollen in the body hairs of the bees and the seeds in the stomach of the birds (Baydar and Bıyıklı 2019). However, it is not yet clearly understood why plants color their underground organs such as root and rhizome.

While the leaves of the plants appear green due to chlorophyll activity, their flowers, fruits and seeds have species-specific colors other than green. The color contrast to green is a sign of bitterness and toxicity against herbivores and pests, in a way a warning to "Stay away from me". For example, capsaicin responsible for bitterness, in addition to the pigment lycopene responsible for the red color is found in paprika fruits. Some species of venomous snakes, frogs, scorpions, centipedes, and spiders also have contrasting colors (e.g., yellow, red, and black). Plants benefit from the colors for many reasons, such as adaptation, defense, pollination, fertilization and reproduction (Baydar and Bıyıklı 2019).

Dazzling colors of the plants have attracted the attention of people throughout history, they have developed very different techniques and methods to acquire the colors of plants, and they have used these natural dyes in all areas of their lives.

3.2 Natural Dyeing in the World

Natural dyes from plants, insects and minerals have been very valuable trade products since ancient times in the world. Blue and purple colours were derived from the plants containing indigo (e.g., *Indigofera tinctoria* and *Isatis tinctoria*), and some other sources (e.g., shellfish and lichens). Red color was often anthraquinone derivatives obtained from plants (e.g., *Rubia tinctorum* and *Platanus orientalis*) or insects (e.g., *Kermes ilicis* and *Dactylopius coccus*). Yellow and oronge colors were mainly flavonoid derivatives obtained from a variety of plant species (e.g., *Crocus sativus* and *Carthamus tinctorius*). Most other colours were produced by mixing cetain colors; for example, greens were created by mixing a blue with a yellow dye (Ferreira et al. 2004).

Secrets of Silk Road presented a wide range of textile motifs, colors and techniques found on cloth recovered from burial sites around the Taklamakan desert of China (Sheng 2010). In a tomb found in the Taklamakan desert, it has been determined that the red and blue-colored textile fragments, which has preserved its original color for centuries, was dyed with madder and woad (Desrosiers and Debaine-Francfort 2016). In the Middle Ages, the exotic natural dyes of the East were transported from China and India to Alexandria and Istanbul by road, and to Venice and Genoa by sea. In this way, the West had the opportunity to meet not only with spices and silk, but also with very valuable natural dyes such as madder, indigo and saffron. The history of the colorful powder dyes scattered around in "Holi" festivals, which are frequently staged in Bollywood films and symbolize the entarance of spring, goes back to ancient times in India which is the land of spices and dyes (Saxena and Raja 2014). The natural dye obtained from the leaves and bark of the henna tree (*Lawsonia inermis*) is still preferred today as leather, silk, hair and hand dye (Alam et al. 2007).

The German dyer Jeremias Friedrich Gülich (1733–1808) made very important contributions to the dyeing of textile raw materials such as wool and cotton. Until the artificial production of chemical dyes in the nineteenth century, natural dyes were used in the dyeing of textile products. However, the era of chemical dyes began with the synthetic production of aniline by Hofmann, mauveine by Perkin and then alizarine by Graebe from coal tar (anthracene) (Johnston 2008). Thus, natural dyes, which migrated to the West in their natural state until the nineteenth century, started to migrate from the West to the East in their synthetic form after this century (Baydar and Bıyıklı 2019).

Chemical dyes from fossil fuels have replaced natural dyes due to their ease of use, standard dyeing, color options and low cost. Despite these advantages of chemical dyes, natural dyes are non-toxic, non-allergenic and non-carcinogenic (healthier), not decompose easily in water (environmentally friendly), higher fastness (longer life) and more permanent and rich colors with mordants (Samantaa and Agarwal 2009). Since many of the dye plants are also medicinal and aromatic plants, their healing, antimicrobial and antioxidant properties are also transferred to the dyed wool yarn with the dyestuff (Çömlekçioğlu et al. 2017).

Fabrics dyed with plants such as thyme, sage, mint, lavender, St. John's Wort, sumac and saffron protect people against microbes with their natural antibiotic effect and keep them away from stress with their sedative effect. Carpets woven on handlooms with wool yarns colored with natural dyes are more suitable for those with asthma and dust allergies as they do not give dust to the air. In order to protect against Covid-19, masks produced using natural dye and vegetable fiber instead of masks produced with synthetic dyes and artificial fibers can provide more effective protection as they are healthier and less allergic (Baydar and Bıyıklı 2019). On the other hands, the factors such as the sources of dyestuff in plants and the colors obtained are limited, certain color composition vary according to climate and soil conditions in the regions where they are grown, dyeing techniques are laborious, expensive and time-consuming, low fastness levels are low, and being able to dye only natural fibers, have reduced the demand for natural dyes and weakened their competition against chemical dyes (Harmancıoğlu 1995).

3.3 Natural Dyeing in Turkey

In Anatolia, the cradle of great civilizations, murals painted with natural dyes have been discovered depicting hunting scenes in Catalhoyuk, one of the main centers of the Neolithic Age (Çamurcuoğlu 2015). They are as famous as the murals in the cave of Altamira in Spain and the caves of Lascoux and Chauvet in France. With the discovery of weaving around 5000 BC, plants were primarily used in the coloring of weaving products. Mesopotamian civilizations, led by the Sumerians, Egyptian and Hittite civilizations frequently benefited from herbal, animal and mineral dyes in fabric and papyrus dyeing. Plant dyes have been used not only in the coloring of the products listed, but also in many areas such as medicine, cosmetics, spices and foods (Baydar 2021). Since natural dyes are used in the threads of carpets and rugs woven on traditional hand looms, weaving and natural dyeing have developed or regressed together in history.

Since the root dye plants (e.g., madder) are the most important plants in plant-based dyeing, the term "Root dyeing" is used for natural dyeing. The excessive use of madder in traditional dyeing is due to the fact that the plant is the primary red color source for the Turkish people. To meet the intense demands from domestic and European countries, madder was not only collected wild from nature, but also cultured in the Turkish provinces such as Bursa, Denizli, Aydin, Edirne, Balikesir, Izmir, Manisa, Ankara, Kayseri, Konya, Tokat, Nigde, Amasya, Siirt and Diyarbakir during the Ottoman period in Anatolia (Kepcioğlu 1942; Canatar 1998; İmer 1999).

Although Anatolian traditional dyeing (Fig. 3.1) and handloom weaving (on the left of Fig. 3.1) and have gradually declined since the second half of the twentieth century, the art of handloom weaving with plant-dyed yarns is tried to continue in the Turkish provinces such as Izmir (Bergama, Selcuk), Manisa (Yunt, Demirci, Kula, Gordes), Canakkale (Ayvacık), Balıkesir (Sindirgi), Denizli, Mugla (Milas, Bodrum), Usak (Esme), Afyon (Bayat), Konya (Ladik), Kayseri (Yahyalı), Antalya (Dosemealti), Isparta, Izmit (Hereke), Sakarya, Bilecik (Sogut), Bursa, Samsun, Tokat, Nigde, Aksaray, Kars, Van and Siirt (Doğan et al. 2003).

Anatolia is home to carpets, rugs and other weavings, which are a very special cultural heritage of the Turks. There are motifs woven in very different ways on traditional Turkish carpets or rugs, which are carefully processed on hand looms with wool dyed with plant dyes. All these motifs have meanings that will shed light on the socio-cultural structure of the society (Çetintaş and Ağırbaş 2019). "Hereke carpets" with motifs such as "Zumruduanka" and "Bahardali", or Bayat rugs with motifs such as "Bindalli" and "Dragon" are the reflections of the cultural richness that Turks carried from Central Asia to Anatolia. These carpets and rugs are the product of the perfect harmony of colors and patterns (Fig. 3.1). Some colors reflect love, some patterns reflect feelings, desires and longings. For example, a girl who embroiders heart, earring, hair tie or dowry box motifs on the carpet gives the message "I fell in love, get me married now" to her family. (Arı et al. 2017).

Fig. 3.1 Traditional dyeing in Turkey: wool yarn is dyed with dye plants

Fig. 3.2 Traditional handloom carpet weaving and a carpet embroidered with Turkish motifs, in Turkey

The techniques and application recipes of commonly used dyestuffs within the scope of natural dyeing, which has been done traditionally in Anatolia from the past to the present still await complete exploration (Fig. 3.2). Within the scope of DOBAG (Natural Dye Research and Development) Project by Department of Textile at the Faculty of Fine Arts of Marmara University, it was decided to keep natural dyeing alive and revive traditional patterns in carpet motifs, and studies were started in Ayvacık town of Canakkale province of Turkey in 1981. With this project, historical carpets and rugs woven on hand looms with yarn dyed with natural dyes were analyzed by techniques such as TLC, HPLC and HPLC/MS, and it was determined which dye plant, dyestuff and mordants were used (Böhmer 1983).

3.4 Anatolian Flora Is a Dyestuff Storehouse

Turkey is one of the world's richest countries with regard to diversity of plant species and plant genetic resources. Flora of Turkey has a rich biodiversity containing 174 families, 1251 genera, 9225 species and over 11,000 generic taxa. This rich biodiversity is due to tha fact that Turkey is located at the crossroads of three different biogeographically regions where consist from European Siberian, Mediterranean and Irano-Turanian regions.

123 plant species belonging to 50 families have been determined as a natural dye sources in the flora of Turkey (Doğan et al. 2003). From these resources almost any color can be obtained. Table 3.1 presents which colors are obtained from which organs or parts of some important dye plants that grow naturally in the flora of Turkey. Almost all of these plants except safron, safflower, walnut, hazelnut, silver

Table 3.1 Dye plants of Turkey

Botanical name	Family	Common name	Part of plant	Color
Achillea millefolium L.	Asteraceae	Yarrow	Flower	Yellow
Alkanna tinctoria L. (Tausch)	Boraginaceae	Dyer's alkanet	Root	Yellow, Brown
Allium cepa L.	Amaryllidaceae	Onion	Dry outer leaf	Yellow, Brown
Alnus glutinosa (L.) Gaert.	Betulaceae	Black alder	Bark	Red, Brown
Anthemis tinctoria L.	Asteraceae	Dyer's chamomile	Flower	Yellow
Berberis vulgaris L.	Berberidaceae	Barberry	Root	Yellow
Carthamus tinctorius L.	Asteraceae	Safflower	Flower	Red, Yellow, Orange
Chrozophora tinctoria (L.) Rafin	Euphorbiaceae	Dyer's croton	Aboveground	Purple
Cistus creticus L.	Cistaceae	Pink rock-rose	Leaf	Yellow, Brown
Cistus laurifolius L.	Cistaceae	White rock-rose	Leaf	Yellow, Brown
Corylus colurna L.	Betulaceae	Turkish hazelnut	Leaf, Bark	Yellow, Green
Cotinus coggygria Scop.	Anacardiaceae	Dyer's sumac	Leaf, Shoot	Yellow
Crocus sativus L.	Iridaceae	Saffron	Stigma	Orange, Yellow
Daphne oleoides Schreber.	Thymelaeaceae	Olive daphne	Aboveground	Yellow, Green
Datisca cannabina L.	Datiscaceae	False hemp	Aboveground	Yellow
Dittrichia viscosa L.	Asteraceae	Yellowhead	Aboveground	Yellow
Euphorbia tinctoria Boiss. & Huet	Euphorbiaceae	Spurge	Aboveground	Yellow
Genista tinctoria L.	Fabaceae	Dyer's broom	Stem, Flower	Yellow
Helichrysum arenarium (L.) Moench	Asteraceae	Golden cudweed	Flower	Yellow, Brown
Hypericum empetrifolium Willd.	Hypericaceae	St John's wort	Aboveground	Yellow
Isatis tinctoria L.	Brassicaceae	Dyer's woad	Leaf, Stem	Blue
Juglans regia L.	Juglandaceae	Walnut	Bark of fruit	Brown
Laurus nobilis L.	Lauraceae	Bay laurel	Leaf	Green
Malva sylvestris L.	Malvaceae	Common mallow	Leaf	Green
Melissa officinalis L.	Lamiaceae	Lemon balm	Leaf	Green
Mentha spicata L.	Lamiaceae	Mint	Aboveground	Green, Grey, Brown
Pinus brutia Ten.	Pinaceae	The Turkish pine	Bark	Brown

(continued)

Table 3.1 (continued)

Botanical name	Family	Common name	Part of plant	Color
Pistacia terebinthus L.	Anacardiaceae	The turpen-tine tree	Leaf	Yellow
Punica granatum L.	Lythraceae	Pomegranate	Bark of fruit	Yellow
Quercus *infectoria* Olivier	Fagaceae	The Aleppo oak	Fruit	Brown
Quercus ithaburensis Decne.	Fagaceae	Valonia Oak	Fruit	Brown
Reseda luteola L.	Resedaceae	Weld	Aboveground	Yellow
Rhamnus petiolaris Boiss. & Balansa	Rhamnaceae	Anatolian buckthorn	Fruit	Yellow
Rhus coriaria L.	Anacardiaceae	Dyer's sumac	Fruit	Yellow, Brown
Rubia davisiana Ehrend.	Rubiaceae	Wild madder	Rhizome	Red
Rubia tinctorum L.	Rubiaceae	Madder	Rhizome	Red
Rumex patientia L.	Polygonaceae	Sorrel	Leaf	Green, Yellow
ssp.	Lamiaceae	Sage	Aboveground	Yellow, Brown, Green
Sambucus nigra L.	Adoxaceae	Elderberry	Fruit	Black, Purple
Tagetes erecta L.	Asteraceae	Marigold	Flower	Yellow, Orange
Thymus zygioides Griseb	Lamiaceae	Thyme	Aboveground	Yellow, Brown, Green
Tilia tomentosa Moench	Malvaceae	Silver linden	Bark, Flower	Brown
Urtica dioica L.	Urticaceae	Common nettle	Aboveground	Yellow
Verbascum sp.	Scrophulariaceae	Mullein	Aboveground	Yellow
Vitex agnus castus L.	Lamiaceae	Chaste tree	Leaf	Green

linden and onion are produced by collecting from nature. Species that have "*tinctoria*", "*tinctorius*", "*tinctorium*", or "*tinctorum*" in their botanical name (e.g., *Alkanna tinctoria, Anthemis tinctoria, Carthamus tinctorius, Coreopsis tinctoria, Genista tinctoria, Isatis tinctoria, Indigofera tinctoria,* and *Rhamnus tinctoria*) contain strong coloring substances. "Dyer's", which is the forename of some dye plants (e.g., dyer's alkanet, dyer's chamomile, dyer's croton, dyer's sumac, dyer's broom, dyer's woad, and dyer's sumac), also emphasizes that that plant is used in dyeing "(Baydar and Bıyıklı 2019).

A dye plant produces by its biosynthesis soluble dyes molecules "dyes" or insoluble compounds "pigments/lacquers" (Garcia et al. 2014). There is a wide variety of dyestuffs from which almost every color except phosphorescent colors is obtained from the dye plants grown wild or cultured in Turkey, such as alizarin (red) from madder (*Rubia tinctorum*) rhizomes, indigon (blue) from dyer's worn

(*Isatis tinctoria*) leaves, rhamnetin (yellow) from buckthorn (*Rhamnus petiolaris*) fruits, alkannin (purple) from alkanet (*Alkanna tinctoria*) roots, and crocin (orange) from saffron (*Crocus sativus*) stigmas (Baydar and Bıyıklı 2019) (see Figs. 3.3 and 3.4).

Fig. 3.3 Dyer's woad (*Isatis tinctoria*) plants that grow naturally in Turkey. (Photo: M. Bischof)

Fig. 3.4 Madder (*Rubia tinctorum*) and buckthorn (*Rhamnus petiolaris*) plants which grow naturally in Turkey

Thousands of plant species and taxa, whose dyestuff aspect has not been explored simply because they have not been researched, yet they show great hope for the development of the art of dyeing. For this reason, research on the discovery of alternative new natural dye sources is of great importance. It is reported that there is a significant increase in the number of companies producing natural dyestuffs from dye plants which grow in Turkey.

3.5 Production and Cultivation of Dye Plants in Turkey

Natural dyes have a special place in the weaving art of ancient Anatolian culture. Especially madder (*Rubia tinctorum* L.) and buckthorn (*Rhamnus petiolaris* Boiss.) have been used extensively for dyeing yarns of the traditional Turkish carpets and flat weavings. These dye plants (Fig. 3.1) were not only gathered wild, but also cultivated in the periods of Seljuks and Ottomans (Genç 2014). In the Ottoman archives, there are records that the madder was produced in Manisa, Konya, Erzincan and Konya, and the buckthorn was produced in Kayseri, Erzincan, Sivas and Silifke (Eşberk and Köşker 1945; Eşberk and Harmancıoğlu 1951). In the eighteenth century, two-thirds of the world's demand for madder was met from Anatolia, and the value of the madder sold to foreign countries from the port of Izmir until 1875 reached five million gold (Genç 2014). The production of cotton and tobacco has taken the lead over the production of madder mainly because synthetic dye substances are cheaper to produce (Enez 1987).

On the other hand, buckthorn was exported to many European countries, primarily France, Germany and England, from the ports of Izmir and Samsun. With the introduction of synthetic dyes in the last quarter of the nineteenth century, natural dyeing and hand weaving, in parallel, entered a period of decline. As the synthetic dyes started to be used gradually in the dye factories operated by the Greeks, the Ottoman Empire banned the use of synthetic dyes, but this ban did not last long (Öztürk 1997). Turkish carpets that are dyed with synthetic dyes have lost their importance (Doğan et al. 2003). But in recent years, the use of natural dyes and the production of dye plants has begun to support by TUBITAK (The Scientific and Technological Research Council of Turkey). For example, within the scope of a project a successful practical generative and vegetative propagation methods in madder has been developed by Baydar and Karadoğan (2006). In addition, anthraquinone (AQ) production was successfully performed by root culture in madder *in vitro* conditions by Biçer et al. (2017) and Aras Aşcı et al. (2018).

In the province of Edirne, which gave its name to "Edirne Red", intensive research is going on into the re-cultivation of madder within the scope of the project "Determination of Agricultural Potential of Root Dye (*Rubia tinctorum* L.) in Edirne Conditions" by Trakya University (Figs. 3.4 and 3.5). Similarly, researches on the cultivation of dye plants and dyestuff properties have been continuing for many

Fig. 3.5 A field established with madder seedlings within the scope of the madder project in Edirne

years by Isparta University of Applied Sciences and Süleyman Demirel University in Isparta province. In addition, Natural Dyes Application and Research Center was opened at Gaziosmanpaşa University in Tokat province. In this center, researches on natural dyeing with dye plants like madder, buckthorn, walnut, weld, saffron, turmeric, and hibiscus are carried out. Although there are 36 species belonging to the genus *Crocus* in the flora of Turkey, the true saffron (*Crocus sativus*) cultivated only in Safranbolu district is not among them.

3.6 Trade of Dye Plants in Turkey

Trade in natural dyes and dye plants has more gained momentum after the COVID-19 epidemic in the world. However consumers have started to complain natural dyes due to the low purity and high cost. Consequently, some public and private organizations have decided to meet their own needs from the particular dye plants gathering from their nature habitats. Even though the gatherers in the Turkish provinces such as Manisa, Aksaray, Nevsehir and Konya meet some of this demand, they are not sufficient.

Unfortunately, official government data on the production and trade of dye plants in Turkey are not yet available. However, we may share information here that provides important estimated data based on free market research and interviews with relevant people. As of 2021, there are 8 herbal dye sources that are subject to trade in Turkey. They are madder powder (16 USD/kg), weld (8 USD/kg), woad/indigo (150 USD/kg), buckthorn (20 USD/kg), walnut hull (3 USD/kg), acorn (3 USD/kg), acorn oak (7 USD/kg), and safflower (20 USD/kg). Among these plants, the most commonly gathered from the wild are the acorn and madder. The annual demand for rhizome powder of madder is about 20 tons that cannot fulfil the demand by collecting from nature.

Acorn is one of the most important plant-based dye sources in Turkey. An average of 4500–5000 tons of raw materials are processed annually in an extraction factory in Manisa province and approximately 1500 tons of valex (acorn extract) is produced. A total of 1200 tons of valex with a trade value of three million dollars is exported to Germany, France, Italy, the Netherlands, Argentina, China and Japan.

3.7 Traditional Dyeing Methods in Turkey

Natural dyeing means the boiling of natural dye sources (e.g., dye plants) together with various fibers and mordants at a certain temperature and time (Fig. 3.1). Natural dyeing is done by two different methods, with and without mordants. The natural dyes having limited substantively for the fibre, require use of the mordant which enhances the fixation of the natural colorant on the fibre by the formation of the complex with the dye. A mordant is a chemical which can be fixed on the fibre and also forms a chemical bond with the natural colourants. Mordanting helps in absorption and fixation of natural dyes and also prevents bleeding and fading of colours i.e., improves the fastness properties of the dyed fabrics (Bhute 2012). Mordants ensure the brightness and wash fastness of the dye and also has great influence on the final colour obtained (Ferreira et al. 2004). Color permanence or fading resistance of plant-based dyes is measured by “fastness degree” which expresses resistance to washing, light, ironing, perspiration and friction (Karadağ 2007).

Dyeing process may refer to first applying the mordant and then dyeing (pre-mordanting) or by simultaneous application of the dye and the mordant (meta-mordanting) or by after treatment of the dyed material with the mordant (post-mordanting) (Bhute 2012). There are three types of mordants, namely metal salts or metallic mordants, tannic acid (tannins) and oil mordants. Some of the important mordants used are alum, potassium dichromate, ferrous sulphate, copper sulphate, zinc sulphate, tannin, and tannic acid. Mordanting with potassium dichromate, ferrous sulfate, and copper sulfate shows the darker shades and lower chromaticity values while alum gives the lighter shades and higher chromaticity values (Feiz and Norouzi 2014). Traditionally, alkali and acidic modifiers or additives such as wood ash, baking soda, white vinegar, citric acid and cream tartar are also can also be used to create variegated colors on fabrics.

The most common mordanting methods in Turkey are the pre-mordanting and meta-mordanting (Eyüboğlu et al. 1983; Karadağ 2007). In general, the method with the best results is pre-mordanting and subsequent dyeing. In traditional dyeing yarn with madder and alum, 1 kg of wool yarn is boiled for 1 h in 25 liters of water containing 200 g alum. Then the yarn removed from the mordant bath are rinsed with cold water and left to dry. Mordanted yarn is boiled for at least 1 h at 100 °C in a cauldron containing 30 liters of cold water and 1 kg of ground madder root. The yarn is kept in the dye bath until the desired bright red color is obtained. After the boiling process is finished, the dyed wool yarn is rinsed, filtered, wrung and dried by hanging in shade. Red dyed wool yarn is then woven on hand looms, making carpets and rugs (Fig. 3.2).

In order to obtain black color, mordanting is done after the dyeing process is completed with a tannin-containing dyestuff. No mordanting is required when dyeing with walnut shell and barberry root. After the wool yarn is boiled in the dyestuff solution for 1 h, it is left for one day and the dyeing process is completed. In the Turkish dyeing tradition, dyeing is carried out without boiling to obtain a purple color with madder. The mordanted threads are kept in cold dye solution for 1 day and then rinsed with water and dried in the shade.

3.8 Conclusions

With the widespread use of chemical fibers and dyes in the textile industry both in the world and in Turkey, traditional weaving art and natural dyeing have gradually lost their importance. However, in recent years, natural dyes have started to gain importance, especially against the negative effects of chemical dyes on human and environmental health. Natural dyes are in great demand not only for dyeing carpets and rugs in traditional handlooms, but also for coloring functional foods, cosmetics and pharmaceutical products. Moreover, children's clothes and toys, which are dyed with natural dyes instead of chemical dyes, are of great interest. In this context, it is necessary to rediscover the plant-based dye sources from which every color will be obtained, and to ensure their sustainable field production and wild harvesting without harming the nature. It has been understood that the flora of Turkey has a unique richness in terms of dye plants. Finally, important research and development projects are carried out in Turkey both on the identification and agricultural production of dye plants from which basic colors are obtained, and the production and evaluation of vegetable dyestuffs at high standards from them. Finally, the increase in investments made by the private sector after the government started to support the agriculture of dye crops in 2015 are promising developments for the future.

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Chapter 4
Phytochemical and Biological Characteristics of Apiaceae Species from Turkey

Temel Özek, Gülmira Özek, and Süleyman Yur

Abstract Turkey has a rich biodiversity having about 12.000 taxa. Species of the family Apiaceae are distributed in most parts of the world with 466 genera and about 3820 species. In Turkey, the family is represented by 500 species belonging to 100 genera or 531 taxa among them 196 endemic species. Apiaceae species are generally rich in essential oils. They may contain essential oils in different organs of the plants such as leaves, flowers, fruits, stem, roots and rhizomes. Chemical diversity may vary significantly regarding underground and aboveground parts of the plant material.

Commercially important species of this family include: anis, cumin, fennel, coriander, caraway etc. Since the members of Apiaceae are present in nearly all types of habitats, it is well distributed in Turkey. Some of the members of the family are grown as vegetables and spices. Due to their content of toxic substances, some representatives can be dangerous for both animals and humans. Due to the rich chemical diversity of family Apiaceae, it is promising for utilization by the health and industries. In this chapter we survey recent literature regarding studies on Apiaceae taxa of Turkish origin.

Keywords Turkey · Apiaceae · Umbelliferae · MAPs · Biodiversity · Essential oil · Extract · Composition

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4.1 Introduction

Eurasia and North America are the most diversified regions of Apiaceae (Umbelliferae), a cosmopolitan family containing 3820 species of 466 genera in the world (Nicolas and Plunkett 2014). The family Apiaceae is the eighth largest family in the Flora of Turkey (Pimenov and Leonov 2004). In the monumental series entitled "Flora of Turkey and the East Aegean Islands" edited by P.H. Davis the family Apiaceae is represented by 101 genera of which 53 have only 1 species and 451 species. It is a major contribution to the floristic study of Southwest Asia and the eastern Mediterranean region. Later, several genera and species have been added to the Turkish flora. The degree of diversity of the Apiaceae on a global scale appears to be better understood through the important world generic checklist by Pimenov and Leonov. According to this Turkey has about 451 species included in 109 genera (Pimenov and Leonov 2004). Ongoing studies on Turkish Apiaceae genera are revealing unique and interesting characters and character states, many of which are presumed to be plesiomorphic within the Apiaceae. Endemism of the family in Turkey is about 37% (Baser and Kirimer 2014). The last updated list of Apiaceae species growing in Turkey is given in the database "bizimbitkiler.org.tr" as follows: 100 Genera, 500 species included in 531 taxa comprising 196 endemics (Guner 2013; Guner et al. 2012). The family members are of considerable economic importance as food condiments, flavouring, ornamental, cosmetic and medicinal plants (Sousa et al. 2021; Thiviya et al. 2021).

4.2 Diversity of Turkish *Ferula* Species

The genus *Ferula* L. is an important genus of the Apiaceae family with applications in pharmaceutical, food, and cosmetic industries (Salehi et al. 2019). The genus *Ferula* L. with 180–185 species is considered as one of the largest genera of the family (Pimenov and Leonov 2004). The genus is classified in the tribe Peucedaneae and six subgenera are recognised with in the genus (Pimenov and Leonov 1993). In the Flora of Turkey, about 131 species can be found, of which approximately 100 are endemic (Duman and Sağıroğlu 2005). The genus species distributed in the Irano-Turanian region were classified into three sections based on the number of their vittae and the shape of their petals: *Peucedanoides* Boiss. *Ferula* Boiss. and *Scrodosma* Bunge (Boissier 1872). Recently, Panahi et al. classified Turkish *Ferula* species under two subgenera: subgenus *Ferula* and subgenus *Narthex* (Falc.) Drude based on nrDNA ITS and plastid DNA sequences (Panahi et al. 2018). The ratio of species endemism in the family is 37.3% (Baser et al. 2021; Pesmen 1971). Among endemic species were listed: *F. amanicola* Hub.-Mor. & Pesmen, *F. anatolica* (Boiss.) Boiss., *F. brevipedicellata* Pesmen ex Sagiroglu & H. Duman, *F. coskunii* H. Duman & M. Sagiroglu, *F. divaricata* Pimenov & Kljuykov, *F. drudeana* Korovin, *F. duranii* Sagiroglu & H. Duman, *F. halophila* Pesmen, *F. huber-*

morathii Pesmen, *F. longipedunculata* Pesmen, *F. lycia* Boiss., *F. mervynii* Sagiroglu & H. Duman *F. parva* Freyn & Bornm., *F. tenuissima* Hub.-Mor. & Pesmen, *F. coskunii* H. Duman & M. Sagiroglu (Pimenov and Leonov 2004; Thiviya et al. 2021). According to recent studies, the *Ferula* genus includes 23 species, of which 14 species are endemic. Recently, new species *Ferula pisidica* Akalin & Miski has been reported (Akalin et al. 2020).

4.2.1 *Major Chemical Constituents and Bioactive Compounds of* Ferula *Species*

The most significant secondary metabolites detected in *Ferula* species were sesquiterpenoid compounds that show unique chemical structure diversity closely associated with their taxonomic status at the subgenera level. Table 4.1 summarizes the results of literature survey on volatile constituents reported for *Ferula* species growing in Turkey.

Akalin et al. postulated in a recent paper that *Ferula* species from subgenus *Merwia* contain mainly sesquiterpene coumarin ethers and some sulfur containing compounds, while the species from subgenus *Ferula* yield both sesquiterpene coumarin ethers and sesquiterpene esters. The *Ferula* species from subgenus *Peucedanoides* mainly afford sesquiterpene esters (Akalin et al. 2020). Table 4.2 summarizes the results of the literature survey on non-volatile constituents reported for *Ferula* species growing in Turkey.

4.2.2 *Traditional Use and Common Knowledge of* Ferula *Species*

In the folk medicine, *Ferula* species have different names between the Turkish populations as “çakşir otu, çaşir otu, şambut, hiltik, hiltit, siyabo, girmizi bolu, heliz”. Different plant parts, commonly roots, aerial parts, leaves and stema have been used for preparation of decoction or infusion to treat diseases. Some *Ferula* species are used for the treatment of diabetes, hypercholesterolemia, stomachache, and gynecologic diseases (Altundag and Ozturk 2011). In Hatay and Adana region of Turkey, roots of *F. elaeochytris* are grinded and mixed with honey then used as aphrodisiac. In East Anatolia the leaves of *F. communis* L. and *F. rigidula* are boiled with water and eaten as a food. Villagers make spices and pickle from *F. orientalis* L. In addition, *F. capsica* (Girmizi bolu) is used as stomachic while the over ground parts of *Ferula orientalis* (Heliz) is used for gynecological problems (Baytop 1999; Yusufoglu et al. 2015). Ethnopharmacological survey of *Ferula* species in Turkey is given in Table 4.3.

Table 4.1 Volatile constituents reported for *Ferula* species growing in Turkey

Ferula species[a]	Plant part	Compound, %	Ref.
F. orientalis	AP	α-Pinene (75.9), β-pinene (3.4)	Karakaya et al. (2019a)
		α-Pinene (27.7–35.5), β-phellandrene (5.6–7.4), naphthalene (4.3–15.3)	Kilic (2015)
	L, Fl	α-Cadinol (10.4–11.7), δ-cadinene (8.1–9.3), germacrene-D-4-ol (6.8–11.9), *epi*-α-muurolol (5.9–6.1)	Ozkan et al. (2014)
F. sandrasica	AP	Limonene (28.9), α-pinene (15.6), terpinolene (13.9)	Karakaya et al. (2019a)
F. caspica M. Bieb.	AP	Sesquiterpene coumarins: 1-(20,40-dihydroxyphenyl)-3,7,11-trimethyl-3-vinyl-6(*E*),10-dodecadien-1-one, 2,3-dihydro-7-hydroxy-2,3-dimethyl-2-[40,80-dimethyl-30,70-nonadienyl]-furo[3,2,c]coumarin, 2,3-dihydro-7-hydroxy-2,3-dimethyl-3-[40,80-dimethyl-30,70-nonadienyl]-furo[3,2,c]coumarin	Kahraman et al. (2019b)
F. szowitsiana DC.	L + St	β − Eudesmol (32.0% and 29.5), α-eudesmol (18.2 and 16.6), α-pinene (8.6 and 6.4)	Ozek et al. (2008)
F. tenuissima Hub.-Mor. & Pesmen	R	Daucane-type sesquiterpenes teferidin, ferutinin, and elaeochytrin-A	Aydogan et al. (2019)
F. huber-morathii Pesmen	R	Sesquiterpenes	Aydogan et al. (2020)
F. elaeochytris Korovin	Fr	Nonane (27.1), α-pinene (12.7), germacrene B (10.3)	Baser et al. (2000a)
F. lycia Boiss.	Fr	α-Pinene (59.9), β-pinene (19.0), limonene (3.2)	Kose et al. (2010)
F. rigidula	Fr	Camphene (15.0), α-pinene (13.0), δ-cadinene (13.0), α-cadinol (10.0), germacrene-D-4-ol (10.0)	Baser et al. (2007a)
	Fr	α-Pinene (24.0%), camphene (20.0), germacrene-D-4-ol (8.0), δ-cadinene (6.0), α-cadinol (5.0)	Miski et al. (2013)
F. mervynii Sagiroglu & H.Duman	AP	α-Pinene (48.1), sabinene (20.0), β-pinene (11.6), terpinen-4-ol (2.5)	Ilhanlı et al. (2018)
F. gummosa Boiss.	Fr	β-Pinene (64.9), Δ-3-carene (7.3), α-pinene (4.6), β-myrcene (2.3)	Mutlucan et al. (2020)

[a]First cited species are given with author(s), *AP* aerial parts, *Fl* flower, *Fr* fruits, *L* leaves, *R* roots, *St* stems

Table 4.2 Non-volatile constituents reported for *Ferula* species growing in Turkey

Ferula species[a]	Plant part	Compound	Ref.
F. caspica M. Bieb.	AP	Phenylpropanoids: laserine/2-epilaserine; Steroid mixtures: stigmasterol and β-sitosterol; Flavonoids: kaempferol-3-*O*-β-glucopyranoside, kaempferol-3-*O*-α-rhamnopyranoside, quercetin-3-*O*-β-glucopyranoside, Benzoic acid derivative; 2,4-dihydroxybenzoic acid	Kahraman et al. (2019b)
	AP	Phenolic acids: 3-caffeoylquinic, 5-caffeoylquinic, 1,5-dicaffeoylquinic, 5-feruloylquinic, dihydroxy benzoic. Flavonoids: quercetin-3-*O*-β-glucoside, kaempferol-3-*O*-β-glucoside, kaempferol-3-*O*-α-rhamnozide, quercetin/hesperidin	Kahraman et al. (2019a)
F. halophila	AP	Phenolic acids: 3-caffeoylquinic, 1,3-dicaffeoylquinic, 1,5-dicaffeoylquinic, 5-caffeoylquinic, 5-feruloylquinic. Flavonoids: quercetin-3-*O*-β-glucoside, kaempferol-3-*O*-β-glucoside, kaempferol-3-*O*-α-rhamnozide, quercetin/hesperidin	Kahraman et al. (2019a)
F. elaeochytris Korovin	R	Fatty acids: linoleic, oleic, palmitic, α-linolenic	Eser et al. (2020)
	R	Salicyloyl and angeloyl esters of jaeschkeanadiol, benzoic, *p*-hydroxybenzoic, *p*-methoxybenzoic and vanillic acid esters, 3-hydroxy-4,5-methylenedioxypropiophenone	Miski et al. (1983)
	AP	Protocatechuic acid	Deveci et al. (2018b)
F. haussknechtii	Fr	Fatty acids	Kucukboyaci et al. (2016)
F. hermonis	Fr	Fatty acids	Kucukboyaci et al. (2016)
F. rigidula	R	Daucane aryl esters, phenyl propanoid ester	Miski and Jakupovic (1990)
	Ap	Coumarins, phenolic acid, flavonoids	Zengin et al. (2020)
F. tingitana	R	Daucane esters: l4-*p*-anisoyloxy-dauc-4,8-diene, acetyltingitanol, acetyldesoxodehydrolaserpitine, 4-β-hydroxy-6-α-*p*-hydroxybenzoyloxy-10-α-angeloyloxydauc-8-ene, sesquiterpene coumarin ethers	Miski et al. (1984, 1985) and Miski and Mabry (1986)

(continued)

Table 4.2 (continued)

Ferula species[a]	Plant part	Compound	Ref.
F. orientalis	AP	Chlorogenic, caffeic, rosmarinic, salicylic, and fumaric acids Quercitrin, quercetin, naringenin, luteolin, apigenin, hispidulin, acacetin, chrysin, hyperoside, rutin, naringin, verbascoside, apigenin- 7-glucoside, luteolin-7-glucoside, luteolin-7-rutinoside, orientin, (−)-epigallocatechin	Zengin et al. (2020) and Kızıltaş et al. (2021b)
F. orientalis var. *orientalis*	R	Daucane and germacrane alcohols esterified with vanillic and hydroxybenzoic acids	Miski et al. (1987)
F. tenuissima	R	Daucane-type sesquiterpenes: teferidin, ferutinin, elaeochytrin-A	Aydogan et al. (2019)
F. anatolica	AP, R	Sesquiterpenes	Kurtoğlu et al. (2013)
F. parva Freyn & Bornm.	R	Norketofervanol vanillate, kurubashic acid tiglate, 1α,10β-epoxy kurubashic acid vanillate, 1β,10α-epoxy kurubashic acid vanillate, fervanol vanillate, fervanol *p*-hydroxybenzoate, kurubashic acid angelate, linoleic acid, falcarindiol, bornyl vanillate, tovarol vanillate, bornyl *p*-hydroxybenzoate, tovarol *p*-hydroxybenzoate	Idug (2016)
F. gummosa Boiss.	Fr	Fatty acids: petroselinic, linoleic, oleic	Mutlucan et al. (2020)

[a]First cited species are given with author(s), *AP* aerial parts, *Fr* fruits, *R* roots

Table 4.3 Ethnopharmacological survey of *Ferula* species growing in Turkey

Ferula species[a]	Plant part	Utilization method	Treatment	Ref.
F. orientalis	AP	Cook in boiling water and eaten, infusion	Diabetes, tension	Güneş and Özhatay (2011)
	R	Decoction, infusion	Gastric pains	Mükemre et al. (2015)
	L + St	Make spices and pickle, fresh	Food	Güneş and Özhatay (2011)
F. longipedunculata Peşmen	R	Powdered drug is mixed with honey	Aphrodisiac	Demirci and Özhatay (2012)
F. elaeochytris Korovin	R	Decoction/oral	Aphrodisiac, antidiabetic, emmenagogue-menstrual regulator	Güzel et al. (2015) and Aytekin et al. (1983)
F. caspica M. Bieb.	AP	Decoction	Antimicrobial	Kahraman et al. (2019b)
	H	Decoction	Stomach ache, internal medicine, gynecologic diseaes, diabetes	Altundag and Ozturk (2011)
F. szowitsiana DC.	Young St	Eaten fresh after peeling		Doğan et al. (2014)
F. rigidula DC.	Young shoots +L	Spice in cheese, pickle cooked as meal		Doğan et al. (2014)

[a]First cited species are given with author(s), *AP* aerial parts, *Fr* fruits, *H* herb, *L* leaves, *R* roots, *St* stems

4.2.3 Pharmacological Properties of Ferula *Species*

The oils and extracts of *Ferula* species were reported for wide range biological activities: antimicrobial (Karakaya et al. 2019a; Baldemir et al. 2006), antibacterial (Utegenova et al. 2018; Eftekhar et al. 2004), antioxidant (Kahraman et al. 2019b; Kose et al. 2010; Kartal et al. 2007), cytotoxic, anticancer (Aydogan et al. 2019; Baykan et al. 2020), aphrodisiac (Aydogan et al. 2020), anticholinesterase (Karimi et al. 2010; Deveci et al. 2018a), anti-tyrosinase (Deveci et al. 2018b), antimutagenic (Ozkan et al. 2014), antidiabetic and antihyperlipidemic (Yusufoglu et al. 2015). Recently, antileishmanial effect was decribed for *F. orientalis* extracts (Babat 2019). The phytochemical investigations of several *Ferula* species growing in Turkey has yielded many sesquiterpenes with antibacterial, antifungal, anticancer, antioxidant, P-glycoprotein inhibitor, immune modulator and hormonal activities (Baykan et al. 2020; Miski 2013). The daucane-type sesquiterpenes from *F. tenuissima*, teferidin, ferutinin, and elaeochytrin-A exhibited the high cytotoxic activity (Aydogan et al. 2019).

4.3 Diversity of Turkish *Prangos* Species

Prangos Lindl. is one of the important genera of Umbelliferae in the world and the largest genus after *Ferula* L., *Bupleurum* L., *Pimpinella* L., *Heracleum* L., *Seseli* L., *Angelica* L., and *Bunium* L. (Pimenov and Leonov 2004). The genus *Prangos* Lindl. comprises about forty-five species occurring from the west coast of Portugal to western Tibet. Most species are found in Asia, and the centre of the diversity of the genus is the Irano-Turanian region. A monographic study of *Prangos* was presented by Herrnstadt and Heyn (Herrnstadt and Heyn 1972, 1977) for Turkey. Within Apiaceae, members of *Prangos* share rare features of fruit anatomy, viz. endosperm with mushroom-like groove on commissural side and division of the mesocarp into two layers: epimesocarp and inner mesocarp. The absence of sclerenchyma's massifs in mesocarp differs from *Prangos* to *Cachrys* (Pimenov and Tikhomirov 1983). *Prangos* is polymorphic and varies considerably in habit and floral and fruit morphology that has made determining the boundaries of the genus difficult. In the Flora of Turkey, the genus *Prangos* is represented by 20 taxa (16 species, 2 subspecies and 2 varieties) (Menemen 2012; Duman 2000). Among recently added species are *P. platychlaena* Boiss. ex Tchih. subsp. *engizekensis* H. Duman & M.F. Watson and *P. heyniae* H. Duman & M.F. Watson (Duman and Watson 1999), *P. abieticola* Aytac & H. Duman (Aytaç and Duman 2016), *P. aricakensis* Behcet & Yapar (Behçet et al. 2019), *P. turcica* A. Duran, Sagiroglu & H.Duman (Duran et al. 2005), *P. hulusii* Senol, Yildirim & Secmen (Gökhan Şenol et al. 2011), *P. ilanae* Pimenov, Akalin & Kljuykov (Pimenov et al. 2005).

4.3.1 Major Chemical Constituents and Bioactive Compounds of Prangos *Species*

The most significant secondary metabolites detected in *Prangos* species were mono- and sesquiterpenoid compounds that show unique chemical structure diversity closely associated with their taxonomic status at the subgenera level. Table 4.4 summarizes the results of literature survey on volatile constituents reported for *Prangos* species growing in Turkey.

However, representatives of *Prangos* genus have been reported for phenolic compounds of different subclasses: coumarins, furanocoumarins, flavonoids, phenolic acids (Table 4.5).

Table 4.4 Volatile constituents reported for *Prangos* species growing in Turkey

Prangos Species[a]	Plant part	Compound	Ref.
P. denticulata Fisch & Mey	Fr	Sabinene (26.1), *p*-cymene (19.7)	Kılıç et al. (2010)
	R	δ-3-Carene (49.3), (*Z*)-3,5-nonadiyne-7-ene (20.4)	
P. heyniae H. Duman & M.F. Watson	Fr	β-Bisabolenal (53.3 and 18.0), β-bisabolenol (14.6 and 2.3) and β-bisabolene (12.1 and 10.1), germacrene D (13.5) and germacrene B (9.4)	Başer et al. (2000)
	AP	β-Bisabolenal (1.4–70.7), elemol (3.4–46.9), kessane (26.9), 3,7(11)-eudesmadien-2-one (16.1), β-bisabolene (14.4), germacrene D (10.3–12.1), β-bisabolenol (8.4), germacrene B (8.2)	Özek et al. (2018)
	AP	Elemol (36.2), β-bisabolenal (14.1), and germacrene D (12.7)	Karahisar et al. (2022)
	Inf	β-Bisabolenal (21.6) germacrene D (15.6), germacrene B (12.4)	Karahisar et al. (2022)
	R	α-Pinene (44.8), limonene (15.3), β -pinene (12.5), and δ-3-carene (10.2)	Karahisar et al. (2022)
	AP	β-Bisabolenal (12.2), caryophyllene oxide (7.9)	Zengin et al. (2022)
P. pabularia Lindl.	Fr	α-Humulene (16.6 and 15.5), bicyclogermacrene (16.1 and 7.9), spathulenol (10.6 and 5.7), germacrene D (5.7 and 2.9) and α-pinene (4.2 and 23.9)	Özek et al. (2007)
	AP	α-Pinene (32.4), δ-3-carene (12.4), germacrene D (8.1), limonene (6.4), bicyclogermacrene (6.2);	Kiliç and Özdemir (2017)
	Fr	Bicyclogermacrene (21%), (*Z*)-β-ocimene (19%), α-humulene (8%), α-pinene (8%) and spathulenol (6%), suberosin (1.8)	Tabanca et al. (2016)
P. peucedanifolia	AP	α-Pinene (38.1), bicyclogermacrene (11.3), δ-3-carene (9.2)	Kiliç and Özdemir (2017)
P. platychlaena Boiss.	–	δ-3-Carene (3.3), *p*-cymene (3.3)	Dirmenci et al. (2006)

(continued)

Table 4.4 (continued)

Prangos Species[a]	Plant part	Compound	Ref.
P. platychlaena Boiss. ex Tchihat. ssp. *platychlaena*	Fr	Acetylenic derivatives: (2*S*)3,5-nonadiyne-2-yl acetate (45.8 and 11.2), 3,5-nonadiyne (24.5 and 5.8), (*Z*)-3,5-nonadiyne-7-ene (0.2), (*E*)-3,5-nonadiyne-7-ene (0.5). Monoterpenes: α-pinene (6.8 and 12.8), α-phellandrene (0.1 and 17.1), β-phellandrene (4.2 and 22.4)	Tabanca et al. (2018)
P. uloptera DC.	AP	*p*-Cymene (10.9), γ-terpinene (7.0), β − phellandrene (7.8), α-phellandrene (6.3)	Özcan et al. (2000)
P. bornmuelleri Hub.-Mor. et Reese	Fr	Germacrene D-4-ol (42.8%), α-cadinol(18.5%), cadinene (10.5%)	Başer et al. (1999)
P. uechritzii Boiss & Hauskn	Fr	*α*-Pinene (40.8), nonene (17.0), β-phellandrene (11.1), δ-3-carene (7.4), *p*-cymene (4.9)	Dirmenci et al. (2006)
	Fr	*p*-Cymene (10.9%), γ-terpinene (7.0%), β-phellandrene (7.8%), α-phellandrene (6.3%) and (*Z*)-β-ocimene (4.6%)	Özcan et al. (2000)
	Fr	Bisabolene derivative: 7-epi-1,2-dehydrosesquicineole	Baser et al. (2000b)
	AP	*p*-Cymene (24.6), caryophyllene oxide (19.6)	Zengin et al. (2022)
P. ferulacea	AP	2,3,6-trimethyl benzaldehyde (66.6), heneicosane (0.02).	Ercan et al. (2013)
P. turcica A. Duran, M. Sagiroglu et H. Duman	Fr	α-Humulene (11.0), germacrene D (10.6), naphthalene (8.5), terpinolene (7.9), bornyl acetate (6.9). *p*-cymene (4.2), γ-elemene (5.1), 1,6-germacradien-5β-ol (4.7), α-pinene (4.3)	Özek et al. (2006)
P. meliocarpoides Boiss. var. *meliocarpoides*	AP	Sabinene (16.7), *p*-cymene (13.2)	Zengin et al. (2022)

[a]First cited species are given with author(s), *AP* aerial parts, *Fr* fruits, *Inf* inflorescence, *R* roots

Table 4.5 Non-volatile constituents reported for *Prangos* species growing in Turkey

Prangos species[a]	Plant part	Compound	Ref.
P. uechritzii Boiss. & Hauskn.	R	Polyacetilenic compounds, Suberosin, 7-demethyl suberosin, psoralen, umbelliferone, imperatorin, oxypeucedanin, oxypeucedanin hydrate, oxypeucedanin methanolate, prantschimgin, ulopterol, marmesin, falcarindiol, panaxynol,	Albayrak et al. (2019) and Sevin et al. (2022)
	Fr	Fatty acids, tocochromanols	Bagci (2007)
P. heyniae H. Duman & M.F. Watson	R	Coumarin glycosides: 7-methoxy isoarnottinin 4′*O*-β -D -glucopyranoside, 7-methoxy isoarnottinin 4′-*O*-rutinoside	Albayrak et al. (2021)
	L	Chlorogenic acid, rutin, β-carotene, lycopene	Oke-Altuntas et al. (2015)
P. denticulata Fisch. & Mey.	L	Chlorogenic acid, rutin, β-carotene, lycopene	Oke-Altuntas et al. (2015)
P. ferulacea	Fr	Fatty acids	Ghafoor et al. (2019)
P. meliocarpoides Boiss. var. *meliocarpoides*	Fr	Fatty acids	Kucukboyaci et al. (2016)
P. pabularia Lindl.	Fr	Fatty acids	Kucukboyaci et al. (2016)
	R	(+)-Oxypeucedanin, (+)-heraclenol, (+)-oxypeucedanin hydrate, (+)-heraclenin, imperatorin, isoimperatorin, (−)-prantschimgin	Sevin et al. (2022)
P. platychlaena Boiss.	AP	Furanocoumarins: solstitialin 13-acetate, cynaro-picrin	Soner et al. (1992)
	Fr	Fatty acids, tocochromanols	Bagci (2007) and Kucukboyaci et al. (2016)
	WP	Coumarins: oxypeucedanin, heraclinin, n-butylbergaptol, imperatorin, isoimperatorin, 8-acetyloxypeucedanin, prangenin, bergaptol	Ulubelen et al. (1995)
P. uechtritzii Boiss. & Hausskn.	Fr	Fatty acids	Kucukboyaci et al. (2016)
P. uloptera DC.	Fr	Fatty acids	Kucukboyaci et al. (2016)
P. hulusii S.G. Senol, H. Yildirim & O. Secmen	R	Prenylated coumarins: 4′-senecioiloxyosthol, osthol, murraol, auraptenol, meranzin, hydroxyosthol-epoxide, meranzin hydrate, isoimperatorin, oxypeucedanin, psoralen. Sterols: stigmasterol, β-sitosterol.	Tan et al. (2017) and Yazici-Tutunis (2016)
P. turcica		Coumarins: osthol, murraol, auraptenol, peroxyauraptenol, 4′-senecioiloxyosthol, meranzin hydrate, scopoletin, umbelliferone, isoimperatorin, oxypeucedanin, xypeucedanin hydrate, oxypeucedanin methanolate, gosferol, psoralen, marmesin	Yazici-Tutunis et al. (2021)

[a]First cited species are given with author(s), *AP* aerial parts, *Fr* fruits, *L* leaves, *R* roots, *WP* whole plant

4.3.2 *Traditional Use and Common Knowledge of* Prangos *Species*

The local name used for *Prangos* species is “çakşir” where the name is given to various species of Apiaceae genera like *Prangos, Ferulago, Ferula* and *Peucedanum* in Turkey. The represents of *Prangos* are used as an aphrodisiac or for fertility both in humans and in animals in southern part of Turkey (Kaval et al. 2014). Some *Prangos* species are used in folk medicine as emolia, carminative, tonic, antifungal and antihelmentics. Some of the species that grow in the Eastern part of Turkey are used externally to improve the traces of bleeding and scars among the people (Bozkurt and Bayir 2021). The ethnopharmacological survey on *Prangos* species are summarized in Table 4.6 (Ulubelen et al. 1995; Bulut et al. 2014; Güzel et al. 2015; Özdemir and Alpınar 2015).

In addition, *P. ferulacea* is used in the preparation of food, the aerial parts of the plant are added to the cheese and other dairy products before blooming (Doğan et al. 2014), and it is consumed as food and canned food from young shoots in the Eastern

Table 4.6 Ethnopharmacological survey of *Prangos* species in Turkey

Prangos species[a]	Plant part	Therapeutic effect	Utilisation method	Treatment	Ref.
P. ferulacea (L.) Lindl.	R	Aphrodisiac	Grated (+ honey)	Eaten	Bulut et al. (2014) and Özdemir and Alpınar (2015)
	Young shoots	Diabetes,	Boiled	Int.	
	L	Antihypertensive	Infusion	Int.	
	AP	Aphrodisiac	Decoction	Int.	
P. meliocarpoides Boiss.	R	Aphrodisiac	Planed (mixed with honey)	Eaten	Özdemir and Alpınar (2015)
P. pabularia Lindl.	R	Aphrodisiac	Planed (mixed with honey)	Eaten	Kaval et al. (2014)
	R	Wound	Crushed	Ext.	
	L	Dyspepsia	Decoction	Int.	
P. platychlaena Boiss.	R	Wound (animal)	Dried then crushed	Ext.	Ulubelen et al. (1995)
	R	Aphrodisiac	Planed (+ honey)	Int.	
	R	Intestinal diseases	Gum	Int.	
		Stop bleeding		Ext.	
P. uechtritzii Boiss. et Hausskn.	WP	Hemorrhoids	Boiled in vinegar	Ext.	Bulut et al. (2014)

[a]First cited species are given with author(s), *AP* aerial parts, *L* leaves, *R* roots, *WP* whole plant

Anatolia (Bozkurt and Bayir 2021; Coşkun et al. 2004; Özcan et al. 2007). *P. uechritzii* has a nutritive value as a native forage (Gülşen et al. 2004).

4.3.3 Pharmacological Properties of Prangos *Species*

The different *Prangos* species such as *Prangos meliocarpoides* var. *meliocarpoides, P. ferulacea, P. uloptera, P. heyniae, P. uechtritzii* plant parts (herb, fruit, root) extracted with different type solvents were subjected to investigation of wide range biological activities, that mostly performed *in vitro* conditions (Albayrak et al. 2021; Sevin et al. 2022). Baser et al. have recently summarized results of research into chemistry and biological activities of *Prangos* Lindl. species of Turkey (Baser et al. 2009). The following biological properties were reported: mosquitocidal (Özek et al. 2018), anticandidal (Karahisar et al. 2022), antioxidant (Ahmed et al. 2011; Cesur et al. 2017; Coruh et al. 2007; Çelikezen et al. 2019; Mavi et al. 2004), metal chelating, radical-scavenging and anti-lipid peroxidative activities (Altuntas et al. 2011), antimicrobial (Tan et al. 2017; Çelikezen et al. 2019; Durmaz et al. 2006; Sagun et al. 2006; Uzel et al. 2006), antifungal (Ozkan et al. 2014), cytotoxic (Yazici-Tutunis et al. 2021), antityrosinase (Zengin et al. 2022), antiglucosidase (Zengin et al. 2020).

Systematic review on investigation of botanic properties, traditional use and biological activity of *P. ferulacea* (L.) Lindl. Plant was reported by Bozkurt (Bozkurt and Bayir 2021). *P. ferulacea* extract demonstrated anti-leishmanial effect (Dursun et al. 2019), essential oil (from aerial parts) had insecticidal effect on *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) and egg parasitoid *Trichogramma embryophagum* Hartig (Ercan et al. 2013; Ercan 2015). A case of acute toxic hepatitis associated with *P. ferulacea* was reported (Dursun et al. 2019). *P. denticulata* Fisch. & Mey. and *P. platychlaena* Boiss. ex Tchih. subsp. *engizekensis* H.Duman & M.F.Watson fruit extracts demonstrated an inhibitory effect against of the food borne bacteria (Oke-Altuntas et al. 2012).

4.4 Diversity of Turkish *Pimpinella* Species

The genus *Pimpinella* L. is among the largest important representative genera of the Apiaceae family with about 180 species all around the world (Yeşil et al. 2016). The species belonging to this genus are mostly annual, biennial or perennial plants, which are naturally distributed in Asia, Africa, America and Europe. The Mediterranean region is known as the most important centre of diversity for this genus. *Pimpinella* species are also common in Turkey with 31 taxa, including 8 endemic out of 26 species together with 5 subspecies and 4 varieties (Yeşil et al. 2016; Karik and Demirbolat 2020; Matthews 1972; Guner et al. 2012; Yesil et al. 2018). The species recorded as endemisms for Turkey are *Pimpinella anisetum* Boiss.

et Balansa ex Boiss., *P. flabellifolia* (Boiss.) Benth. ex Drude, *P. isaurica* V.A. Matthews, *P. lazica* (Boiss.) M.Hiroe, *P. ramosa* Schischk., *P. sintenisii* H.Wolff (Deveci et al. 2018a). Among the recently discovered species are *Pimpinella enguezekensis* Yıldırım, Akalın & Yeşil that has been named as "Engüzek Anasonu" in Turkish, *P. ibradiensis* Çingilbel & Eren, H.Duman & Gökceoğlu and *P. tunceliana* Yıld. (Yeşil et al. 2016; Çinbilgel et al. 2015; Kilic and Yildirimli 2015). Endemic *P. isaurica* V.A. Matthews subsp. *sumbuliana* R.S. Göktürk is closely related to *P. isaurica* subsp. *Isaurica* (Göktürk 2008). *P. cypria* Boiss. is an endemic species of the Turkish Republic of Northern Cyprus. It is locally known as "Cyprus-rocky anise" (Muti and Özhatay 2020). The common species of this genus, *Pimpinella anisum* L., called as "anis" is widely cultivated in Europe, Africa, Asia and America, as an aromatic spice crop. It is highly valued due to its economic importance as a flavoring agent in food and perfumery industries. The seed of *P. anisum* is often used as a flavoring in liqueurs and in cooking. As a medicine it is highly valued for its carminative effect (Tabanca et al. 2007; Ulusoy et al. 2019; Tepe and Tepe 2015). Aniseed spirits are obtained by the distillation of pressed fermented saccharated raw materials, flavored with star aniseed (*Illicium verum*), fennel (*Foeniculum vulgare*), green aniseed (*Pimpinella anisum*), or some other plants (Anli and Bayram 2010).

4.4.1 *Major Chemical Constituents and Bioactive Compounds of* Pimpinella *Species*

Representatives of *Pimpinella* genus are well known for important metabolites accumulated in their seeds. Seed oils have shown various health benefits due to high concentration of bioactive lipid components like fatty acids, tocopherols, tocotrienols and sterols (Ahmed et al. 2020). These oils are also important macromolecules for industrial applications such as cosmetic and painting (Kucukboyaci et al. 2016). *Trans*-anethole and its isomer methylchavicol-isoanethol are the main volatiles of anise. *Trans*-Anethole, which forms a ratio of 78.6% and 95.2% of the aniseed volatile oils, is responsible for the aromatic properties of aniseed (Arslan et al. 2004). The essential oils were isolated mostly from the fruits (Hayta et al. 2015; Kilic 2014; Özbek et al. 2015). Chemistry of many *Pimpinella* species growing in Turkey has been comprehensively investigated by Tabanca et al. (Tabanca et al. 2003, 2004, 2005a, b, c, 2006, 2007; Baser et al. 2007b). Phenylpropanoid derivatives isolated from Turkish *Pimpinella* species are: (*E*)-pseudoisoeugenol (2-methoxy-4-(prop-1-enyl)phenol), 4-(prop-2-enyl)phenyl angelate, and 4-(3-methyloxiran-2-yl)phenyl 2-methylbutanoate. New bisabolene-type sesquiterpenoid: [1-methyl-4-(6-methylhepta-1,5-dien-2yl)-7-oxabicyclo [4.1.0]heptane ("aureane")], and a new trinorsesquiterpene: 4-(6-methylbicyclo[4.1.0]hept-2-en-7-yl)butan-2-one ("traginone") (Baser et al. 2007b; Tabanca et al. 2005a). Other type secondary metabolites found in *Pimpinella:* β-hydroxydihydrochalcone and flavonoid glycosids (Özbek et al. 2015, 2016a, b; Guvenalp et al. 2010). The list of some mono- (Nasır and Yabalak 2021), sesqui-

(Özbek et al. 2015), meroterpenes (Tabanca et al. 2005a), phenylpropanoids (Tepe et al. 2006) and flavonoid glycosides (Özbek et al. 2015, 2016a, b; Demirezer et al. 2012) determined in Turkish *Pimpinella* species is presented in Table 4.7.

Table 4.7 Secondary metabolites determined in *Pimpinella* species growing in Turkey

Pimpinella species	Compounds
Terpenes	
tunceliana	β-Caryophyllene, β-bisabolene, anethole, sabinene, limonene, germacrene D
flabellifolia	Limonene, (*E*)-anethole, α-pinene
cappadocica	Kanalpin
peregrina	*trans*-Pinocarveol, peregijerene, α-cubebene, (+)-epibicyclosesquiphellandrene, α-terpineol
enguezekensis	(*E*)-Anethole, methyl chavicol, pseudoisoeugenol 2-methylbutyrate
kotschyana	β-Caryophyllene, α-humulene, germacrene D
corymbosa	β-Farnesene, β-bisabolene, (*E*)-anethole
tragium ssp. *lithopila*	Germacradiene-6-*O*-(6'-*O*-acetyl)-β-D-glucoside, germacradiene glucoside, radicol
tragium ssp. *lithopila, kotschyana, corymbosa, peregrina*	4,6-Guaiadiene
peucedanifolia, rhodantha, isaurica	Alismol
kotschyana, corymbosa	12-Hydroxy-β-caryophyllene acetate
tragium ssp. *lithopila affinis, puberula, anisetum, koschyana, rhodantha, peucedanifolia, tragium* ssp. *pseudotragium, saxifraga, cappadocica* var. *cappadocica*	Dictamnol
kotschyana	Triterpene glycoside (saikogenin F 3-*O* (β-D-glucopyranosyl-(1 → 2)-[β-D-xylopyranosyl-(1 → 4)-β-D-glucopyranosyl-(1 → 3)]-β-D-fucopyranoside)), sterol (α-spinasterol-β-D-glucopyranoside)
Phenylpropanoids	
peucedanifolia, kotschyana, corymbosa	4-(Prop-(1*E*)-enyl)phenyl isobutyrate
isaurica	4-(Prop-2-enyl)phenyl angelate
saxifraga, aurea, peregrina, peucedanifolia	4-[(2*R*,3*R*)-3-Methyloxiranyl]phenyl (2S)-methylbutyrate
tragium ssp. *lithopila, affinis, puberula, tragium* ssp. *pseudotragium, cappadocica* var. *cappadocica*	4-[(1*S*,6*R*,7*S*)-6-Methyl-bicyclo[4.1.0]hept-2-en-7-yl] butan-2-one = traginone
corymbosa, olivieroides, kotschyana, peucedanifolia, saxifraga, peregrina, tragium ssp. *lithopila, tragium* ssp. *pseudotragium*	4-(1-Prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate = anethol 2-methylbutyrate
aurea, peregrina, tragium ssp. *lithopila, nudicaulis*	(1*R*,4*R*,6*S*)-1-Methyl-4-(6-methylhepta-1,5-dien-2-yl))-7-oxabicyclo [4.1.0] heptane = aureane
nudicaulis, flabellifolia, tragium ssp. *pseudotragium, peregrina, saxifraga*	*trans*-Isoosmorhizole

(continued)

Table 4.7 (continued)

Pimpinella species	Compounds
isaurica, aurea, tragium ssp. *pseudotragium, cappadocica var. cappadocica*	4-(Prop-(1*E*)-enyl)phenyl tiglate = anol tiglate
aurea	4-[(2*R*,3*R*)-3-Methyloxiranyl]phenyl tiglate
isaurica, anisetum	4-Methoxy-2-(prop-(1*E*)-enyl)phenyl angelate
isaurica, anisetum, tragium ssp. *polyclada, tragium* ssp. *pseudotragium, peregrina, anisetum, affinis, aurea, cappadocica* var. *cappadocica, olivieroides*	4-Methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate
corymbosa, anisetum, aurea, koschyana, olivieroides, peucedanifolia, saxifraga, cappadocica var. *cappadocica, tragium* ssp. *pseudotragium, tragium* ssp. *lithopila, affinis, puberula, rhodantha*	4-Methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl (2*S*)-methylbutyrate
peregrina, peucedanifolia, kotchyana	4-Methoxy-2-[(2*R*,3*S*)-3-methyloxiranyl]phenyl isobutyrate
rhodantha, tragium ssp. *polyclada*	4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate
anisum, aurea, saxifraga, peregrina, cappadocica var. *cappadocica, olivieroides, kotschyana, tragium* ssp. *lithopila, tragium* ssp. *polyclada, tragium* ssp. *pseudotragium*	4-Methoxy-2-(prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate
isaurica, tragium ssp. *polyclada, tragium* ssp. *pseudotragium, rhodantha, affinis, anisetum, cappadocica* var. *cappadocica, peregrina*	4-Methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl angelate
tragium ssp. *lithopila* *anisetum*	Thellungianin E (*E*)-Anethole, methyl chavicol
Flavonoid derivatives	
kotschyana	Quercetin 3-*O*-α-L-(3″-*trans*-coumaroil) rhamnopyranoside, quercetin 3-*O*-α-L-(2″,3″--di-*trans*-coumaroil) rhamnopyranoside)
cappadocica	Erzurumin, ilicanin
tragium var. *lithopila*	Rhamnetin-3-*O*-(2′′-*O*-β-D-glucopyranosyl)-β-D-galactopyranoside
rhodantha	β-Hydroxydihydrochalcone glycoside ziganin, isorhamnetin-3-*O*-α-L-(200,300-di-*O*-*trans*-coumaroyl)-rhamnopyranoside), β-hydroxydihydrochalcone glycoside, hydroxybenzoic acid derivative
Fatty acids, tocopherols	
saxifrage	Palmitic, palmitoleic, stearic, vaccenic, linoleic, linolenic, arachidic, gadoleic, behenic acids, γ-tocopherol, δ-tocopherol, γ-tocotrienol
affinis, aromatica	Fatty acids: 14:0, 16:0, 16:1-ω9, 17:0, 18:0, 18:1- ω6, 18:1-ω9, 18:1- ω11, 18:2- ω 912, 18: 3- ω9,12,15, 20:0, 20:1-ω11, 22:0, 22:1-ω9, 24:0

4.4.2 Traditional Use and Common Knowledge of Pimpinella *Species*

Beside the other species, *P. anisum* has long been used as a folk remedy for the treatment of cough, bronchitis, asthma, colic, cancer, cholera, insomnia, and nausea by the local people (Arslan et al. 2004). Aniseed's long popularity throughout so many lands stems from its many uses: flavourant, culinary, household, cosmetic and medicinal. While the entire plant is fragrant, it is the fruit of anise, commercially called aniseed, that has been highly valued since antiquity. *P. anisum* is also used as flavor enhancer in food, pharmaceutical and beverage industries. Several spirit drinks prepared from anis seed named as raki in Turkey (Anli and Bayram 2010). *Pimpinella* species have also been used as animal feed to increase milk secretion (Tabanca et al. 2007; Baser and Franz 2010). Aromatic plants such as *P. isaurica, P. aurea,* and *P. corymbosa* are used as animal feed to increase milk secretion in Turkey (Tabanca et al. 2005a). *P. saxifraga* is known in Turkey as "Teke maydonozu" (goat parsley) or "tas maydonozu" (rock parsley), and its roots are used as a demulcent, stomachic, expectorant, and tonic (Tabanca et al. 2006). Some *Pimpinella* species are included in the composition of herbal teas used for galactagogue effects (Ulusoy et al. 2019).

4.4.3 Pharmacological Properties of Pimpinella *Species*

Pimpinella species have been proven to have various biological activities such as carminative, antioxidant, antiseptic, antifungal, antibacterial, antidepressant, antispasmodic, expectorant, diuretic, diaphoretic, stimulant, insecticidal and stomachic (Tabanca et al. 2004, 2007; Ulusoy et al. 2019; Tepe and Tepe 2015; Baser et al. 2007b; Ciftci et al. 2005; Süntar et al. 2014). Biological activities of *Pimpinella* species are mainly attributed to phenylpropanoid derivatives, and (*E*)-pseudoisoeugenol has been found only in the *Pimpinella* genus (Tabanca et al. 2005a). Representatives of Turkish *Pimpinella* species have been the subject of various biological activity tests. The extracts obtained with solvents of different polarities demonstrated antimicrobial (Ateş and Turgay 2003), antioxidant (Gülçin et al. 2003), anticholinesterase and antityrosinase (Menichini et al. 2009) properties. The essential oils were reported for estrogenic (Tabanca et al. 2004), anti-inflammatory (Tabanca et al. 2007), repellent (Erler et al. 2006), antibacterial (Basmacıoğlu-Malayoğlu et al. 2011), antioxidant (Karik and Demirbolat 2020; Tepe et al. 2006) effects.

4.5 Diversity of Turkish *Angelica* Species

The genus *Angelica* L. is an important representative of the Apiaceae family and comprised by about 115 species around the world. According to last records, *Angelica* is one of the largest Apiaceae genera in Asia with 87 species recorded (Pimenov and Leonov 2004). Taxonomically, *Angelica* is one of the most complex genera in Umbelliferae (Pimenov and Leonov 1993). *Angelica* species have many synonymies which can be divided into several homotypic groups. In the Flora of Turkey, two species were recorded (Chamberlain 1972). *Angelica archangelica* L. was new record for the Turkish flora (Daşkın and Kaynak 2012). Recently, new species *Angelica turcica* Hamzaoğlu & Koç has been described. It is a highly distinct species that is immediately characterized by a gigantic habit, with large leaves and inflated sheaths. In fruit shape it resembles *Angelica purpurascens* (Avé-Lall.) Gilli., which is known in Caucasia, Turkey and Iran (Hamzaoğlu and Koç 2016).

4.5.1 Major Chemical Constituents and Bioactive Compounds of Angelica *Species*

Chemical profile of Turkish *Angelica* species was investigated in terms of volatile and non-volatile compounds. The most significant secondary metabolites detected in Turkish *Angelica* species were mono- and sesquiterpenoid compounds. The essential oils of the fruits of *A. sylvestris* var. *sylvestris* obtained with hydrodistillation, microdistillation and micro-steam distillation - solid-phase microextraction techniques contained α-pinene (25.6%, 36.2% and 9.2%, respectively), β-phellandrene (9.1%, 9.9% and 3.2%), bornyl acetate (7.3%, 4.3% and 6.9%), limonene (5.6%, 4.3% and 2.1%), myrcene (4.4%, 4.0% and 1.3%), camphene (3.9%, 4.7% and 1.2%), α-chamigrene (3.4%, 4.4% and 9.1%) and β-sesquiphellandrene (2.5%, 3.8% and 8.7%). *p*-Cresol (6.5%), epi-α-bisabolol (5.6%), (*Z*)-β-farnesene (5.5%), naphthalene (4.4%), daucene (3.1%), amorpha-4,11diene (3.1%) and γ-muurolene (2.5%) were also among the main constituents of the oil isolated by micro-steam distillation - solid-phase microextraction (Özek et al. 2008). In aerial parts of *A. sylvestris* var. *sylvestris* angelicin (0.31 ± 0.015 mg/100 g) and imperatorin (2.36 ± 0.033 mg/100 g) were reported as well as high content of flavonoids (Orhan et al. 2016). *A. purpurascens* (Avé-Lall.) Gilli. fruit essential oil contained the highest level of monoterpene β-phellandrene (47.6%) and limonene (8.2%). The canals, existing in the flowers were qualified by a presence of sesquiterpenes β-caryophyllene (12.1%), germacrene D (4.5%) and ether octyl acetate (11.9%). The fruits of *A. purpurascens* contained non-volatile constituents, like stigmasterol, β-sitosterol, and coumarins, bergapten and oxypeucedanin (Karakaya et al. 2020).

4.5.2 Traditional Use and Common Knowledge of Angelica *Species*

Angelica species are known under local name "mandak", their leaves are used as mush for treatment of epidermal wounds. The mixture included leaves of *Allium ampeloprasssum*, *Angelica sylvestris* and *Rumex acetosella* was used by oral as anthelmintic remedy (Sener et al. 2022). The plants are collected before flowering, pickled in salt water and then added into the cheese to prepare "otlu peynir" (herbal cheese) (Özçelik 1994). Traditional angelica jam is produced from the stems of *A. sylvestris*, which is collected from the mountain villages of Bursa (Koç Ömeroğlu and Yolci 2019).

4.5.3 Pharmacological Properties of of Angelica *Species*

The antioxidant capacity of *A. archangelica* branch and leaf extracts, which were determined *in vitro* and had high total flavonoid content, were determined by seven different analytical methods (Topal et al. 2021). The extract of *A. sylvestris* var. *sylvestris* aerial part had significant butyrylcholinesterase inhibition effect (Orhan et al. 2016). The compounds from fruits of *A. purpurascens* like stigmasterol, β-sitosterol, bergapten, and oxypeucedanin have shown high inhibitory potential towards to cholinesterase and carbonic anhydrase as well as lipid peroxidation (Karakaya et al. 2020).

4.6 Diversity of Turkish *Ferulago* Species

Turkey is known to the centre of biodiversity in the middle-sized Apiaceae genus *Ferulago* W.Koch, and is most likely the main area of its origin and primary diversification (Pimenov and Leonov 2004; Pesmen 1972). *Ferulago* W. Koch genus is represented by about 50 taxa around the world and 35 of them grow naturally which 19 are endemic in Turkey (Akkol et al. 2022; Süzgeç-Selçuk et al. 2020; Sanli et al. 2020; Mohammed et al. 2020; Karakaya et al. 2019d, e). While three sections are seen in Turkey, the other two members of the sections grow naturally in Balkanes. Several recently described species have been added into the Flora of Turkey: *F. idaea* Özhatay & Akalın, *F. trojana* Akalın & Pimenov, *F. glareosa* Kandemir & Hedge, and *F. cypria* H. Wolff is a new record (Uruşak and Kizilarslan 2013). In general, the taxonomy of the genus is very difficult, and it is believed closely related to *Ferula* L. and *Peucedanum* L. (Özhatay and Akalın 2000).

4.6.1 *Major Chemical Constituents and Bioactive Compounds of* Ferulago *Species*

Ferulago species are well known as rich sources of volatiles/essential oils, as well as lipids deposited in the fruits/seeds. The essential oils of this genus contain mono-, sesquiterpenes, and some fatty acids. Some representatives of the genus contain also secondary metabolites of phenolic structure, namely coumarins, phenylpropanoids, flavonoids etc. Anthocyanins, steroids, and tannins are other secondary metabolites that have been confirmed to be present in this genus. Results of the literature survey on the volatile constituents of Turkish *Ferulago* species is summarized in Table 4.8.

Non-volatile secondary metabolites detected in *Ferulago* species are generally coumarins, phenolic acids and flavonoid glycosides. Table 4.9 shows the list of major constituents isolated from the different plant parts of *Ferulago* plants.

4.6.2 *Traditional Use and Common Knowledge of* Ferulago *Species*

Ferulago species have been used in folk medicine for treatment of skin diseases, bronchitis, depression, surd mutism, to increase body strength, as immunostimulant, aphrodisiac and sedative. Some parts of *Ferulago* species are available in the market to increase sex drive as "çakşır otu" in Turkey. These products are being sold in the market as food supplements, and are used for disorders like fatigue, lack of sex drive, and also to increase the quality and quantity of sperm (Akkol et al. 2022; Özhatay and Akalın 2000; Baytop 1999). These species have been used since antiquity for the treatment of intestinal worms, hemorrhoids and as a sedative, tonics, digestive and antiparasitic agents. The species are commonly known in traditional medicine as carminative, digestive, sedative, tonic, aphrodisiac as well as in the treatment of intestinal worms and hemorrhoids (Süzgeç-Selçuk et al. 2020).

4.6.3 *Pharmacological Properties of* Ferulago *Species*

The genus is used in the treatment of hemorrhoids, intestinal worms, ulcers, snake bites, digestive problems and headaches. It is also known that the genus has sedative and stimulant effects. Because of these wide uses, studies on the biological activities of the genus have accelerated in recent years and the results obtained from these studies have revealed that *Ferulago* has antidiabetic (Karakaya et al. 2018d, 2019c), anticholinergic (Kızıltaş et al. 2021a), antioxidant (Mohammed et al. 2020; Karakaya et al. 2018c, 2019b; Celik et al. 2013), anticholinesterase (Karakaya et al. 2018c, 2019b), antimicrobial and antifungal (Süzgeç-Selçuk et al. 2020; Karakaya et al. 2018c, 2019a, d, e; Kurkcuoglu et al. 2010; Demirci et al. 2000;

Table 4.8 Volatile constituents reported for *Ferulago* species growing in Turkey

Ferulago Species	Plant part	Compound, %	Ref.
F. angulate subsp. *carduchorum*	AP	α-Pinene (24.0), β-pinene (23.0), β-phellandrene (20.5)	Bagci et al. (2016)
F. antiochia	R	Myristicine, germacrene esters, alloaromadendrane ester	Miski et al. (1990)
F. asparagifolia	Fr	2,3,6-Trimethylbenzaldehyde (38.9–42.0), myrcene (18.2), α-pinene (11.4)	Karakaya et al. (2019d), Baser et al. (2001), and Baser et al. (2002)
F. aucheri	Fr	α-Pinene (35.9)	Baser et al. (2002)
F. blancheana	AP	Bornyl acetate (11.7), β-caryophyllene (10.2)	Karakaya et al. (2016)
	Fl	α-Pinene (14.0), sabinene (23.2), myrcene (17.5)	Karakaya et al. (2016)
	R	Bornyl acetate (11.5), β-caryophyllene (10.5), (*E*)-2-decenal (20.3), caryophyllene oxide (17.8), spathulenol (11.2), α-cadinol (12.0)	Karakaya et al. (2016)
F. bracteata	AP	7-Methoxy-6-(3-methyl-2-butenyl)-coumarin (86.7)	Karakaya et al. (2019d)
	Fl	α-Phellandrene (22.8), bornyl acetate (12.7), α-pinene (12.1), δ-3-carene (10.1)	Karakaya et al. (2019d)
	R	Hexadecanoic acid (40.4), (*E*)-2-decenal (13.9)	Karakaya et al. (2019d)
F. campestris	Fr	Myrcene (33.4–39.7), α-pinene (22.7–23.0), γ-terpinene (8.1–10.9)	Karakaya et al. (2019d)
	R	α-Pinene (58.3–75.0)	Karakaya et al. (2019d)
F. cassia	Fr	α-Pinene (7.6–12.4), sabinene (1.1–10.9), myrcene (3.4–10.4), limonene (4.7–27.4), chrysanthenyl acetate (13.5–24.5)	Sanli et al. (2020)
F. confusa	Fr	2,5-Dimethoxy-*p*-cymene (63.4), *p*-cymene (24.0)	Baser et al. (2002)
	Fr	*cis*-Chrysanthenyl acetate (37.7), α-pinene (36.7)	Kurkcuoglu et al. (2010)
F. galbanifera	Fr	α-Pinene (31.8), *trans*-chrysanthenyl acetate (17.2), sabinene (15.8), *p*-cymene (11.9), limonene (6.6–10.3)	Baser et al. (2002) and Demirci et al. (2000)
F. humulis	Fr	(*Z*)-*β*-Ocimene (31.9–32.4), limonene (17.3–31.4), α-pinene (12.1), *trans*-chrysanthenyl acetate (12.1)	Baser et al. (2002) and Demirci et al. (2000)
F. idaea	Fr	*p*-Cymene (18.4), α-pinene (16.1), 2,3,6-trimethylbenzaldehyde (14.1), carvacrol methyl ether (13.4), 2,5-dimethoxy-*p*-cymene (13.2)	Baser et al. (2002)

(continued)

Table 4.8 (continued)

Ferulago Species	Plant part	Compound, %	Ref.
F. isaurica	Fr	α-Pinene (31.5), limonene (24.2), myrcene (16.9)	Erdurak et al. (2006)
	R	Terpinolene (42.1), myrcene (27.0), γ-terpinene (11.7)	Erdurak et al. (2006)
F. longistylis	AP	*cis*-Chrysanthenyl acetate (24.2), 2,3,6-trimethyl benzaldehyde (29.8)	Karakaya et al. (2019d)
	Fr	2,3,6-Trimethyl benzaldehyde (29.0), α-pinene (17.0), (*Z*)--β-ocimene (16.0)	Özkan et al. (2008)
F. macrosciadia	Fr	Carvacrol methyl ether (78.1), *p*-cymene (19.4)	Baser et al. (2002)
F. mughlae	Fr	α-Pinene (25.4), cubenol (12.7)	Baser et al. (2002)
F. pachyloba	AP	Sabinene (16.0), (*Z*)-β-ocimene (15.1)	Karakaya et al. (2019d)
	Fl	Sabinene (25.8), (*Z*)-β-ocimene (27.5)	Karakaya et al. (2019d)
	Fr	Bicyclogermacrene (11.1)	Karakaya et al. (2019d)
	R	Hexadecanoic acid (15.4), (*E*)-2-decenal (14.3)	Karakaya et al. (2019d)
F. pauciradiata	Fr	*trans*-Chrysanthenyl acetate (24.9), α-pinene (23.7), 2,3,6-trimethyl benzaldehyde (20.7)	Karakaya et al. (2018c)
F. platycarpa	AP	*cis*-Chrysanthenyl acetate (24.2), 2,3,6-trimethyl benzaldehyde (29.8)	Karakaya et al. (2019d) and Kilic et al. (2010)
F. sandrasica	Fr	α-Pinene (15.6–40.8), limonene (28.9), terpinolene (13.9)	Baser et al. (2002) and Karakaya et al. (2019a)
	L	Ocimene (30.5), δ-3-carene (27.4), α-pinene (17.8)	Celik et al. (2013)
F. setifolia	AP	2,4,5-Trimethyl benzaldehyde (77.8)	Polat et al. (2010)
F. silaifolia	Fr	*trans*-Chrysanthenyl acetate (83.5)	Baser et al. (2002)
F. sylvatica	Fr	*p*-Cymene (45.8), 2,5-dimethoxy-*p*-cymene (40.2)	Baser et al. (2002)
F. syriaca	Fr	Myrcene (15.3), 4,6-guaiadiene (10.7)	Erdurak et al. (2006)
	R	Terpinolene (12.5), bornyl acetate (69.4)	Erdurak et al. (2006)
F. thirkeana	Fr	Ferulagone (63.5), germacrene D (14.0),	Başer et al. (2002)
F. trachycarpa	Fr	(*Z*)-β-Ocimene (30.7–34.1), spathulenol (32.8), myrcene (27.7%), bicyclogermacrene (23.0), *p*-cymene (21.6), germacrene D (10.4)	Karakaya et al. (2019d), Baser et al. (2002), Demirci et al. (2000), and Baser et al. (1998)
	AP	(*Z*)-β-Ocimene (13.8), bornyl acetate (10.9), spathulenol (25.0)	Karakaya et al. (2019d)
	R	(*E*)-2-Decenal (11.9)	Karakaya et al. (2019d)

AP aerial parts, *Fl* flower, *Fr* fruits, *L* leaves, *R* roots

Table 4.9 Non-volatile constituents reported for *Ferulago* species growing in Turkey

Ferulago species	Plant part	Compound	Ref.
F. antochia	R	8-α-Benzoyloxyspathulenol; 6-acetyl-8-benzoyltovarol; 6-acetyl-8-benzoylshiromodiol; 6-acetyl-8-benzoylantakyatriol; 6-acetyl-8-*t*-cinnamylantakyatriol	Miski et al. (1990)
F. blancheana	AP R	Osthole; imperatorin; bergapten; prantschimgin; grandivitinol; xanthotoxin; felamidin; marmesin; umbelliferone; stigmasterol; β-sitosterol; peucedanol-2′-benzoate	Karakaya et al. (2017, 2018d, 2019d)
F. bracteata	AP	Osthole; imperatorin; bergapten; prantschimgin; peucedanol-2′-benzoate; grandivitinol; suberosin; xanthotoxin; felamidin; umbelliferone; stigmasterol; β-sitosterol	Karakaya et al. (2019e)
	R	Peucedanol-2′-benzoate; osthole; imperatorin; bergapten; prantschimgin; grandivitinol; suberosin; xanthotoxin; felamidin; umbelliferone; stigmasterol; β-sitosterol	Karakaya et al. (2017, 2018a)
F. cassia	AP, Fr, Fl, R	Peucedanol; suberosin; grandivitinol; umbelliferone	Karakaya et al. (2019b)
F. humilis	AP Rz	Isoimperatorin; bergapten; oxypeucedanin; marmesin senecioate; oxypeucedanin hydrate; apigenin; rutin; isorhamnetin 3-galactoside; quercetin 3-*O*-glucoside; luteolin; rhamnetin; 1-acetylhydroquinone; 4-galactoside; quinol monoacetate	Süzgeç-Selçuk et al. (2020)
F. isaurica	AP R	Isoimperatorin; bergapten; prantschimgin; xanthotoxin	Karakaya et al. (2018b)
F. pachyloba	AP R	Osthole; imperatorin; bergapten; prantschimgin; grandivitinol; xanthotoxin; felamidin; umbelliferone; stigmasterol; β-sitosterol; peucedanol-2′-benzoate	Karakaya et al. (2017, 2018d, 2019e)
F. platycarpa	n.a.	Gallic acid; chlorogenic acid; epicatechin; cinnamic acid; sringic acid; catechin; quercetin	Mohammed et al. (2020)
	R	Prantschimgin	Satir et al. (2009)
F. stellata	n.a.	Ascorbic acid; chlorogenic acid; verbascoside; orientin; caffeic acid; rutin; rosmarinic acid; hyperoside; quercitrin; quercetin; salicylic acid; chrysin; acacetin	Kızıltaş et al. (2021a)
F. syriaca	AP	Isoimperatorin; bergapten; prantschimgin; xanthotoxin	Karakaya et al. (2018b)
F. trachycarpa	AP	Osthole; imperatorin; bergapten; prantschimgin; grandivitinol; suberosin; xanthotoxin; felamidin; umbelliferone; ulepterol; stigmasterol; β-sitosterol	Karakaya et al. (2017, 2018d, 2019e)
	Rz	Crenulatin; suberosin; marmesin seneociate (prantschimgin); ulopterol	Karakaya et al. (2017) and Dikpınar et al. (2018)
	S	9-Octadecenoic (68–74%); 9,12-octadecadienoic (23–18%)	Erdemoglu et al. (2008)

AP aerial parts, *Fl* flower, *Fr* fruits, *L* leaves, *R* roots, *Rz* rhizomes, *S* seeds

Celik et al. 2013), anticancer (Filiz et al. 2016), anxiolytic and antidepressant (Karakaya et al. 2016) and antiulcerogenic (Gürbüz et al. 2004) effects. The essential oils and extracts as well as pure compounds isolated from *Ferulago* species have been tested for wide range of pharmacological effects. *F. bracteate* root methanolic extract demonstrated positive effect in erectile dysfunction and may be an herbal alternative to synthetic drugs (Karakaya et al. 2019c). Aqueous extracts of the aerial parts and roots *of F. isaurica* and *F. syriaca* showed significant gastroprotective activity *in vivo* conditions (Gürbüz et al. 2004).

4.7 Conclusions

In this chapter, the results of scientific research on plants of the Apiaceae family growing in Turkey are compiled. The species of this family are generally widely used as both food and folk medicine. Although there are many representative species of the Apiaceae family in Turkey, only the genera *Ferula, Prangos, Pimpinella, Angelica* and *Ferulago* are summarized in this review. The taxonomic data given for the Apiaceae family are up to date. In view of the ongoing taxonomic studies, the statuses of some genera can be continuously under revision.

For each genus mentioned above, its chemical diversity, major chemical constituents (volatile and non-volatile) and bioactive compounds were summarized. The scope of study was extended to include traditional uses of these genera, similarly to their *in-vivo* and *in-vitro* pharmacological studies.

The aerial parts of *Ferula* species, particularly fruits, were found to contain essential oils rich in monoterpene hydrocarbons, while the underground plant parts contained sesquiterpenes. In addition, fixed oils were found to occur together with volatiles. As characteristic non-volatile substance groups of the genus, phenylpropanoids, phenolic acids and flavonoids were found in the aboveground plant parts. As a contrast, underground parts are rich primarily in daucane-type sesquiterpenes.

The fruits and the aerial parts of the *Prangos* species are rich in monoterpenes and sesquiterpenes, as well as in acetylenic derivatives. The non-volatile compounds of the genus are mainly coumarins and fixed oils.

In several *Pimpinella* species, while mono- and sesquiterpenes were extensively found, also triterpene compounds have been detected. Representatives of the genus contain phenylpropanoid, flavonoid derivatives, fatty acids and tocopherols. Besides phenylpropanoid derivatives, (*E*)-pseudoeugenol has been found only in the *Pimpinella* genus.

The most significant secondary metabolites isolated from Turkish *Angelica* species were mono- and sesquiterpenoid compounds. The fruits contained non-volatile constituents, like stigmasterol, β-sitosterol, and coumarins, bergapten and oxypeucedanin.

The fruits of *Ferulago* species have been found to be rich in oxygenated and monoterpene hydrocarbons. Some of the species contain benzoyl derivatives (benzaldehyde) in their aerial parts, extensively. Coumarins and phenolic acid derivatives have been identified as non-volatile substance groups of the genus.

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Chapter 5
The Genus *Salvia* in Turkey: Morphology, Ecology, Phytogeograpy, Endemism and Threat Categories

Ferhat Celep and Musa Doğan

Abstract *Salvia* is one of the largest Angiosperm genera with about 1000 species. *Salvia* is also a well-known genus due to its medicinal importance and lever like stamens. On the basis of revisional studies and latest scientific publications, there are 115 *Salvia* (sage) taxa growing in Turkey, 63 taxa of which are endemic (54.7%). Molecular phylogenetic studies have revealed that the Turkish species are represented by seven clades: *Zhumeria*, *Salvia*, *Sclarea*, *Glutinaria, Heterosphace, Dorystaechas* and *Rosmarinus*. The distribution of species according to phytogeographical regions is as follows: 57 taxa Irano-turanian element, 31 taxa Mediterranean element, 6 taxa Euro-Siberian element and 21 taxa Multiregional element. The distribution of the threatened species according to national level is as follows: 2 taxa DD (Data Deficient), 17 taxa CR (Critically Endangered), 17 taxa EN (Endangered), 17 taxa VU (Vulnarable) and 15 taxa LC (Least Concern). The species in Turkey grow from sea level to up to *ca*. 3000 m, in a very wide range of different habitats. Distribution of threatened *Salvia* species in Turkey and the degree of their endangerement are summarized according to IUCN categories. This chapter is expected to call attention to the need to further protect the already endangered species of the important genus *Salvia*.

Keywords Lamiaceae · Taxonomy · *Salvia* · Turkey

5.1 Introduction

Salvia L. is a plant genus that includes many species commonly known as sage. *Salvia* is one of the most species rich genera of flowering plants, with about 1000 species currently accepted (Walker and Sytsma 2007; Will and Claßen-Bockhoff 2017; Drew et al. 2017; Kriebel et al. 2019, 2020). *Salvia* has major centers of

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diversity in the Mediterranean region, Southwest Asia, Mexico and Central/South America, and East Asia (Harley et al. 2004; Drew et al. 2017; Will and Claßen-Bockhoff 2017; Kriebel et al. 2019). Within the Mediterranean region and Southwest Asia, Turkey has more species of *Salvia* than any other countries. Turkey has the second highest number of *Salvia* species in the world (Mexico has the most) (Celep et al. 2015; Celep and Dirmenci 2017). It is likely *Salvia* is so diverse in Turkey due to the country's climatic, geologic, topographic and pollinator diversity (Celep et al. 2020a).

Since the publication of the Flora of Turkey and East Aegean Islands Vol. 7 (Hedge 1982), a number of new taxa, new records and taxonomic changes have been published, particularly in the last two decades (Huber-Morath 1982; Vural and Adıgüzel 1996; Dönmez 2001; Hamzaoğlu et al. 2005; Behçet and Avlamaz 2009; Celep et al. 2009a, b, 2011a, b, 2015, 2016, 2020b; Eminagaoglu et al. 2022; Fırat 2020; Ilcim et al. 2009, 2023; Kahraman et al. 2009, 2010, 2011; Celep and Doğan 2010; Bagherpour et al. 2011). Based upon molecular phylogenetic results and the classification of Drew et al. (2017), Kriebel et al. (2019, 2020) and our morphological treatments, Turkish species are represented by seven clades: *Zhumeria*, *Salvia*, *Sclarea*, *Glutinaria, Heterosphace, Dorystaechas* and *Rosmarinus* (Table 5.1).

In traditional medicine, *Salvia* is one of the oldest medicinal plants used by humans, and it is considered as a universal panacea (Uritu et al. 2018). In the folk medicine of Anatolia, *Salvia* (mostly *S. fruticosa* Mill., *S. tomentosa* L., *S. multicaulis* Vahl.) was used to treat several diseases such as asthma, bronchitis, colds– flu, tonsilitis, stomach disorders, carminative and diabetes (Everest and Ozturk 2005; Senol et al. 2010; Polat et al. 2017). In addition, biological activity studies conducted on *Salvia* taxa have revealed that several taxa have antiinflammatory, antibacterial, and antiviral effects, in parallel with the traditional uses of the genus (Akkol et al. 2008; Karataş and Ertekin 2010; Erdogan et al. 2011; Coisin et al. 2012; Selvi et al. 2022; Firuzi et al. 2013).

One of the most well-known species of sages reputed for its medicinal properties is *Salvia officinalis*, or common sage. It has been traditionally used to treat a variety of ailments, including digestive issues, sore throat, and menstrual problems. It contains compounds such as rosmarinic acid, which has anti-inflammatory and antioxidant properties, and thujone, which can have psychoactive effects in high doses. Other species of sage, such as *Salvia miltiorrhiza* (known as Danshen in Chinese medicine) and *Salvia hispanica* (known as chia), have also been used in traditional medicine for their various health benefits. *Salvia miltiorrhiza* has been shown to have cardiovascular and liver-protective effects, while *S. hispanica* is a rich source of omega-3 fatty acids and fiber (Wang 2010). *Salvia divinorum* has psychoactive properties and is used for spiritual and medicinal purposes in some cultures (Hamidpour et al. 2014).

In *Salvia,* the pollination process is mostly mediated by a staminal lever mechanism in which each connective of the two anthers is elongated and together form two lever arms that are movable around the filament tips. The upper connective arm typically bears one fertile theca with two pollen-sacs usually hidden below the upper lip of corolla. The lower connective arm is placed in the middle of the flower entrance, thus restricting access to nectar. A pollinator searching for nectar pushes

Table 5.1 Distribution of threatened *Salvia* species and degree of their endangerement according to IUCN 2014 categories, in Turkey

No	Taxon name	Phtogeography	Endemism	National Threat Category (IUCN 2014)	Clade (Kriebel et al. 2019)
1	*S. aristata*	Ir.Tur.	–	CR	Zhumeria
2	*S. divaricata* subsp. divaricata	Ir.Tur.	+	VU	Salvia
3	*S. divaricata* subsp. artvinensis	Ir.Tur.	+	CR	Salvia
4	*S. aucheri* subsp. aucheri	Medit.	+	VU	Salvia
5	*S. aucheri* subsp. canescens	Medit.	+	VU	Salvia
6	*S. fruticosa*	Medit.	–	–	Salvia
7	*S. tomentosa*	Multiregional	–	–	Salvia
8	*S. aramiensis*	Medit.	–	–	Salvia
9	*S. kurdica*	Ir.Tur.	–	VU	Salvia
10	*S. macrochlamys*	Ir.Tur.	–	–	Salvia
11	*S. tigrina*	Medit.	+	CR	Salvia
12	*S. recognita*	Ir.Tur.	+	LC	Salvia
13	*S. pilifera*	Medit.	+	VU	Salvia
14	*S. pinnata*	Medit.	–	–	Salvia
15	*S. bracteata*	Ir.Tur.	–	–	Salvia
16	*S. reeseana*	Ir.Tur.	+	DD	Salvia
17	*S. trichoclada*	Ir.Tur.	–	–	Salvia
18	*S. anatolica*	Ir.Tur.	+	CR	Salvia
19	*S. cedronella*	Medit.	+	EN	Salvia
20	*S. adenophylla*	Medit.	+	EN	Salvia
21	*S. potentillifolia*	Medit.	+	EN	Salvia
22	*S. nydeggeri*	Medit.	+	EN	Salvia
23	*S. rosifolia*	Ir.Tur.	+	VU	Salvia
24	*S. huberi*	Ir.Tur.	+	VU	Salvia
25	*S. marashica*	Medit.	+	CR	Salvia
26	*S. wiedemannii*	Ir.Tur.	+	LC	Salvia
27	*S. freyniana*	Ir.Tur.	+	CR	Salvia
28	*S. pisidica*	Medit.	+	LC	Salvia
29	*S. albimaculata*	Medit.	+	EN	Salvia
30	*S. tchihatcheffii*	Ir.Tur.	+	EN	Salvia
31	*S. heldreichiana*	Medit.	+	LC	Salvia
32	*S. aucheri subsp. canescens* × *S. heldreichiana*	Medit.	+	CR	Salvia
33	*S. caespitosa*	Ir.Tur.	+	LC	Salvia
34	*S. pachystachys*	Ir.Tur.	–	–	Salvia
35	*S. hedgeana*	Ir.Tur.	+	CR	Salvia

(continued)

Table 5.1 (continued)

No	Taxon name	Phtogeography	Endemism	National Threat Category (IUCN 2014)	Clade (Kriebel et al. 2019)
36	*S. suffruticosa*	Ir.Tur.	–	–	Salvia
37	*S. suffruticosa x S. bracteata*	Ir.Tur.	–	–	Salvia
38	*S. ballsiana*	Ir.Tur.	+	CR	Salvia
39	*S. quezelii*	Medit.	+	CR	Salvia
40	*S. haussknechtii*	Medit.	+	DD	Salvia
41	*S. cadmica var. cadmica*	Ir.Tur.	+	LC	Salvia
42	*S. cadmica var. bozkirensis*	Ir.Tur.	+	LC	Salvia
43	*S. smyrnaea*	Medit.	+	EN	Salvia
44	*S. blepharochlaena*	Ir.Tur.	+	LC	Salvia
45	*S. pomifera*	Medit.	–	–	Salvia
46	*S. hydrangea*	Ir.Tur.	–	–	Salvia
47	*S. euphratica var. euphratica*	Ir.Tur.	+	LC	Salvia
48	*S. euphratica var. leiocalycina*	Ir.Tur.	+	LC	Salvia
49	*S. cerino-pruinosa*	Ir.Tur.	+	EN	Salvia
50	*S. pseudeuphratica*	Ir.Tur.	+	CR	Salvia
51	*S. kronenburgii*	Ir.Tur.	+	EN	Salvia
52	*S. sericeo-tomentosa var. sericeo-tomentosa*	Medit.	+	VU	Salvia
53	*S. sericeo-tomentosa var. hatayica*	Medit.	+	VU	Salvia
54	*S. multicaulis*	Ir.Tur.	–	–	Salvia
55	*S. absconditiflora*	Ir.Tur.	+	LC	Salvia
56	*S. aytachii*	Ir.Tur.	+	EN	Sclarea
57	*S. viridis*	Multiregional	–	–	Sclarea
58	*S. syriaca*	Multiregional	–	–	Sclarea
59	*S. hypargeia*	Multiregional	+	LC	Sclarea
60	*S. montbrettii*	Ir.Tur.	–	–	Sclarea
61	*S. spinosa*	Ir.Tur.	–	–	Sclarea
62	*S. macrosiphon*	Ir.Tur.	–	–	Sclarea
63	*S. reuterana*	Ir.Tur.	–	–	Sclarea
64	*S. palaestina*	Ir.Tur.	–	–	Sclarea
65	*S. eriophora*	Ir.Tur.	+	CR	Sclarea
66	*S. brachyantha subsp. brachyantha*	Ir.Tur.	–	–	Sclarea
67	*S. brachyantha subsp. tankutiana*	Ir.Tur.	+	EN	Sclarea

(continued)

Table 5.1 (continued)

No	Taxon name	Phtogeography	Endemism	National Threat Category (IUCN 2014)	Clade (Kriebel et al. 2019)
68	*S. sclarea*	Multiregional	–	–	Sclarea
69	*S. chrysophylla*	Medit.	+	EN	Sclarea
70	*S. aethiopis*	Multiregional	–	–	Sclarea
71	*S. ceratophylla*	Multiregional	–	–	Sclarea
72	*S. chionantha*	Medit.	+	EN	Sclarea
73	*S. atropatana*	Ir.Tur.	–	–	Sclarea
74	*S. longipedicellata*	Ir.Tur.	+	VU	Sclarea
75	*S. argentea*	Multiregional	–	–	Sclarea
76	*S. microstegia*	Multiregional	–	–	Sclarea
77	*S. xanthocheila*	Ir.Tur.	–	–	Sclarea
78	*S. frigida*	Multiregional	–	–	Sclarea
79	*S. yosgadensis*	Ir.Tur.	+	VU	Sclarea
80	*S. ekimiana*	Ir.Tur.	+	EN	Sclarea
81	*S. modesta*	Ir.Tur.	+	EN	Sclarea
82	*S. tobeyi*	Eu-sib.	+	EN	Sclarea
83	*S. poculata*	Ir.Tur.	–	–	Sclarea
84	*S. odontochlamys*	Ir.Tur.	+	CR	Sclarea
85	*S. candidissima subsp. candidissima*	Multiregional	–	–	Sclarea
86	*S. candidissima subsp. occidentalis*	Multiregional	–	–	Sclarea
87	*S. cyanescens*	Multiregional	+	LC	Sclarea
88	*S. vermifolia*	Ir.Tur.	+	EN	Sclarea
89	*S. cyanescens* × *S. vermifolia*	Ir.Tur.	+	CR	Sclarea
90	*S. cilicica*	Medit.	+	VU	Sclarea
91	*S. cassia*	Medit.	–	LC	Sclarea
92	*S. adiyamanensis*	Ir.-tur.	+	CR	Sclarea
93	*S. limbata*	Ir.Tur.	–	–	Sclarea
94	*S. indica*	Multiregional	–	VU	Sclarea
95	*S. siirtica*	Ir.Tur.	+	CR	Sclarea
96	*S. forskahlei*	Eu-sib.	–	–	Sclarea
97	*S. glutinosa*	Eu-sib.	–	–	Glutinaria
98	*S. staminea*	Ir.-tur.	–	–	Sclarea
99	*S. virgata*	Multiregional	–	–	Sclarea
100	*S. pratensis*	Eu.-sib.	–	–	Sclarea
101	*S. viscosa*	Medit.	–	VU	Sclarea
102	*S. halophila*	Ir.Tur.	+	VU	Sclarea
103	*S. nemorosa*	Multiregional	–	–	Sclarea
104	*S. amplexicaulis*	Eu-sib.	–	–	Sclarea
105	*S. adenocaulon*	Medit.	+	VU	Sclarea

(continued)

Table 5.1 (continued)

No	Taxon name	Phtogeography	Endemism	National Threat Category (IUCN 2014)	Clade (Kriebel et al. 2019)
106	*S. dichroantha*	Multiregional	+	LC	Sclarea
107	*S. nutans*	Eu-sib.	–	–	Sclarea
108	*S. verbenaca*	Multiregional	–	–	Sclarea
109	*S. hasankeyfensis*	Ir.Tur.	+	CR	Sclarea
110	*S. verticillata subsp verticillata*	Multiregional	–	–	Heterosphace
111	*S. verticillata subsp. amasiaca*	Multiregional	–	–	Heterosphace
112	*S. russellii*	Multiregional	–	–	Heterosphace
113	*S. napifolia*	Medit.	–	–	Heterosphace
114	*S. dorystaechas*	Medit.	+	VU	Dorystaechas
115	*S. rosmarinus*	Medit.	–	–	Rosmarinus

this barrier back, thereby lowering the upper connective arm downwards, and has pollen grains loaded on its back. When the pollinator visits a second flower, the pollen load is transferred to the stigma (Claßen-Bockhoff et al. 2003, 2004). The staminal lever in *Salvia* has been considered a key innovation (Claßen-Bockhoff et al. 2004) and, along with its associated floral traits, has been considered to play a major role in the adaptive radiation and speciation in *Salvia* due to its function involved in the process of pollen transfer, individual fitness, and ecological specialization (Claβen-Bockhoff et al. 2004; Wester and Claßen-Bockhoff 2007; Kriebel et al. 2020). A diverse array of staminal lever types have been reported from different clades within *Salvia* (Claßen-Bockhoff et al. 2003; Walker and Sytsma 2007; Zhang et al. 2011; Claßen-Bockhoff 2017, Fig. 5.1). Due to different types and sizes of the staminal levers and a diversity of floral morphologies among potentially co-occurring species, pollen grains are loaded on different parts of the pollinators' body causing mechanical isolation and facilitating sympatry (Claßen-Bockhoff et al. 2004; Celep et al., 2020a). On the other hand, the staminal lever mechanism is not functional in some species and the lower lever arm is highly reduced in some clades as in the Old World *Salvia verticillata* group (Claßen-Bockhoff et al. 2003; Claßen-Bockhoff 2017; Drew et al. 2017; Will and Claßen-Bockhoff 2017).

5.2 Phytogeography, Endemism and Threat Categories of the Turkish *Salvia* Species

Though Celep et al. (2010) and Kahraman et al. (2012) reported conservation status of *Salvia* species in Turkey, taxonomy of the genus has been changed a lot and new taxa and new records have been added from Turkey. In addition, new populations are discovered, therefore new and updated conservation status, phytogeography and endemism of the genus *Salvia* from Turkey are reported in here.

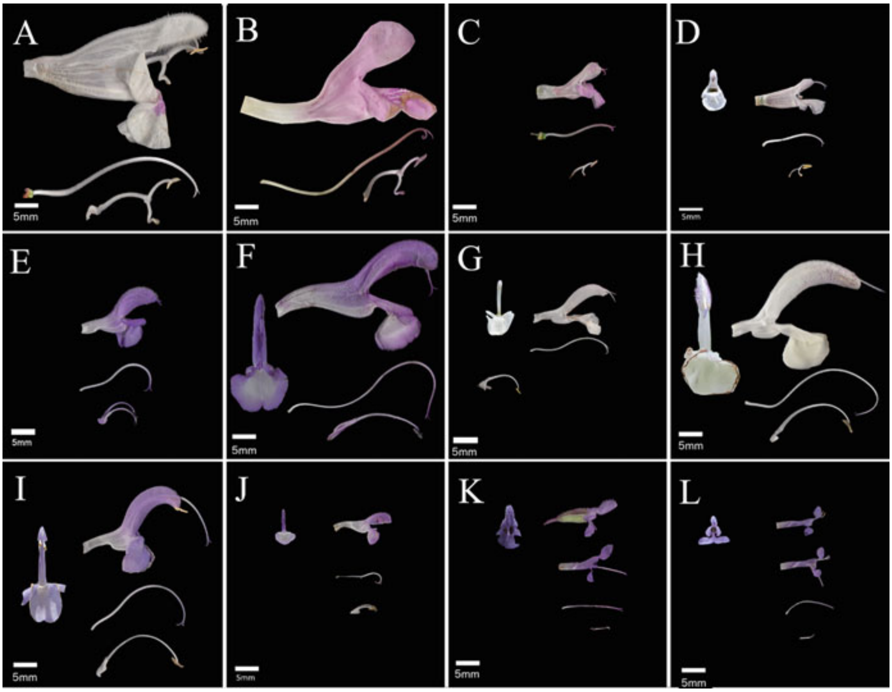

Fig. 5.1 Flower front, flower side view, style, and stamen of the studied species. (**a**) *Salvia blepharochlaena*. (**b**) *Salvia recognita*. (**c**) *Salvia absconditiflora*. (**d**) *Salvia tchihatcheffii*. (**e**) *Salvia virgata*. (**f**) *Salvia hypargeia*. (**g**) *Salvia aethiopis*. (**h**) *Salvia candidissima*. (**i**) *Salvia cyanescens*. (**j**) *Salvia viridis*. (**k**) *Salvia verticillata* subsp. *amasiaca*. (**l**) *Salvia russellii*. (Taken from Celep et al. 2020a)

On the basis of revisional studies and latest papers, there are 115 *Salvia* (sage) taxa grow in Turkey. The distribution of species according to phytogeographical regions is as follows: 57 taxa Irano-turanian element, 31 taxa Mediterranean element, 6 taxa Euro-Siberian element and 21 taxa Multiregional element. In total, 63 taxa are endemic. Endemism ratio is 54.7%. 36 endemic taxa belong to Irano-Turanian element. 23 endemic taxa belong to Mediterranean element, 1 taxon belong to Euro-Siberian element and 3 taxa are Multiregional element. Endemism ratio according to phytogeographical regions is as follows: 63% in the Irano-Turanian phytogeographical region, 74% in the Mediterranean phytogeographical region, 16.6% in the Euro-Siberian phytogeographic region and 14.2% in the Multiregional (Table 5.1).

Although the genus is distributed in the whole country, some cities have many more taxa than the other cities, i.e.: Antalya, Burdur, Karaman, Adana, Mersin, Hatay, Kahramanmaraş, Ankara, Sivas, Yozgat, Kayseri, Erzincan, Erzurum and Van.

The distribution of the threatened species according to national level is as follows: 2 taxa DD (Data Deficient), 17 taxa CR (Critically Endangered), 17 taxa EN (Endangered), 17 taxa VU (Vulnarable) and 15 taxa LC (Least Concern) (Table 5.1).

5.3 Habitat, Phenology and Altitudional Range of the Species

The native species in Turkey grow from sea level to up to c. 3000 m, in a very wide range of different habitats such as, *Quercus* and *Pinus* woodland, macchie or phrygana, limestone cliffs, igneous slopes, rocky places, steppe, cornfields and fallow fields, dry meadows, roadsides, calcareous rocks, serpentine slopes, chalky rocks, sandy dunes, moist places under *Pinus, Fagus, Alnus* and *Corylus* sp., alpine and subalpine meadows and cultivated fields. For example, *S. fruticosa* is common on near the sea in the south-west Mediterranean phytogeographical region of Turkey. *Salvia potentillifolia, S. cedronella, S. adenophylla* and *S. nydeggeri* grow open *Quercus* macchie. *S. caespitosa, S. cadmica* and *S. smyrnaea* grow on rocky limestone slopes; *S. albimaculata* grows in soft chalky hills. *Salvia viridis, S. sclarea, S. syriaca, S. virgata, S. verbenaca* and *S. bracteata* are common and grow different habitats such as roadsides, fallow-fields and cultivated fields. *Salvia glutinosa* grows under *Fagus* forests.

Research findings show that flowering periods and altitudional ranges of some species reveal some additional information to those data reported in the Flora of Turkey (Hedge 1982). In the study area, flowering occurs is between at the beggining of the March and at the end of the October, however the best flowering time is between at the mid of the April and at the mid of the July. *Salvia fruticosa, S. marashica, S. pomifera, S. pinnata, S. verbenaca* and *S. pilifera* flowers early in April, however, *S. glutinosa, S. adenocaulon* and *S. chrysophylla* flowers late in July to October. According to the Flora of Turkey, endemic *S. quezelii* flowers in August, however our studies show that the species flowers at the end of the May. Similarly, flowering time of *S. cassia* and *S. sericeo-tomentosa* should be changed as May. In the Flora of Turkey, flowering period of the *S. haussknechtii,* known only from type gathering in 1865, was given in August. However, the type specimen of *S. haussknechtii*, photos obtained from Edinburgh and specimens seen in Geneva herbarium, has not flowers. As well as I could not find it during field trips in August. Therefore, we do not know exact flowering period of it, but we can suggest its best flowering time probably in June to July.

In Turkey, *Salvia* species grow between 1 and ca. 3000 m (above see level), however, they are mainly concentrated between 600 m and 2200 m. Altitudional ranges of the endemic species are clearly less than in the case of non-endemic species.

5.4 Morphology of *Salvia* Species in Turkey

Recent morphometric and phylogenetic research on *Salvia* species has led to understand several important characteristica that contribute to the vast ecologicalc adaptability ((e.g.: radiation) of members of this important genus (Kriebel et al., 2020). The following concise description of morphological features is meant to offer a brief insight into this vast versatility.

5.4.1 Growth Form and Habit

In Turkey, many species are either shrubs or perennials with woody rootstocks and remaining species are herbaceous. The shrubby species which can be up to 2 m high are mostly distributed in the central (i.e.: *S. wiedemannii, S. recognita, S. tchihatcheffii*), west (i.e. *S. pomifera, S. fruticosa*), east (i.e. S. euphratica, S. cerino-pruinosa) and south Anatolia (i.e. *S. heldreichiana, S. cedronella, S. adenophylla, S. potentillifolia, S. marashica* and *S. sericeo-tomentosa*). Herbaceous species occur throughout the country and are mainly perennial and biennial, only one species being annual (*S. viridis*).

5.4.2 Stem Morphology

The species have procumbent, ascending to erect stem or rarely stemless. Some herbaceous species have procumbent, ascending to erect stem i.e. *S. pinnata, S. pilifera, S. quezelii, S. cadmica* and *S. blepharochleana,* however some other herbaceous plants have clearly erect stem i.e. *S. sclarea, S. candidissima, S. cilicia, S. chrysophylla, S. argentea* and *S. virgata*. Similarly, some shrubby species have ascending to erect stem i.e. *S. albimaculata, S. pisidica, S. heldreichiana, S. marashica* and *S. tchihatheffii*, but some others have clearly erect stem i.e. *S. aucheri, S. cedronella* and *S. pomifera*.

5.4.3 Leaf-Shape, Division and Texture

Shape and margin of the leaves are very useful taxonomic characters. Leaves are various in their shape between simple, pinnatisect, trisect, lyrate and pinnatifid. Most of Turkish *Salvia* has simple leaves. Majority of the endemic species have pinnatisect leaves such as *S. pisidica, S. albimaculata, S. potentillifolia, S. cedronella, S. pilifera, S. heldreichiana, S. caespitosa, S. tchihatcheffii, S. wiedemannii, S. tigrina,* and *S. quezelii*. Some other endemic species have simple leaves such as *S. chionantha, S. aucheri* subsp. *canescens,* *S. sericeo-tomentosa, S. hypargeia, S. cilicica, S. cyanescens, S. modesta.* On the other hand, *S. fruticosa, S. cadmica, S. tomentosa*, *S. aucheri* subsp. *aucheri* have simple leaves with trilobed forms.

Outline of the leaves is various (linear-lanceolate to broadly ovate) and quite valuable for taxonomy. *Salvia chionantha, S. montbretii, S. hypargeia* and *S. vermifolia* have linear-lanceolate leaves, but *S. sclarea*, *S. cilicica* and *S. cassia* have clearly ovate leaves. However, most of the species have oblong to ovate leaves such as *S. aramiensis, S. tomentosa, S. aucheri, S. cadmica, S. virgata, S. dichroantha, S. adenocaulon, S. verbenaca*.

There is a great variation on leaves margins such as entire, serrate, crenulate and erose or their variations. Most of the species have crenulate margins such as *S. fruticosa, S. tomentosa, S. aramiensis, S. dichroantha, S. adenocaulon, S. cadmica, S. smyrnaea, S. russellii*. Serrate margin can be seen in *S. glutinosa*, entire margin in *S. wiedemannii*, *S. hypargeia* and *S. chionantha*, erose margin in *S. aethiopis* and erose to dentate margin in *S. indica*.

All species have herbaceous leaves, but some species have thick-textured or membranous. Example is provided by *S. pilifera* and *S. viscosa,* their juvenile leaves are thick, but their adult leaves are more-or-less membranous in texture. However, most of the species have usually normal or thick leaves. Especially, *S. chionantha, S. sericeo-tomentosa, S. microstegia* and *S. hypargeia* have thick leaves.

5.4.4 Inflorescences

All *Salvia* species have an inflorescence of opposite reduced cymes which form false whorls usually known as verticils or verticillasters. Some, such as *S. aethiopis*, have widely branched paniculate inflorescences but most species have much less spreading inflorescences or unbranched. The number of flowers in a verticil is diagnostic as in *S. aucheri*, *S. divaricata*, *S. kurdica* and *S. quezelii*, where they are 1–2 flowered, but usually the range from 4–12. In *S. verticillata*, *S. russellii*, *S. napifolia*, the number of flowers in a vertcillaster reach up to 40 flowers.

Floral leaves, sometimes called bracts, are always present. They are either quickly deciduous or persistent. In a few species such as *S. sclarea* and *S. palaestina* the floral leaves are very large and coloured. In *S. viridis*, the inflorescence is topped by a coma of conspicuous floral leaves.

5.4.5 Calyx

The calyx provides several important characters for species recognition and for defining species-group. Most of Turkish species have thick-tectured calyx (e.g. the member of sect. *Salvia, Aethopis, Horminum, Drymopshace, Plethiosphace* and *Hemisphace*) and remaining have memranous calyces (sect. *Hymenosphace*).

Thick-textured calyces scarcely enlarge after anthesis but membranous calyces enlarge considerably after anthesis until they are broadly infundibular.

The shape of the upper calyx lip may also be important. For example, in *S. verbenaca*, *S. virgata* and other sect. *Plethiosphace* members, the upper lip of the fruting calyces is prominently bisulcate and reflexed. In many other species, the calyx upper lip is not reflexed.

5.4.6 Corolla

The corolla provides several important characters for species recognition. Useful diagnostic characters at specific and higher level are provided by the size of the corolla (e.g. *S. chionantha*, *S. indica*, *S. blepharochleana* 30–50 mm and *S. yosgadensis*, *S. modesta* 12–14 mm), the shape and length of tube, by the presence or absence of an annulus (e.g. *S. caespitosa* annulate, *S. adenocaulon* non-annulate), the shape of the upper lip (*S. chionantha* falcate, *S. cadmica* straight), and the length of the lower lip relative to the upper. Corolla colour is often characteristic for species. For example, *S. heldreichiana* has blue-purple, *S. nydeggeri* has yellow and *S. cassia* has white corollas.

5.5 Conclusions

The genus *Salvia* numbering ca. 1000 species around the World, is the largest and most important genus of the Lamiaceae family. İn Southwest Asia Turkey has been described to have a great species diversity with 99 *Salvia* species (Bahadirli and Ayanoglu 2021).

Several studies have been conducted to determine the taxonomic, as well as biological features of *Salvia* spp. in Turkey. Turkish distribution of threatened *Salvia* species and degree of their endangerement as summarized according to IUCN categories, is expected to call attention to the need to further protect the already endangered species of the important genus *Salvia*.

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Chapter 6
Threatened Medicinal and Aromatic Plants and Conservation Studies, in Turkey

Emine Akalin

Abstract In recent years, the increasing interest in medicinal and aromatic plants all over the world has created an intense ever-increasing threat to these plants. Turkey is one of the richest countries in terms of plant diversity in the northern hemisphere. In addition to the threats to biodiversity, in general, the pressure of over-harvesting of medicinal and aromatic plant resources has become imminent.

In this chapter, besides Turkey's richness of medicinal and aromatic plants, their active status, threats, conservation studies and future strategies are discussed.

Keywords Turkey · Medicinal and aromatic plants · Threats · Conservation · Plant diversity

6.1 Introduction

6.1.1 Turkey's Plant Richness

Turkey is at the forefront among the countries in the northern hemisphere with its plant diversity. Turkish flora is represented by 1220 genera and 9753 species belonging to 154 families (11.466 with subspecies taxa). These numbers are valid only for naturally growing plants and can increase to 11,707 taxa when introduced and widely planted foreign plants are included (Güner et al. 2012). Considering that the number of plant taxa in the entire European continent is approximately 12.000, the floristic richness of Turkey can be understood very easily (Tutin et al. 1964–1980). Remarkably an additional approximately 32% of these species are endemic (Güner et al. 2012).

Turkey's abovementioned diversity is influenced by her location, climate and surface forms, and geographical factors. Turkey is bordered by three seas and extends across both Europe and Asia, as a large peninsula that is influenced three

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different climates: continental, oceanic, and Mediterranean. As a result different altitudes from sea level to 3000 m, wetlands, different soil structures and vegetation types can be observed.

Turkey falls within three distinctive phytogeographical regions that are tied in closely with the three climatic zones, and these are keys to understanding the floristic richness of Turkey:

I. Euro-Siberian Phytogeographical Region: North Anatolia and northern parts of Thrace
II. Mediterranean Phytogeographical Region: Western and southern Turkey and Southern coast of Thrace
III. Iran-Turano Phytogeographical Region: Central and East Anatolia and central parts of Thrace, that is the largest of the three phytogeographical regions in Turkey (Davis 1965).

Turkey is also located in a region that has hosted many different human communities since ancient times. The first sedentary societies and the first agriculture began in this geographic area. In ethnobotanical studies, which is one of the scientific studies in which traditional uses are recorded, evaluating the use of plants in Turkey, it is seen that there are predominantly medicinal uses. From the first book is "The Healing Herbs in Bergama and Lokman Hekim" (Bayatlı 1938) written by Osman Bayatlı to the last ethnobotanical studies, 1546 species are recorded as medicinal plants in Turkey (Tuzlacı 2016).

Turkey is located in tree important Vavilovian gene centers where the cultivars originated, the Inter-Asiatic center (includes the interior mountains of Asia Minor), Caucasian center (includes of northern part of Anatolia) and Mediterranean centre (includes countries bordering on the Mediterranean Sea (Hummer and Hancock 2014).

Some important genera of Anatolian origin are: *Triticum, Hordeum, Avena, Cicer, Lens, Vitis, Allium, Prunus, Beta*.

6.1.2 *Threats to Plant Diversity*

Plants are threatened around the world. The major threats for plant diversity, apart from global ones like climate change, habitat loss, fragmentation and degradation, overexploitation, include the spreading of invasive species and pollution (Corlett 2016) Table 6.1.

Conversion of lands to agricultural areas, deforestation, opening of roads or large structures such as dams and canals are the most important factors in the loss of land. Land loss is the most important factor in the extinction of some rare and endemic plants that grow in special regions.

As an example, Istanbul, Turkey's largest city, is the region where biodiversity is intense, but the pressure on biodiversity is also the most intense. Out of the 60 Turkish endemic plants 10 species are endemic only to Istanbul. *Allium istanbulense* Özhatay, Koçyigit, Brullo & Salmeri is a new recorded species from İstanbul;

Table 6.1 Summary of Threatened Species in the World (IUCN Red List version 2021–2023)

	Estimated Number of described species	Number of species evaluated by 2021	% of described species evaluated by 2021	Number of threatened species by 2021	Estimated % threatened species in 2021
Mosses	21,925	282	1.3%	165	Insufficient coverage
Ferns and Allies	11,800	739	6%	281	Insufficient coverage
Gymnosperms	1113	1016	91%	403	40% 41% 42%
Flowering plants	369,000	56,232	15%	22,477	Insufficient coverage
Green Algae	12,090	16	0.1%	0	Insufficient coverage
Red Algae	7445	58	0.8%	9	Insufficient coverage
Subtotal	423,373	58,343	14%	23,335	

Source: https://www.iucnredlist.org/resources/summary-statistics#Summary%20Tables

Cephalaria tuteliana S.Kuş & GÖktürk, there is an ongoing conservation plan for the species; *Colchicum micranthum* Boiss. and *Crocus olivieri* Gay subsp. *istanbulensis* Mathew are geophyte, *Erysimum aznavourii* Polatschek dunal plant; also *Erysimum sorgerae* Polatschek; *Euphorbia belgradica* Forssk. is not found in distributed areas, the existence of this species is doubtful (Tuncay and Akalin Urusak 2018).

Excessive collection / use is a most common situation for medicinal plants. It is the beginning of the processes leading to extinction, especially in the case of medicinal plants that are subject to trade.

Invasive alien species are another potential threat to native plant diversity. A recent study showed that more than 13,000 species (3.9% of the world's vascular flora) have been naturalized outside of their native range, as a result of human activity (van Kleunen et al. 2015). However, these plants generally have less pressure on plant biodiversity than others.

Changes in air quality, especially due to the intense use of fossil resources, continue to affect especially in developing countries. Accordingly, and increasing global climate change with other human behaviors, it has come to the fore as the biggest global threat to plants.

The threat of extinction mentioned above is similarly imminent to medicinal plants, especially regarding uncontrolled overcollection.

According to IUCN data, as of 2021, among the 423,373 plant species, 23,335 of the 58,343 evaluated species are threatened (Table 6.1).

Head of TRAFFIC's Medicinal Plant Programme, Susanne Honnef says "About 15,000 of the estimated 50,000–70,000 plant species used for medicine, cosmetics or dietary supplements are threatened" (https://www.iucn.org/content/therapy-medicinal-plants).

Another study evaluated 5411 (21%) out of 25,791 species defined as medicinal plants according to the IUCN Red List (IUCN 2020) standards, and 723 (13%) were identified as threatened. However, considering that medical use may not have been reported here, it is thought that this number will be higher. In addition, more realistic evaluations can be made when the coverage of higher groups rich in medicinal plants is expanded at the genus or family level (Howes et al. 2020).

Although this number may change with new studies and new perspectives, even its current state gives us important warnings.

In Turkey, threats to plant biodiversity are increasing with the impact of human activities. More work is being done in this area and it is seen that more plants are in the stages of deterioration, decline and extinction in their population. The main reasons for this process are the rapid increase in population and the irrational use of our natural resources. For example, *Galanthus* species, which is an important geophyte for its medicinal use, or some endemic Origanum species that are collected and sold for use as a spice, such as *O. minutiflorum* O. Schwarz & P.H. Davis or the cycloartane group compounds it contains, *Astragalus* species, which are collected indiscriminately and have many rare and endemic species, can be counted.

6.2 Medicinal Plant Richness and Threats in Turkey

6.2.1 Current Status of Medicinal Plants in Turkey

Plants are used in different ways of treatments: isolated active drug substance (morphine), modified active molecule as drug substance (colchicine) or imitation of the mechanism of action (biomimetic) (curare). These molecules are considered drugs and evaluations are made in this process. The standardized use of herbal extracts (e.g.: *Ginkgo biloba* extract) and herbal teas in the phytotherapy, like several instances of similar uses are based on conventional knowledge. Although there has been an increase in the cultivation of medicinal plants and new technologies such as biotechnological methods are used in the production of active substances, large amounts of plants are still collected from nature.

Today, many medicinal plants are facing extinction or severe genetic loss in parallel with the extinction of plant diversity. However, first of all, it is necessary to accept the lack of detailed information about medicinal plants. Although rapid studies have been carried out to identify plants with traditional use, most of the basic studies such as their status in nature and the risks on them have not been done yet. No protection measures have been taken for most of the endangered medicinal plant species. Plants are important sources in the discovery of new drugs, and traditional use provides important gains for the beginning. Studies in this area need to be done more systematically. The Ministry has accelerated such studies with the ethnobiological inventory studies on a provincial basis. Studies on "Determination of Traditional Knowledge Based on Biological Diversity" are carried out under the coordination of the Republic of Turkey Ministry of Agriculture and

Forestry, General Directorate of Nature Conservation and National Parks, Biological Diversity Department which started in 2017–2018.

Many Turkish plants are collected such as *Glycyrrhiza glabra* (licorice), *Rosmarinus officinalis* (rosemary), *Salvia* sp. (Sage types), *Sideritis* sp. (Ironwood worth), *Origanum* sp. (Marjoram), *Satureja* sp. (Savory), *Capparis* sp. (Kebere), *Gypsophilla* sp. (Soapwort) and some bulbous plants such as *Galanthus* sp. (Snowdrop) and *Orchis* sp. (Orchid) are traded in both national and international trade (Özhatay et al. 1997).

In Turkey, agricultural production of 20 kinds of medicinal and aromatic plants occupy 526,000 hectares, although it has changed over the years. Black tea, red pepper, poppy, cumin, mint, oregano, rose oil and anise are placed near the top in terms of quantities produced (http://www.turktarim.gov.tr/Haber/64/turkiye-tibbi-ve-aromatik-bitki-yetistiriciliginde-oncu-ulkelerden).

6.2.2 Threats to Medicinal Plants

Threats to medicinal plants or rare and endemic plants have not been statistically investigated, in Turkey. Urbanization, road construction, dam or channel construction, intensive agricultural activities, pollution, and water intake due to discharge, overgrazing, over-collection, industry or pollutions originating from enterprises and mining are the leading causes of imminent dangers.

The forests that once covered a large part of Turkey's land surface are gradually decreasing. Wood cutting, overgrazing and in recent years, forest fires have also created an additional risk for forests and therefore also for medicinal plants, which are regarded as non-forest products. As an example for this process: the vegetation of Thrace's central parts has turned from forestry areas to steppe vegetation, due to the thousands of years of human settlements; also in the same area, the *Taxus baccata* L. forests were cut with only a narrow area remaining; or the Taurus Cedar (*Cedrus libani* A.Rich.), which once formed large forested areas, is now growing only in rather limited areas, in the Taurus Mountains.

Although uncontrolled collection comes first for medicinal plants, most of the general risks to biodiversity also apply to them.

There are publications with lists of wild plants sold in local markets or by herbalists. Unfortunately, the last published study on commercially collected and sold medicinal plants is from 1997. According to Özhatay et al. (1997) and Akalin et al. (2020) 347 and some 350 plants are collected in large quantities for commercial purposes (Özhatay et al. 1997).

Another important problem is that natural plant collectors do not recognize some rare and endemic species, and these species are accidentally collected. Since *Astragalus* (Geven) species are morphologically very close species, it is very difficult to distinguish them in the field except by non-experts. However, of course, the main problem is the deliberate collection of endangered species and their escape from control mechanisms. For example, *Ferula* (Çakşır) root is used.

6.3 Conservation Strategies

Conservation strategies are usually carried out in four stages; inventory, protected area/species planning, monitoring and training (Chen et al. 2016).

Inventory provides critical data for prioritizing and decision making. Critical standards in medicinal plant protection (Akalın et al. 2020),

- Medicinal plants in the site: Ethnobotanic data or regional anthropologic research. It is important for calculating direct values.
- Threatened species in the medicinal plants: Endemic and rare plants, especially only grew up a certain habitat, slowly growing or extensive collecting (eg. *Gentiana lutea*)
- Threatened habitats: The last 40 years, rare habitats are threatened in Turkey (mining, deforestation or reforestation, to achieve land, water policy, etc.)
- Rich genera or families where have important medicinal plants: such as *Papaver, Salvia* genera or Apocynaceae, Apiaceae or Labiatae families. It is important for calculating indirect values such as scientific value or educational value.

  Inventory studies that form the beginning of conserving a medicinal plant or an area important for medicinal plants usually include field trips, studies and publications on the subject, herbarium data, and databases from which numerous studies have been compiled.

  Herbarium data: There is not a national herbarium in Turkey yet. However, especially in faculties of pharmacy herbaria are located and have rich collection of medicinal plants. ISTE has nearly all species of important medicinal genera (*Papaver, Salvia, Allium, Rosa, Ferula* etc) and all important medicinal species.

  Databases: The databases will be a considerable important step in the systematically determination and protection of traditional medical plants.
- Data Bank of Turkish Folk Remedies (TUHIB-Türk Halk İlaçları Bilgi Bankası); Accordingly, this database, the number of species used as folk remedy in Turkey has recently been figured around 1500.
- Turkish Ethnobotanical Data Bank (TEBVET Türk Etnobotanik Veri Tabanı); It is reported that approximately 1200 species used for medicinal purposes.
- The most comprehensive one is the nuhungemisi database (www.nuhungemisi.gov.tr), which contains the data obtained from the Project on Recording of Traditional Knowledge Based on Biodiversity since 2017.

Conservation is recognized as a valuable tool also in the case of medicinal plant conservation. This includes inventorying and monitoring of medicinal plant species and their populations, medicinal-plant resource management and the role of gene banks and tissue cultures. Species Action Plan Projects have been targeted for 100 endangered species (plants and animals) between 2013–2019 years. But none of these plants are used for medical purposes or collected from the wild. However, these plants do not necessarily have medicinal significance.

In another ongoing project, "Preparation, Implementation and Monitoring of Species Action Plans for Endangered Species in Turkey within the Concept of a

New Methodology" Project has been launched on 31st of August 2020 with the collaboration between Ministry of Environment and Urbanization, Ministry of Agriculture and Forestry and AGRECO Consortium., and prepares proposals for the conservation of new species.

The overall objective of this is to "promote conservation of endangered species, through enhancing institutional capacity of the responsible organizations and the cooperation between them". This will be a long-term challenge to Turkey. This operation will lay the foundation of effective species conservation. The overarching objective is the increase of viable healthy populations of threatened species in Turkey." (www.tehlikedekiturler.org). One of the high-value criteria in the selection of the species is its medical importance or potential for use.

In the protection of biodiversity and therefore in the protection of medicinal plants, basically two methods are planned: *Ex-situ* (outside the habitat) and *in-situ* (in the living habitat) conservation and cultivation applications (Chen et al. 2016; NBSAP 2007).

Ex-situ conservation is carried out by establishing gene banks, seed banks, zoos and botanical gardens, as well as taking the necessary precautions for the long-term survival of these institutions. Contrary to *in-situ* conservation, in *ex-situ* conservation, genetic materials are protected by artificial means.

In-situ conservation is an approach that recognizes that species are dependent on the natural environment for their preservation and survival in their own ecosystems.

The actions of the Ministry of Forestry regarding *in-situ* protection are National Parks, Nature Parks, Nature Protection Areas, Natural Monuments, Wildlife Protection Areas and Forest Recreation Areas. The General Directorate of National Parks and Hunting-Wildlife is responsible for the management of all these areas that contribute to *in-situ* conservation. However, most of these areas have been prepared for recreation (NBSAP 2007).

According to *Ministry* of Environment, Urbanization and Climate Change, protected areas in Turkey are summarized in the Table 6.2.

Another approach to conservation is the area-based protection (preservation of habitats) and species-based protection.

Site-based conservation may also include endangered species, but if the site is not protected, species protection planning takes precedence. The site-based protection was mentioned in the previous paragraph.

Species-based conservation is recognized as a valuable tool also in medicinal plant conservation. This includes inventorying and monitoring of medicinal plant species and their populations, medicinal-plant resource management and the role of gene banks and tissue cultures. Eighty species action plans have been completed by Species Action Plan Projects since 2020 (UBENIS 2020). While there was a conservation action plan for many rare and threatened species, an action plan, however, these plants do not necessarily have medicinal significance. Some plant species that their protection action plans have been completed or ongoing such as *Astragalus beypazaricus* Podlech & Aytaç (Beypazarı Geveni), *Bellevalia edirnensis* Özhatay & B.Mathew (Edirne sümbülü), *Centaurea tchihatcheffii* (Peygamber Çiçeği), *Cephalaria tuteliana* S.Kuş & GÖktürk (Sultan Pelemiri),

Table 6.2 Status of areas under protection in Turkey

The Ministry of Agriculture and Forestry, Protected Areas	2013 Number	2017 Number
National Parks	40	42
Nature Parks	192	223
Nature Conservation Areas	31	30
Nature Monuments	112	111
Wildlife Conservation Areas	80	81
Wetlands (Internationally Important)	135	
Wetland of Local Importance (1)		8
Ramsar Areas (1)		14
Nationally Important Wetlands (1)		45
Protection Forests	55	55
Honey Forests	200	
City Forests	128	142
Gene Conservation Forests (in-situ)	257	308
Seed Stands (in-situ)	351	321
Seed Orchard (ex-situ)	179	185
TOTAL OVERLAPPING	1760	1565
Ministry of Environment and Urbanisation, Protected Areas		
Special Environmental Protection Areas	16	16
Natural Sites	1273	2426
GENERAL TOTAL OVERLAPPING	3049	4007

Sources: For areas protected by Ministry of Agriculture and Forestry, General Directorate of Nature Conservation and National Parks; Status Reports on Nature Conservation (2002–2013), (2014–2015), (2016–2017)

Ferula mervynii Sağıroğlu & H.Duman (Kerkür), *Galanthus trojanus* A.P.Davis & N.Özhatay (Truva Kardeleni), *Hypericum malatyanum* Peşmen (Malatya Kantaronu), *Lilium candidum* L. (Ak Zambak), *Tchihatchewia isatidea* Boiss. (Allıgelin), *Thermopsis turcica* Kit Tan & al. (Eber Sarısı- Piyan) (UBENİS 2020).

The legal status of biological diversity in Turkey is determined by The Turkish Constitution, Laws, International Conventions, Protocols and relevant Regulations.

Medicinal plants have special importance for Turkey. Cultivation, harvesting, production and trading processes are under the regulatory jurisdiction of different ministries, such as agriculture, forestry or health. Ministry of Agriculture and Forestry controls and improves the techniques for the harvesting, processing and storing of medicinal plants, as well as the preparation of products by the Horticultural Research Institutes. Herbal monographs of important medicinal plants for Turkey are preparing to take part in the Turkish Pharmacopoeia by the Ministry of Health.

In Turkey, most areas belong to a Protected Area System and are governed by the Ministry of Agriculture and Forestry, General Directorate of Nature Conservation and National Parks. 48 National Parks, 31 Nature Conservation Areas, 261 Nature Parks, 113 Natural Monuments, 81 Wildlife Protection Areas, 58 Protective Forests, 16 Special Protected Areas in Regional; 14 Ramsar Sites, 1 Biosphere Reserve Areas, 11 World Heritage Areas in Global are found by 2023 (DKMP 2023).

6.4 Conclusions

The use of plants in the treatment of illnesses covers a wide area with traditional foundations and goes up to the drug molecule. Despite the use of advanced scientific methods in plant breeding and production (e.g.: plant biotechnology) nature is still an important resource of medicinal and aromatic plants. Importantly, medicinal plants face risks associated with intensive harvesting, which also implies additional threats to general biodiversity. It is, therefore, urgently needed to develop national and global protection strategies for the protection of medicinal plants resources and evaluate - not only their current use value - but also their future use.

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Chapter 7
Cultivation and Breeding of Medicinal and Aromatic Plants in Turkey

Kenan Turgut, Hasan Baydar, and İsa Telci

Abstract Turkey (Türkiye) is one of the top 20 countries in the world in the production and trade of medicinal and aromatic plants (MAPs). Currently, it is one of the main producers of the MAPs such as anise, black cumin, cumin, coriander, fennel, fenugreek, laurel, lavender, mahaleb, oil-bearing rose, oregano, poppy, sage, sumac and tea. Turkey's rich biodiversity is under threat, as many of the valuable species are still wild collected from nature. For this reason, it has gained importance to domesticate and cultivate the species that are gathered from nature intensively, and the Turkish state provides support for MAP cultivation on the condition that good agricultural practices (GAP) are applied. As a result, Anatolian sage, blessed thistle, buckwheat, blueberry, caper, chamomile, corn mint, echinacea, garden mint, laurel, lavender, lemon balm, mountain tea, nettle, Passiflora (passion flowers), peppermint, rosehip, rosemary, salep orchids, sandy everlasting, savory, stevia, St. John's Wort, tarragon, thyme, quinoa, and yarrow began to be produced in the large-scale agricultural fields. There seems to be a need for increasing the cultivated area of bulbous, tuberous and rhizome plants, such as gentian, gypsophila, licorice, madder, snowdrop and summer snowdrop, whose generations are in danger, should also be widespread. In Turkey, especially in the first quarter of the twenty-first century, there has been a remarkable increase in both the breeding studies and the release of registered varieties. In the national list of registered and licensed varieties published by the Seed Registration and Certification Centre (TTSM), out of a total of 84 registered and permitted cultivars, 43 were registered by Agricultural Research Institutes, 35 by the private seed sector, and 6 by universities. Considerable activities are also carried out on *in vitro* micropropagation and *in vitro* secondary metabolite production of MAPs in Turkey.

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Keywords Turkey · MAPs · Biodiversity · Ethnobotany · Cultivation · Breeding · Variety registration and certification · Biotechnology

7.1 Flora of Turkey and Its Medicinal and Aromatic Plant Values

MAPs contain bioactive substances (secondary metabolites) such as alkaloids, terpenes/terpenoids and phenolics that have pharmacological activity. These active principles contained in one, several or all organs such as leaves, flowers, fruits, seeds, stems, bark, roots, rhizomes, corms and tubers can serve as raw materials for pharmaceuticals, perfumes, cosmetics, spices, dyestuffs etc. (Baydar 2021). MAPs are also the most important sources of natural (ethnobotanical) medicines used in traditional treatments. According to the World Food and Agriculture Organization (FAO), about 17% (72,000) of the 422,000 flowering plant taxa distributed in the world have medicinal value and about 3000 of them are involved in world trade (Schippmann et al. 2006).

Turkey (Türkiye) is a centre of origin (diversity) for many valuable MAPs species as it is located at the intersection of different phytogeographical regions such as Euro-Siberia, Mediterranean and Irano-Turanian. There are 9753 species and 11,707 taxa belonging to 154 families in the flora of Turkey. Moreover, approximately one third of the widespread plant species and taxa (3035 species and 3649 taxa) are endemic (Güner et al. 2000, 2012). We can say that the flora of Turkey, whose flora is very rich in terms of endemic species, is an important source of ethnobotanical research and has extremely important bioactive molecules for pharmaceutical chemistry. There is a consensus that Anatolian plants are an endless source of active molecules or substances for the treatment of many diseases whose treatment is unknown. However, the medicinal and aromatic value of Anatolian biodiversity has not been scientifically researched in detail and evaluated economically.

The fact that throughout the centuries, Anatolia hosted traditional medicine practices and famous folk physicians such as Hippocrates, Dioscorides and Galenos is undoubtedly closely related to the fact that its flora is very rich in terms of MAPs (Başer 2002). Many ethnobotanical studies have been conducted on MAPs used in Anatolian folk medicine and their traditional uses (Baytop 1999). For example, medicinal oil (rich in hypericin) obtained from the flowering shoots of St. John's Wort is widely used in Turkish traditional medicine for the treatment of burns, wounds, bacterial and viral infections and ulcers (Suntar et al. 2010). It is estimated that approximately 20% of the taxa distributed in the flora of Turkey have medicinal and aromatic values. Although almost every family is a potential source of MAPs, the families Amaryllidaceae, Apiaceae, Asteraceae, Cannabaceae, Fabaceae, Iridaceae, Lamiaceae, Lauraceae, Liliaceae, Orchideaceae, Papaveraceae, Ranunculaceae, Rosaceae, Rutaceae, Solanaceae, Tiliaceae and Theaceae contain much more economically rich species and taxa. Among the 1000 geophytes (plant species with underground storage organs) that add value to the flora of Turkey, only the biodiversity of geophytes such as snowdrop (*Galanthus*), crown imperial (*Fritillaria*), and salep orchids (*Serapias, Barlia, Orchis, Ophrys, Dactylorhiza*, and *Anacamptis*) species is sufficient to express the richness of Turkey's flora (Ekim et al. 1991).

MAPs continue to be collected wild from nature in Turkey, as in other countries of the world, approximately 90% of the drugs of MAPs supplied in world trade are obtained from wild-collected plants (WHO 1993). As a result of excessive and uncontrolled collections, the survival of more than 20% of medicinal plant species is in danger (Bramwell 2003). For example, in Turkey, intensive, uncontrolled or illegal collection of MAPs from nature cause great damage to the biodiversity of some valuable species such as in *Fritillaria, Gentiana, Gypsophila* and *Glycyrrhiza* as shown Fig. 7.1 (Özhatay et al. 1997). The Good Agricultural and Field Collection Practices (GACP) developed for MAPs by WHO cover to some degree ecological aspects (WHO 1993) but need to be more clearly focussed on this aspect before they can make a meaningful contribution to ensuring sustainability (Honnef et al. 2005). For sustainable wild collection of MAPs, the "International Standard for Sustainable Collection of MAPs from Nature (ISSC-MAP)" was established in 2007. On the other hand, the European Cooperative Programme for Crop Genetic Resources

Fig. 7.1 (**a**) Crown imperial (*Fritillaria imperialis*) (Photo: Fethullah Tekin), (**b**) Gentian (*Gentiana lutea*) (Photo: Serdar Erken), (**c**) The rhizomes of gypsophila (*Gypsophila arrostii*) (Photos: Hasan Aslancan), and (**d**) The rhizomes of licorice (*Glycyrrhiza glabra*) (Photo: Anadolu Agency) gathered wild from the flora of Turkey

Networks (ECP/GR) is a collaborative programme including most European countries like Turkey aimed at facilitating the long-term conservation and the increased utilization of plant genetic resources (Baričevič et al. 2004).

7.2 Cultivation of MAPS in Turkey

The larger proportion of Medicinal and Aromatic Plants continue to be sourced from their natural populations. This situation will not change also in Turkey. Still, due to its numerous beneficial aspects, the cultivation of an increasing domesticated and/or introduced species is going on at an increasing pace.

7.2.1 Advantages of MAP Cultivation

The wild collection and evaluation of MAPs, which are the oldest sources of remedies and aromas, are as old as human history. Despite many regulations, conventions and laws at national and international levels such as CITES (1973), Chiang Mai Declaration (1988) and Rio (1992), the sustainable collection and evaluation of MAPs from nature has not been fully controlled. The best way to protect the species of MAPs is to cultivate them on farmland taking into account the balance of supply and demand (Schippmann et al. 2002). Cultivation of MAPs is not only a means for meeting current and future demands for large-volume production of plant-based drugs, but also a means for relieving harvest pressure on wild populations. Active substances having therapeutic properties show a much wider variability in wild-collected plants. This variability makes it difficult to standardize on key criteria such as purity, safety and efficacy in the final product. It is easier to standardize MAPs grown under culture conditions. Moreover, the cultivation of MAPs also allows agronomic and breeding activities that will increase raw drug productivity and quality.

Since wild plants grow in adverse and competitive conditions compared to cultivated plants, they keep the secondary metabolite synthesis pathways constantly active. For this reason, active substances and amounts of wild plants are generally higher than cultivated plants. Moreover, since they are not exposed to chemicals with high residual effects such as pesticides, fertilizers, hormones, they are often treated as organic products and are found to be more natural and of higher quality. For this reason, field production of MAPs should be planned within the scope of good agricultural practices (GAP) and good manufacturing practices (GMP). Because raw and processed drugs produced in this way can be marketed more easily and at a higher value (Schippmann et al. 2006).

Based on the explanations made so far, the main advantages of cultivation over collection are as follows; (1) it is easier to meet quality standards, (2) production costs decrease as yields increase, (3) production is more stable as the negative effects of environmental factors can be tolerated, even partially, (4) the possibility of mixing with harmful and poisonous plants is eliminated, (5) the processes such as harvesting threshing, drying, sterilization, packaging, storage, marketing and transportation can be arranged more technically and professionally, (6) if desired, organic or ecological farming can be done to obtain certified products, (7) the problems caused by conventional agriculture can be eliminated, and (8) with breeding studies under culture conditions, cultivars with high drug yield and active substance content can be developed.

7.2.2 Successful MAP Domestications in Turkey

The Turkish state supports the cultivation of MAPs on the condition of applying good agricultural practices (GAP) since 2015. Finally, Anatolian sage, blessed thistle**,** buckwheat, blueberry, caper, chamomile, corn mint, echinacea, garden mint, laurel, lavender, lemon balm, mountain tea, nettle, Passiflora (passion flowers), peppermint, rosehip, rosemary, salep orchids, sandy everlasting, savory, stevia, St. John's Wort, tarragon, thyme, quinoa, and yarrow have begun to be produced in the fields. Among these species, one of the most interesting achievements has been the cultivation of salep orchids which are intensively collected from nature of Turkey as explained below.

Salep is a very valuable beverage and ice cream raw material obtained from the glucomannan-containing tubers of salep orchids which are represented by 166 species (30 taxa are endemic) belonging to 24 genera in the flora of Turkey. Of the 80 species that can form tubers, at least 35 are collected wild from nature to obtain salep (Sezik 2002). The salep plant can only produce one or a few baby tubers from the main tubers, yearly. While all tubers are gathered wild during the flowering period, salep orchids fail to reproduce themselves. Also, although they manage to form seeds and pour them into the ground, the germinate rates were very low because of the weak endosperm. In addition, mycorrhizal fungi such as *Rhizoctonia* must be present in the soil in order for the seeds of salep orchids to germinate (Çalışkan and Kurt 2019).

Due to the reasons explained above, the intensive removal of salep from nature has revealed the risk of loss of many orchid species, and finally collection of salep orchids from their natural environment is prohibited in the scope of the regulation on the "*Collection, production and export of natural flower bulbs from nature*" in 2017. As a result of these developments, research on the cultivation of *Serapias*, *Orchis, Ophrys, Barlia, Dactylorhiza* and *Anacamptis* genera were started. It was determined by the Aegean Agricultural Research Institute in İzmir that *Serapias vomeracea, Orchis sancta* and *Ophrys umbilicata*, which can form multiple tubers (Fig. 7.2), can be successfully cultivated (Karık et al. 2020). In the case of salep orchids, yield varies between 2500–7500 kg/ha according to the number and weight of tubers of salep orchids under culture conditions, and only 1 kg of dry tubers can be obtained from 5 to 7 kg of fresh tubers. Moreover, the success in the cultivation of

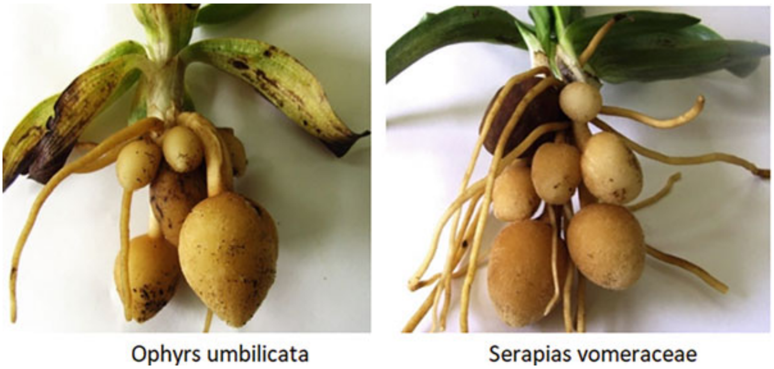

Fig. 7.2 *Ophrys* and *Serapias* orchid species collected as salep in Turkey. (Photos: Mehmet Tutar)

salep orchids has also served as an example of the cultivation of other bulbous, tuberous and rhizome plants such as gentian, gypsophila, licorice, madder, snowdrop and summer snowdrop.

Currently, Turkey is one of the world's most important producers of anise, black cumin, cumin, coriander, fennel, fenugreek, laurel, lavender, mahaleb, oil-bearing rose, oregano, poppy, sage, sumac and tea. Among these MAPs, Turkish oregano (*Origanum onites*) deserves mentioning. While 90% of Turkish oregano was collected wild from nature 30 years ago, today more than 90% is grown under cultural conditions. This extraordinary success has made Turkey a leader in oregano production and trade in the world.

Labiatae (Lamiaceae) in Anatolia is represented with family's primary 45 genera, 546 species and 730 taxa. The flora of Turkey has 38 species of *Thymus* (52% endemic), 23 species of *Origanum* (65% endemic), 14 species of *Satureja* (28% endemic) and 2 species of *Thymbra* (Başer 2002). They are regarded as oil-rich (>2%) with high percentages of carvacrol and thymol. Economically and agriculturally most valuable oregano types in Turkey are *Origanum* species. Turkish oregano (*O. onites*), Istanbul oregano (*O. vulgare* ssp. *hirtum*), Sütçüler (upland) oregano (*O. minutiflorum*), Alanya oregano (*O. majorana,* syn. *O. dubium)*, Syrian oregano (*O. syriacum* var. *bevanii*) are found in Aegean, Mediterranean and Southeastern Anatolia regions (Başer 1993).

Turkish oregano (*Origanum onites* L.) known as "Izmir kekigi" is naturally grown in Aegean and Mediterranean regions up to 1750 m altitude. As oregano plants are excessively and uncontrollably collected from nature, they are taken under preservation. Domestication of oregano types that have commercial values are organized. After Turkish tobacco law No. 4733 of 2002, tobacco (*Nicotiana tabacum*) fields sharply decreased by nearly 50%. After this, Turkish oregano was tried, as an alternative product, to take the place of tobacco, especially in the rainfed conditions of Denizli province of Turkey. In this province, Turkish oregano production areas increased in parallel with decreases in the tobacco cultivation lands. Oregano plantations are carried out by

Fig. 7.3 Turkish oregano (*Origanum onites*) cultivation in Denizli province of Turkey

planting seedlings obtained from seeds. Once the plantation is established, the crop is harvested from the same plantation for decades. In the flowering stage, the herb is cut from 10 to 15 cm above the soil level and then it is sun-dried and blended (the average of dry leaves yield is 1500 kg/ha). After this process, it is marketed and sold as drug (Folia Origani). Besides, it is distilled with steam distillation method through which essential oils (3–4%, up to 7%) are made (Aetheroleum Origani) and carvacrol rich (>70%) oil is exported (Baydar and Arabacı 2013). Turkey supplies more than 50% of the world's exported oregano (*Origanum types*). Nearly 21,000 tonnes per year of dried oregano leaves are produced and approximately 64 million US Dollars export income is earned (TUIK 2021). Denizli has become the oregano valley of Turkey with 85% of Turkey's oregano production (Fig. 7.3).

7.2.3 *Commercially Cultivated MAPs in Turkey and Their Geographical Distribution*

There has been a great increase in agricultural production areas and production amounts of MAPs with the state support on the condition of applying good agricultural practices in Turkey since 2015. The list of MAPs cultivated in Turkey in 2020 with a production area of more than 300 ha is presented in Table 7.1. The production area of each of tea, tobacco, poppy, sesame, cumin, oregano, anise and red pepper plants is over 10,000 ha. Tea is produced in the Eastern Black Sea Region, especially

Table 7.1 Production area and amount of medicinal and aromatic plants cultivated in Turkey (2020)[a]

MAPs	Botanical name	Drug type	Area (ha)	Amount (1000 tons)
Tea	*Camellia sinensis*	Leaf	83,500	1418
Tobacco	*Nicotiana tabacum*	Leaf	75,000	76,5
Poppy	*Papaver somniferum*	Capsule	46,100	20,5
Poppy	*Papaver somniferum*	Seed	46,100	20,5
Sesame	*Sesamum indicum*	Seed	25,700	18,7
Cumin	*Cuminum cyminum*	Seed	21,200	13,9
Oregano	*Origanum onites* & *O. vulgare*	Leaf	18,500	23,9
Anise	*Pimpinella anisum*	Seed	15,500	10,7
Paprika	*Capsicum annuum*	Fruit	12,000	257
Damask rose	*Rosa damascena*	Flower	4100	18,2
Black cumin	*Nigella sativa*	Seed	3400	3,4
Fennel	*Foeniculum vulgare*	Seed	2200	4,4
Lavender	*Lavandula intermedia* & *L. angustifolia*	Flower	2200	3,5
Mint	*Mentha spicata* & *M. piperita*	Herb	1500	23,5
Sage	*Salvia officinalis* & *S. fruticosa*	Leaf	700	1,3
Fenugreek	*Trigonella foenum-graecum*	Seed	700	0,7
Hop	*Humulus lupulus*	Cone	300	1,9

[a]TÜİK (2021) Crop production statistics. https://data.tuik.gov.tr/Accessed 15/03/2021

in Rize province. Tobacco is cultivated intensively in the Aegean Region. Poppy is grown in 13 provinces, depending on the permission, in Inner Aegean, Western Mediterranean and Northern Central Anatolia, especially in Afyonkarahisar and Konya provinces. Hemp is grown in the Central Black Sea Region, especially in the provinces of Amasya and Samsun. However, after the "Hemp Cultivation and Control of Regulations" in 2016, industrial hemp cultivation is now allowed in 20 provinces. Cumin is cultivated intensively in Central Anatolia and transition regions, especially in Konya, Ankara, Kayseri, Sivas, Eskisehir and Afyonkarahisar. Anise is cultivated intensively in Denizli, Afyon, Uşak, Muğla and İzmir provinces in the Aegean Region, Konya, Ankara and Eskisehir provinces in the Central Anatolian Region, Burdur and Antalya provinces in the Western Mediterranean Region. Fennel and coriander are cultivated intensively in the Western Mediterranean Region (especially in Burdur and Antalya provinces), and the Central Anatolian Region (especially in Konya, Ankara and Eskisehir provinces).

Black cumin is extensively cultivated in Burdur and Antalya (Western Mediterranean Region), Uşak, Kütahya and Afyonkarahisar (Inner Aegean Region), Konya, Çorum and Ankara (Central Anatolia Region). Fenugreek is cultivated extensively in Central Anatolia, especially in Karaman, Sivas, Konya, Yozgat, Kayseri and Ankara provinces. Sesame is grown in 25 provinces under the influence of the

Mediterranean climate, mainly in Manisa, Antalya Adana, Muğla, Uşak and Balıkesir provinces. Red pepper is produced in South-eastern Anatolia, especially in the provinces of Kahramanmaraş, Gaziantep and Şanlıurfa provinces. Oil-bearing rose, lavandin and iris are cultivated in the Lakes region, especially in the provinces of Isparta, Burdur, Denizli and Afyonkarahisar provinces in Western Mediterranean and Inner Aegean (Fig. 7.4). For the last 10 years, lavender production has been carried out in almost all regions. Sage is cultivated intensively in the Aegean Region, especially in provinces of Denizli, Kutahya, Muğla, Manisa, Uşak and İzmir, and in the Mediterranean Region, especially in the provinces of Antalya, Burdur, Adana and Hatay. Mint is cultivated intensively in Mersin, Adana, Hatay, Gaziantep, Malatya and Şanlıurfa provinces of South and South-eastern Anatolia. Hops are cultivated only in Pazar town of Bilecik province, saffron mainly in Safranbolu town of Karabük province, salep mainly in 19 Mayıs town of Samsun province, purple basil only in Arapgir town of Malatya province and savory only in Altınözü town of Hatay province. Apart from these products, blessed thistle, buckwheat, blueberry, caper, chamomile, echinacea, laurel, lemon balm, mountain tea, nettle, Passiflora, rosehip, rosemary, sandy everlasting, savory, stevia, St. John's Wort, tarragon,

Fig. 7.4 The fields of oil-bearing rose (on top), traditional alembics (bottom left) and distillation stills (bottom right) in Parfume Valley of Isparta province, Turkey. (Photos: Ayten Altıntaş and Hasan Baydar)

thyme, quinoa, and yarrow have also begun to be produced in the large agricultural fields. However, the culture of bulbous, tuberous and rhizome plants, such as gentian, gypsophila, licorice, madder, snowdrop and summer snowdrop, whose generations are in danger, should also be widespread.

7.2.4 Trade of MAPs in Turkey

A significant part of MAPs produced in Turkey by growing in cultural areas or collecting from the flora are exported abroad as raw drugs. Although it is not known for certain, about 350 herbal drugs are exported (about 100 of them are given Customs Tariff Statistics Position (GTIP) numbers) in Turkey. Turkey is among the top 20 among 110 countries in the world's trade in medicinal and aromatic plants (Özhatay et al. 1997). In 2021, the export of medicinal and aromatic plants produced in Turkey by culturing or collecting from nature amounted to 67 thousand tons with a value of 212 million dollars.

MAPs produced in Turkey were exported to 130 countries, primarily the USA, Germany and China. Tobacco and tobacco products, which are among the most important export products of Turkey, are not included in these data. The highest exports were made in oregano, bay leaves, cumin, anise, poppy seed, sage, red pepper, carob, sumac, rosemary, and tea. Oregano had a share of 30% in total spice exports with 64 million dollars. It was followed by bay leaf with an export of 44 million dollars and cumin with an export of 11 million dollars. Especially during the Covid-19 pandemic, there was a significant increase in the consumption of spice products such as oregano. Turkey's most important foreign market is the USA and EU countries, primarily Germany, England, France, Belgium, Netherlands and Poland. These counted countries, along with China and India, are also important exporters of medicinal and aromatic plants.

Turkey's annual imports of medicinal and aromatic plants (coffee, tea, spices and raw drugs) amounted to 344 million dollars in 2020. Most of the tropical products such as coffee, cardamom, black pepper, clove, nutmeg, vanilla, allspice, ginger and turmeric, and plants used in herbal medicine and herbal tea production were imported. In addition, there are significant increases in the imports of some products that we traditionally produce. For example, Turkey's annual sesame seed production is around 20 thousand tons; however, since domestic production is not enough, over 100 thousand tons of sesame seeds are imported every year.

Production, processing and marketing of MAPs are not only traders and companies but also some public institutions (e.g.: TMO and Çay-Kur), unions/cooperatives (e.g. Gülbirlik, Gül-Coop., TARBES, Ot-Gül Coop. and Gözler Coop.), associations (e.g.,: Buckwheat Growers Association, Quinoa Growers Association, Lavender Association, Laurel Association, ATABDER, EKOMDER) and companies. Within the scope of the Forestry Law in Turkey, non-wood forest products such as laurel, sumac, carob, pine nuts and cones, juniper seeds and bark, oak, chestnut, walnut,

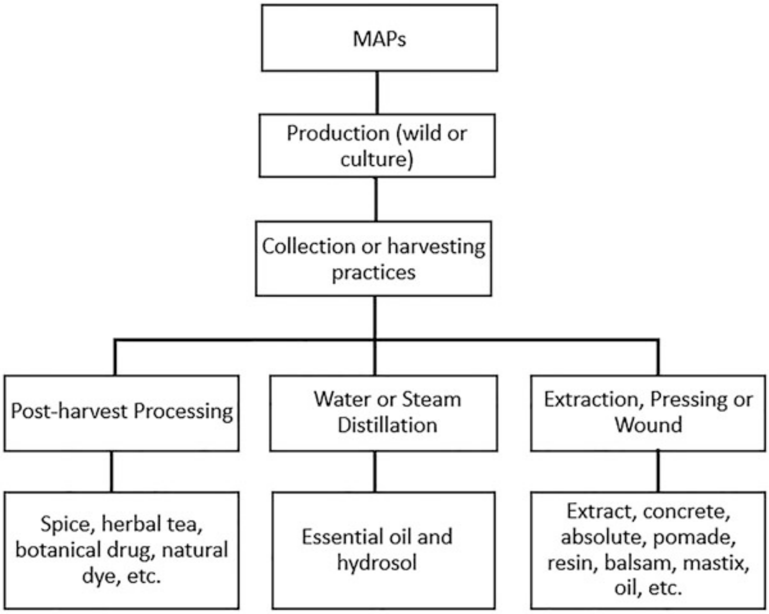

Fig. 7.5 The main commercial products and main production steps of MAPs in Turkey

myrtle, blue berry, thyme, linden, rosehip, stinging nettle, rhododendron, mushroom, snowdrops, cyclamen, and the other are exported.

In Turkey, MAPs are exported not only as raw drugs but also as processed products, such as morphine, rose oil, rose concrete, rose absolute, oregano oil, citrus oils, laurel oil, lavender oil, peppermint oil, lemon balm oil, myrtle oil, sage oil, rosemary oil, iris (lily) oil, oleoresin, resin, turpentine, gum, and other aromatic extracts (Fig. 7.5). Turkey's export of essential oils and aromatic extracts is approximately 50 million dollars. In the export of essential oils, especially rose oil, rose concrete, rose absolute, oregano oil, laurel oil, lavender oil, citrus oils, aromatic extracts and extracts are included. Turkey paid a total of 1.2 billion dollars in imports of essential oils, resinoids, perfumery, cosmetics, or toilet preparations in 2020, and earned a total of 953 million dollars from the export of the same products (TUIK 2021).

7.3 Breeding of MAPs in Turkey

7.3.1 Breeding Approaches of MAPs in Turkey

Plant breeding is the science and art of developing varieties by changing or modifying the genetic structure of plants. The ultimate goal of a plant breeder is to develop new species and varieties that are more productive and of higher quality. To achieve this goal, the breeders use classical breeding methods and techniques such as selection, hybridization and mutation, and modern breeding methods and techniques such as *in vitro* and biotechnology (Acquaah 2012). They make selections according to the results of observation, measurement, test and analysis among a group of plants that contain genetic variation. Finally, they select lines or clones that differ from their parents in at least one trait and submits cultivar candidates to registration.

In order to be successful in plant breeding, plant gene resources that show genetic diversity and contain related genes are needed. Wild species, transitional forms, populations, local (village) varieties, commercial varieties are the most valuable genetic material for breeding of MAPs. Having valuable gene collections, first of all, existing gene resources must be conserved. The two main ways of conserving the plant genetic resource are *in situ* preservation in their natural habitats and *ex situ* in gene banks. There are many international institutions and organizations such as NPGS, IBPGR, IRRI, CIMMYT, CIAT, AVRDC, IITA, CIP and ICARDA in the World, and "National Gene Bank" in Izmir Aegean Agricultural Research Institute and "Turkey Seed Gene Bank" in Ankara Field Crops Central Research Institute in Turkey where gene resources are collected, protected and evaluated. For instance, a sample of 232 different mint (*Mentha* spp.) populations were collected from different regions of Turkey in collaboration with the Turkish Extension Service and conserved in National Gene Bank (Sarı and Oğuz 2004).

To ensure rural development in Turkey, cultural production of MAPs has been supported by state since 2015. Along with agricultural supports, there has been a significant increase in the production areas and production amounts of MAPs. These positive attempts have made the variety breeding and seed production activities of MAPs even more important. The purpose of the International Union for the Protection of New Plant Varieties (UPOV), of which Turkey is a member, is to protect intellectual property and breeder rights on varieties. According to the UPOV contract, it is obligatory to prove the origin of a variety in order to be registered and marketed. In accordance with both international (the UPOV contract) and national (the Seed Law No. 5553) regulations, commercial production of local varieties or populations that do not show uniformity and stability is not allowed, while only the trade of seeds belonging to registered varieties is allowed. This situation has made the variety development and registration, seed certification and protection more important and perhaps even mandatory in MAPs. Considering that all progresses, variety breeding and seed production activities of MAPs are of vital importance for Turkish agriculture (Baydar and Telci 2015).

7.3.2 Challenges and Advantages in the Breeding of MAPs in Turkey

MAPs have more limited culture areas compared to other agricultural crops. Moreover, they contain a large number of cultivated or potentially imported species. The fact that most of MAPs were collected from nature and eventually cultivated late, their breeding and variety development studies were delayed in Turkey as well as in the world. With the growing importance of the cultivation of MAPs, there was a need to develop varieties with high drug yield and quality conforming to international standards. However, since there are many MAPs, it is not easy to develop specific breeding methods for each. In addition, pollination and fertilization biology of many MAPs, biosynthesis and genetics of specific secondary metabolites have not yet been sufficiently clarified.

Apart from genetic and environmental factors, active substances show significant changes (variability) according to the organs of the plant (morphogenetic), life cycles (ontogenetic) and even different hours of the day (diurnal). Therefore, breeding studies on secondary metabolites in MAPs are very exhausting and time-consuming. Since ultimate goal in MAPs is the production of secondary metabolites, it is necessary to have a well-equipped laboratory infrastructure (such as TLC, GC-MS, LC-MS, HPLC, NIR, NMR) to determine the active substances (phytochemicals) that have a direct effect on drug quality. In recent years, many universities and research institutes in Turkey have very advanced laboratory facilities where qualitative and quantitative analyses of secondary metabolites can be made. Another important problem is that although there are many researchers working on the agronomy of MAPs, there are very few researchers who are experts on breeding and genetics. In addition, since the methods specific to MAPs breeding have not yet been fully developed, the breeders try to modify the methods applied to other cultivated plants. Despite all these difficulties, significant progress has been made in the breeding of medicinal and aromatic plants in Turkey in the last 30 years, and many varieties have been developed and registered (Table 7.2).

The greatest advantage of plant breeders in Turkey is that they have a wide genetic variation and a rich biodiversity of MAPs in Turkey's flora. In the flora of Turkey, there are 9753 species and 11,707 taxa belonging to 154 families. Moreover, approximately one third of the widespread plant species and taxa (3035 species and 3649 taxa) are endemic (Güner et al. 2012). Considering MAPs only, 99 species of sage (*Salvia*) with 57 endemic taxa, 96 species of St. John's wort (*Hypericum*) with 47 endemic taxa, 83 species of thyme (*Thymus, Origanum, Thymbra,* and *Satureja*) with 49 endemic taxa, 55 species of daisy (*Anthemis, Matricaria,* and *Chamaemelum*) with 35 endemic taxa, 45 species of mountain tea (*Sideritis*) with 40 endemic taxa, 42 species of flax (*Linum*) with 26 endemic taxa, 36 species of poppy (*Papaver*) with 15 endemic taxa, 39 species of crocus (*Crocus*), and 25 species of anise (*Pimpinella*) with 7 endemic taxa were found (TUBIVES 2020).

Most of the MAPs are cross-pollinated species, and hence not genetically uniform. Because of this genetic heterogeneity it is possible to select better genotypes or chemotypes for agronomic and quality traits. Although basil (*Ocimum basilicum*), is not found naturally in the flora of Turkey, many local varieties have emerged in Anatolia over the centuries. In a study by Telci et al. (2006), seven different chemotypes were identified as (1) linalool, (2) methyl cinnamate, (3) methyl cinnamate/linalool, (4) methyl eugenol, (5) citral, (6) methyl chavicol (estragole), and (7) methyl chavicol/citral (new chemotype) among 18 basil local varieties grown in Turkey. Such rich biodiversity allows rapid variety development even with a

Table 7.2 Registered and permitted cultivars of MAPs in the field crops group in Turkey

MAPs	Botanical name	Research Institutes	Private Companies	State Universities	Total
Anatolian sage[a]	*Salvia fruticosa*	1	0	0	1
Anise[a]	*Pimpinella anisum*	1	3	0	4
Basil[a]	*Ocimum basilicum*	0	7	0	7
Black cumin[a]	*Nigella sativa*	1	0	0	1
Blessed thistle[a]	*Scolymus hispanicus*	1	0	0	1
Buckwheat[a]	*Fagopyrum esculentum*	2	0	0	2
Buttercup[a]	*Ranunculus ficaria.*	0	1	0	1
Cannabis[a]	*Cannabis sativa*	1	0	1	2
Capers[a]	*Capparis ovata*	1	0	0	1
Chufa[a]	*Cyperus esculentus*	2	0	0	2
Common sage[a]	*Salvia officinalis*	1	0	0	1
Coriander[a]	*Coriandrum sativum*	4	0	2	6
Corn mint[a]	*Mentha arvensis*	0	0	1	1
Cumin[a]	*Cuminum cyminum*	1	0	0	1
Echinacea[a]	*Echinacea purpurea*	1	0	0	1
Fenugreek[a]	*Trigonella foenum-graecum*	1	0	2	3
Ginger[b]	*Zingiber officinale*	0	1	0	1
Hop[a]	*Humulus lupulus*	0	7	0	7
Lavender[b]	*Lavandula angustifolia*	3	0	0	3
Lemon balm[a]	*Melissa officinalis*	1	0	0	1
Mountain tea[a]	*Sideritis perfoliata*	1	0	0	1
Oregano[a]	*Origanum onites*	1	2	0	3
Phacelia[a]	*Phacelia tanacetifolia*	1	3	0	4
Poppy[a]	*Papaver somniferum*	15	0	0	15
Quinoa[a]	*Chenopodium quinoa*	0	5	0	5
Rosemary[b]	*Rosmarinus officinalis*	2	0	0	2
Saffron[a]	*Crocus sativus*	1	0	0	1
Stevia[a]	*Stevia rebaudiana*	0	5	0	5
Turmeric[b]	*Curcuma longa*	0	1	0	1
TOTAL		43	35	6	84

TTSM (2021)
[a]Registered varieties
[b]Permitted varieties

simple selection method. For example, *Origanum, Thymus, Satureja* and *Thymbra* species show a wide variation in essential oil compounds, and chemotypes rich in geraniol (G), α-terpineol (A), linalool (L), carvacrol (C) and thymol (T) can be selected within the same population of a species due to at least 5 multiple alleles (G, A, L, C, and T) in a gene locus for the synthesis of essential oil components (Vernet 1976).

Secondary metabolites are mainly defence and adaptation metabolites of plants, for example, sage (*Salvia* sp.) activates genes responsible for the synthesis of thujone to attract pollinating insects, and the synthesis of camphor to repel herbivorous insects (Başyiğit and Baydar 2017). Whichever active substance is the precursor of the other in the synthesis pathway, an increase in one causes a decrease in the other. For example, there is a negative relationship between morphine and papaverine in the poppy plant; papaverine chemotypes contain very low morphine (Kara and Baydar 2021). As a result, if how the target secondary metabolite is inherited and synthesized is well known, much more success can be achieved in plant breeding studies. Therefore, scientific research on the inheritance and biosynthesis of secondary metabolites is of great importance for plant breeding.

7.3.3 Goals and Achievements in Breeding of MAPs in Turkey

MAPs can fight well against diseases, pests, weeds and heavy and toxic elements in the soil due to the active substances like alkaloids, terpenes and phenolics they carry. However, in cases where the economic damage threshold is exceeded in culture conditions, pesticides are often used for the control of diseases, pests and weeds. For organic or good agricultural practices, breeding of varieties having strong antimicrobial and antioxidant effects s is becoming increasingly important. For example, the development of cumin (*Cuminum cyminum*) and anise (*Pimpinella anisum*) varieties resistant to blight (*Alternaria* and *Cercospora*), wilt (*Fusarium*) and rot (*Macrophomina*) diseases is among the priority breeding targets. Since existing varieties of cumin and anise are susceptible to these diseases (Maden 2004; Özer and Bayraktar 2015), these crops can be replanted after several years in the same field. As labour is becoming increasingly expensive in Turkey, another important breeding goal in cumin and anise is to develop the varieties that form their umbels higher on the main stem, do not shed their seeds easily, and mature homogeneously for machine harvesting.

In Turkey, some breeding studies are carried out to change the active ingredient composition of MAPs. For example, noscapine is the second most common alkaloid in opium (*Papaver somniferum*) after morphine and is an antitussive (Yazıcı and Yılmaz 2017). While 12 of 15 poppy varieties registered by Turkish Grain Board (TMO) in Turkey are rich in morphine, the others are rich in noscapine (Ofis NM and Ofis NP) and thebaine (TMO-T). Also, oregano (*Origanum vulgare* ssp. *hirtum*) varieties named Tınmaz and Baser developed by Ataturk Horticultural Central Research Institute (ABKAE) are rich in essential oil (5–7%) and carvacrol (70–80%). In order to comply with international standards, it is not desired to change the essential oil components of some aromatic plants by breeding studies. For example, although many genotypes of oil-bearing roses (*Rosa damascena*) with high flower and oil yield were obtained in Isparta University of Applied Sciences, they were not registered because their essential oil compositions did not comply with the international standard of rose oil (ISO I9842:2003) (Baydar et al. 2016). On the other hand, lemon balm (*Melissa officinalis* var. Melis), common sage (*Salvia officinalis* var. Elif) and Anatolian sage (*Salvia fruticosa* var. Karık) were developed for higher drug leaf and essential oil yields by Aegean Agricultural Research Centre (ETAE) without changing the specific essential oil composition (Karık 2015; Sarı and Ceylan 2002).

Increasing the amount of active substance in the breeding of MAPs should be more important than increasing the drug yield. When the morphine ratio is increased from 0.5% to 1% with poppy breeding, twice as much alkaloid yield will be obtained from the same production area. When the essential oil ratio is increased from 0.025% to 0.05% by oil-bearing rose breeding, it will be sufficient to distil 2.5 tons of fresh flowers instead of 5 tons of fresh flowers to obtain 1 kg of rose oil. In plant breeding studies, not only positive selections over desired active substances, but also negative selections overactive substances that have negative effects on health and therefore undesirable have gained great importance. For example, food-grade poppy varieties that do not contain (0.01% or less) narcotic alkaloids such as morphine (Bernáth and Németh 1999) and industrial hemp varieties that do not contain (0.2% or less) tetrahydrocannabinol (Δ^9-THC) have been developed (Meijer 2014). Thanks to these varieties, only poppy for seed production or cannabis for fibre/seed production can be grown without the need for legal permissions. Finally, two Turkish hemp (*Cannabis sativa*) cultivars (Narlı and Vezir) with low Δ9-THC ratios (<0.2%) were developed and registered by Samsun Ondokuz Mayıs University and Black Sea Agricultural Research Institute in order to expand industrial type (for fiber and seed) production (Aytaç 2020). Apart from these examples, due to toxic and allergic effects of some compounds, methyl eugenol-free oil-bearing rose, camphor-free sage and lavender varieties are being developed by advanced breeding methods in Isparta University of Applied Sciences in Turkey (Baydar et al. 2016; Kara and Baydar 2012a, b; Tuğlu and Baydar 2019).

7.3.4 Breeding Methods of MAPs in Turkey

Since MAPs are both autogamy and allogamy, breeding methods based on the reproductive (pollination or fertilization) biology can be classified as (1) methods applied in self-pollinated plants, (2) breeding methods applied in cross-pollinated plants, and (3) breeding methods applied in clone or apomictic plants. Breeding studies on MAPs in Turkey are not different from classical breeding methods such as introduction, selection, hybridization, polyploidy and mutation applied to other cultivated plants. In addition, depending on biotechnological developments, tissue cultures and genetic engineering applications, the production of secondary metabolites and the identification, isolation, sequencing and transfer of genes involved in the synthesis of bioactive substances are being investigated (Baydar 2021). The first breeding research on MAPs in Turkey started at Aegean University and Aegean Agricultural Research Institute in the 1970s. These institutions in Izmir were followed by the faculties of agriculture in Adana and Ankara. Today, research on the cultivation and breeding on MAPs continue in about 36 faculties of agriculture and about 10 research institutes across the country.

Populations are the most important sources of genetic diversity. The genotypic and phenotypic variations are wider in cross-pollinated populations than in self-pollinated populations. Therefore, cross-pollinated populations consist of highly heterozygous (hybrid) plants as opposed to self-pollinated populations. However, since self-pollinated plants continue to selfing for generations, such populations arise from homozygous pure lines. If the flowers of cross-pollinated plants are isolated and forced to pollinate with their own pollen, they will give self-fertile offspring (inbreed lines). The breeding of quantitative traits with low heritability (e.g.: drug yield and quality, resistance to cold and drought, etc.) controlled by many additive genes (polygenic) is very laborious and time consuming. Whereas breeding of qualitative traits (e.g.: flower, fruit, seed colour, shape, form etc.) with high heritability and controlled by one or a few genes (monogenic or oligogenic) is easier and faster (Acquaah 2012).

Mass selection, pure-line selection, and hybridization in self-pollinated plants, and recurrent selection, hybrid (heterosis), synthetic and composite variety breeding in cross pollinated plants are the more common breeding methods. In addition, there are classical breeding methods such as introduction, mutation and polyploidy that can be applied to all plants. In addition to these classical breeding methods, biotechnological and molecular breeding methods based on in vitro (cell and tissue cultures) techniques, molecular techniques (such as MAS and QTL) and transgenic (GMO) cultivar development are modern breeding methods that are becoming increasingly widespread.

7.3.4.1 Introduction

Introduction is not actually a breeding method, but rather a method that covers the production of a previously registered variety in another countries. In this way, a new and different species or variety can be brought into a country quickly and economically. For example, although their homeland is not Anatolia, many temperate, subtropical and even tropical origin species such as basil, buckwheat, common sage, corn mint, echinacea, ginger, hemp, hop, lavender, lavandin, peppermint, quinoa, tea, tobacco, turmeric and stevia that entered Turkey through introduction. The gene source of the Turkish varieties registered in these species are the varieties or populations brought from the gene banks such the USDA-ARS National Plant

Germplasm System (NPGS). Since the pharmaceutical quality of MAPs is most important, the ecological conditions of the original habitat and genetic properties are the basis of the variation in quality. To select proper agricultural conditions for cultivation it is necessary to know the ecological tolerance of the species (Schneider 2004). Introductions are also be used as starting or midway genetic material in breeding programs (eg, as parents in crosses). However, in cases where quarantine measures are not taken, diseases and pests that have not been seen before in that country or region may be transported and spread (e.g. stolbur phytoplasma from lavender varieties of France).

7.3.4.2 Selection

Variety (variation) and selection (selection) are the two most important sequential steps in plant breeding; first the variation is created, then the genotypes with the desired characters are selected from this variation by selection. There are four main selection methods, namely mass, pure line, clone and recurrent. Even with the simplest selection methods, it is possible to select and develop superior types and forms from populations. Anise, cumin, black cumin, coriander, fennel, fenugreek, lemon balm, oregano, thyme and sage varieties developed in Turkey have been developed from local varieties and populations usually by positive and negative mass selection and sometimes by single plant or pure line selection method.

In mass selection, a large number of plants having similar phenotype are selected and their seeds are mixed together to constitute a new variety. Thus, the population obtained from selected plants will be more uniform than the original population. However, they are genotypically different. In the application of the mass selection method, two different ways are followed: "Positive selection" and "Negative selection". Positive selection is made if plants with the desired characteristics are phenotypically selected and harvested collectively, and negative selection is made if plants with undesirable characteristics are removed, and the rest are harvested collectively. Since quantitative traits driven by multiple genes (polygenes), such as drug yield, are strongly influenced by the environment, the effectiveness of mass selection depends on the degree of inheritance (H or h^2) of the character concerned. Traits with low heritability and selectable after flowering respond weaker to mass selection, traits with high heritability and selectable before flowering respond more strongly to mass selection.

In pure line selection, a large number of plants are selected from a self-pollinated crop consisting of a large number of inbred (homozygotic) plants. This selection method is based on the principle of testing the offspring of each plant selected from a population separately. A variety developed by single selection is called "pure line variety" because it gives homozygous offspring similar to itself. While the variety released by pure line selection method is a pure line, the variety released by mass selection method is a mixture of pure lines. Generally, a pure line variety is expected to have narrower adaptation and lower stability in performance than a mixture of pure lines.

Clone selection was successfully applied in cross pollinated plants that can be propagated both generatively and vegetatively, especially in Lamiaceae members such as mint, sage, lavender, lemon balm, oregano, rosemary, and thyme in Turkey (Bayram 2001; Ceylan et al. 1994; Karık 2015; Kırpık and Özgüven 2018; Özgüven and Kırıcı 1997; Sarı and Ceylan 2002). For example, clones with essential oil ratios between 5% and 14% and carvacrol ratios between 73% and 88% were obtained by clone selection method in Alanya oregano (*Origanum dubium*) (Turgut et al. 2016). Oregano varieties such as "Ceylan", "Tayşi", "Başer" and "Tınmaz", *Stevia rebaudiana* varieties such as "Levent 93", "Turgut 82" and "Tütüncü", tea varieties such as "Çaykur", "Derin" and "Erten" were developed by clone selection breeding in Turkey. Another plant that is very suitable for variety development with clone selection is laurel (*Laurus nobilis*). Plants derived from seeds collected from female laurel plants exhibit a rich genetic diversity. Among these, genotypes with high yield and quality can be registered by clone selection method (Ayanoglu et al. 2013). In addition, the genetic diversity of St. John's Wort, which is represented by 96 species in the flora of Turkey, is very suitable for clone selection. For example, the seeds of *Hypericum perforatum* collected from 8 provinces and 35 locations in the flora of Aegean Region are collected and many genotypes hypericin content (>0.3%) were selected clonally (Ceylan et al. 2005).

The quite practical and effective method causing genetic variation in the woody or shrubby perennial MAPs propagated both generatively and vegetatively like oil-bearing rose, rosehip, lavender, sage, rosemary, laurel and tea is to get seedlings derived from the seeds. These seedlings from the open-pollinated flowers may differ genetically due to the segregation of the alleles at heterozygous loci during meiosis (Baydar et al. 2016). The plants with superior characteristics can be propagated clonally in successive generations as clones A, B, C and D with organs such as cuttings, roots, tubers, onions, rhizomes, stolons (Tuğlu and Baydar 2019). After adaptation and stability tests, one or more clones those competing with standard varieties are submitted for registration as cultivar candidates.

Recurrent selection is a method widely used for population improvement in both self- and cross-pollinated plants, aiming to gradually increase in a population the allelic genes responsible for the inheritance of beneficial traits. For example, the lines containing more than 5% essential oil and more than 65% carvacrol in savory (*Satureja hortensis*) plant have been developed by the method of recurrent selection (Pank et al. 2004).

7.3.4.3 Hybridization and Hybrids

Plant hybridization is the process of crossing between genetically dissimilar parents to produce a hybrid. The pollen of the male parent is transferred on the stigma of an emasculated flower of the female parent, and the pollinated flower must be kept isolated, e.g., with a paper bag, during the period of stigma fertility. By crossing, useful genes from two different parents can be brought together (combination crossing), and only a useful gene can be transferred to another genotype that does not carry that gene (backcross). With backcrossing, it is also possible to develop isogenic lines, each differing from the other in only one gene. If it is aimed to benefit only from the heterosis in F_1 by hybridization, hybrid varieties (hybrid breeding) are obtained, if it is aimed to benefit from the variation (segregation and transgression) in F_2 obtained by inbreeding F_1s, line varieties (selection breeding) are obtained. Different crossing methods such as topcross, polycross, biparental, line x tester, diallel, North Carolina are used to determine the general and specific matching abilities of inbred lines and to determine gene actions (additive, dominant and epistatic). By crossbreeding, genetic research can also be carried out on many subjects such as gene linkage, heritability, genetic mapping, marker development, MAS selection and QTL analysis (Acquaah 2012).

Many new species and cultivars have been obtained through hybridizations in MAPs. Crosses can be made not only within the varieties but also between the species. For example, low camphor-containing *Salvia officinalis* lines were obtained by crossing *Salvia officinalis* with *S. fruticosa* with low camphor (Baydar 2021). Lavandin (*Lavandula x intermedia*), which is widely cultivated today, is a hybrid of *Lavandula angustifolia* x *Lavandula spica*. Perhaps the most successful applications of hybridization breeding have been in the roses (*Rosa* sp.). In the eighteenth century, after European rose species (e.g., *R. gallica, R. phoenicia, R. damascena, R. multiflora*) were crossed with Asian rose species (e.g., *R. chinensis, R. odorata, R. gigantea, R. foetida*), modern rose hybrids (e.g.: Bourbon, Floribunda, Grandiflora, Polyantha, Miniature) have been developed. Ornamental roses grown in parks and gardens today are the descendants of these rose hybrids (Gudin 2010).

The male and female parents are crossed, and the hybrid seeds from male parents are sown to generate F_1. The heterozygous F_1 plants are selfed under isolated conditions and the selfed seeds are sown to generate F_2. Since the F_2 plants is a segregating population with phenotypic and genotypic variation (mixture of homozygous and heterozygous plants), selection is started from this generation. In classical plant breeding in self-pollinating plants, three methods of selection are commonly applied as pedigree, bulk and single seed descent (Acquaah 2012). In pedigree method, individual plants are selected from F_2 and the subsequent generations (F_3, F_4, and F_5), and their progenies are tested. However, in bulk selection, seeds of F_2 plants are mixed and grown in bulk without selection for at least four generations. At the end individual plants are selected and evaluated in a similar manner as in pedigree method. Bulk selection, which is suitable for self-pollinated crops only, is simple, convenient and inexpensive than pedigree selection, but breeding time is longer. On the other hand, genetic progression is quite rapid compared to mass selection. Single seed descent method is based on the representation of all F_2 plants with one seed, fruit, pod, capsule or head for subsequent advanced generation until they become homozygous. Finally, as in pedigree and bulk selection methods, preliminary yield trials and then multi-location yield trials and quality tests with at least a check are conducted with 3 or 4 replications at different locations (genotype x environment interaction). Most of the poppy and tobacco varieties registered in Turkey are developed by combination hybridization. For example, Hungarian cultivars (such as HN1) were used as parents in the development of Turkish noscapine-type poppy cultivars Ofis NP and Ofis NM by Turkish Grain Board (TMO).

One of the most important goals of plant breeding studies is to develop hybrid (F_1) varieties. F_1 hybrids often outperform their parents due to heterosis. Especially in cross- pollinated ones. Hybrid (F_1) varieties are obtained by controlled crossing between two or more inbred lines with high compatibility abilities (GCA and SCA). Self-incompatibility (SI) and pollen sterility (cytoplasmic and/or genetic male sterility, CMS) mechanisms are utilized in hybrid seed production (Acquaah 2012). Hybrid varieties, which are an F_1 stage, lose their superior characteristics in the advancing generation (F_2) due to inbreeding depression and genetic segregation. For this reason, the seed (F_1 seed) of hybrid varieties must be renewed every year to get high yields. Many inbred lines with high performance and combination abilities are open pollinated and the seeds harvested from all are combined to obtain "Synthetic varieties".

Hybrid breeding is an important breeding method for MAPs as well as for other cultivated plants. Most of the Virginia and Burley tobacco varieties in the world are hybrids. F_1 seed of hybrid cultivars in tobacco is produced by crossing the parents as classical castration (hand castration of female parent) or CMS assisted (female parent is pollen sterile). Research on the development of hybrid oriental tobacco varieties continues in Turkey (Kınay et al. 2019). Although high heterosis values were obtained in F_1 generation in controlled crosses between different Turkish poppy varieties, commercial hybrid cultivars have not been registered yet in Turkey (Doğramacı and Arslan 2018; Gümüşçü 2002; Yazıcı and Yılmaz 2017). In recent years, significant progress has been made on hybrid and synthetic variety breeding in some MAPs. For example, a high rate of heterosis occurs when controlled pollination of stevia with a high rate of foreign pollination due to self-incompatibility with its close relatives with high compatibility. Stevia has properties suitable for obtaining synthetic and composite varieties as well as hybrid varieties.

7.3.4.4 Mutation and Polyploidy

Mutation breeding is the process of exposing plants to chemicals or radiation to generate mutants with desirable traits. Physical mutagens such as γ-rays, and chemical mutagens such as ethyl methane sulfonate (EMS) can be applied not only to seeds, but also to buds, eyes, cuttings, shoots, pollen, cells and tissues *in vivo* and *in vitro* to create genetic variations at gene (a change in a DNA sequence), chromosome (inversion, deletion, duplication, and translocation) or genome (polyploidy or aneuploidy) level (Harten 1998). M_1 generation is obtained by sowing mutagen-treated seeds. In the M_2 generation, which is the inbred product of M_1 plants, a large number of putative plants are selected. Thousands of single plants selected from M_2 are grown in individual rows as M_3 for progeny testing. Selection of superior mutants is continued in the next M_4 and M_5 generation. Mutant lines competing with standard cultivars are determined by establishing yield trials and quality tests in multiple locations in M_6-M_8 generations.

Mutation breeding is economical, fast, reliable and reproducible compared to other methods (Pathirana 2011). Since cross-pollinated plants are genotypically highly heterozygous, it is not easily understood whether the genetic variation is due to mutations or heterozygous allelic gene segregation. Therefore, mutation breeding is generally used more effectively in self-pollinated plants and pure (homozygous) line varieties. Many varieties have been developed by mutation breeding in the world after the International Atomic Energy Agency (IAEA) established in 1957. In Turkey, which is a member of this agency, gamma irradiation applications can be made by the Atomic Energy Agency (TAEK), which was opened in Ankara in 1962. For instance, gamma rays at doses of 0, 100 and 200 Gy of radioactive Cobalt-60 were applied to oil-bearing rose seeds to create genetic variations. The mutants grown from irradiated seeds were significantly different with flower colours from white to dark pink and petal numbers from 5 to 100 (Fig. 7.6), which was as a way to create effective genetic variations for floral and scent characteristics. (Baydar et al. 2021).

The nucleus of an organism with a diploid (2n) genome has two basic sets of chromosomes (2x). Polyploidy refers to the presence of more than two complete sets (3x, 4x, 5x, 6x, 7x, 8x, . . .) of chromosomes per cell nucleus (Simmonds 1980). Among MAPs, there are species with different auto and allo ploidy levels from diploid (e.g., common sage 2x = 14), triploid (e.g., saffron 3x = 24), tetraploid (e.g., oil-bearing rose 4x = 28), hexaploid (e.g., basil 6x = 48), and octoploid (e.g., water mint 8x = 96). For example, oil-bearing rose (*Rosa x damascena*, 4x = 28) widely cultured in Turkey is an allotetraploid species, a natural hybrid of *R. gallica* and *R. phoenicia* (Gudin 2010). On the other hand, peppermint (*Mentha x piperita*, 6x = 72) is an allohexaploid species, a natural hybrid of water mint (*M. aquatica*, 8x = 96) and spearmint (*M. spicata*, 4x = 48) (Tucker 2012).

Colchicine, an alkaloid obtained from the autumn crocus (*Colchicum autumnale*), is one of the efficient chemical mitotic inhibitors by inhibiting microtubule polymerization during anaphase cycle resulting in the cell formation with doubled chromosome number. Based on numerous studies on artificially induced polyploidy by colchicine after the first treatment by Blakeslee and Avery (1937), it is most likely expected to be an enlargement or increment in both vegetative and generative cells, tissues and organs of the putative polyploids with a phenomenon described as gigas effect (Sattler et al. 2016). However, autoploidy induction can lead to high rates of multivalent pairing during meiosis and an associated reduction in fertility due to the production of aneuploid gametes (Acquaah 2012). Therefore, autoploidy in plant breeding is usually restricted to crops cultivated for their vegetative organs and those with vegetative propagation, due to the low rates of viable pollen and seed production (Levin 1983). The reduction in fertility is a hindrance to the use of induced autopolyploid, especially when the organs of interest are reproductive like fruits or seeds (Dewey 1980).

Since polyploid plants have more than two alleles associated with a single gene locus (eg, in autotetraploid each gene has 4 identical alleles), inheritance of traits is more complex than in plants with a normal diploid genome. With polyploidy,

Fig. 7.6 Floral images of oil-bearing rose mutants derived from the gamma rays induced seeds. (Photos: Hasan Baydar)

enlargement of organs such as leaves, flowers, fruits and seeds, an increase in the number of stomata and chloroplasts and the number of secondary metabolites occur. For example, it was noted that higher morphine yield was obtained from different ploidy levels, especially triploid ones ($3x = 33$), obtained by applying colchicine to poppy (*Papaver somniferum*) (Andreev 1963). In Lavender (*Lavandula angustifolia*), it has been determined that tetraploids carry larger flowers and larger essential oil glands than diploids, and accordingly, their essential oil content is higher (Urwin 2009). In German chamomile (*Matricaria recutita*), tetraploid cultivars ($4x = 36$) were found to contain more essential oil in flowers and higher chamazulene in essential oil than diploid cultivars (Bucko and Salamon 2007).

Polyploid mint (*Mentha longifolia*, 4x = 48) was successfully obtained by the application of colchicine to the explants grown in *in vitro* conditions at Ankara University. Single node explants were cultured in aseptic conditions on MS (Murashige & Skoog) nutrient medium containing 100 mg/l colchicine for one week (Tepe et al. 2002). Again, in a study on obtaining autopolyploid goldenberry (*Physalis peruviana*), the incubation of seeds on colchicine containing MS medium was found to be the only effective method and tetraploid plants (4x = 48), were produced in this way. The highest tetraploid at a rate of 4.1–58.8% was achieved by adding 0.06 and 0.09% colchicine to MS medium for 21–30 days (Çömlekçioğlu and Özden 2019). In another research that was started by Baydar at Isparta University of Applied Sciences in 2020 and still continues, autotetraploidy induction in common sage (*Salvia officinalis*, 2n = 2x = 14) and Anatolian sage (*Salvia fruticosa*, 2n = 2x = 14) was performed by colchicine treatments with 0.1–0.5% concentration to the germinated seeds and cotyledonal shoot tips. As a result of flow cytometric and chromosome counting analyses performed in C1 plants, total 25 autotetraploid sage (2n = 4x = 28) was developed by artificial autopolyploidy.

Since cultivated saffron (*Crocus sativus*) is an autotriploid species (2n = 3x = 24), it is genetically sterile and does not produce viable gametes and seeds. For this reason, saffron is produced vegetatively with its bulbs formed under the ground. It is also a self-incompatible male-sterile plant but is capable of setting seed to some extent following interspecific crosses (Chichiriccò 1987). The induction of sexual stability in saffron by chromosomal doubling may open up avenues for its genetic improvement through breeding. Triploidy is desired in crop plants that are cultivated for their seedless fruits (Wang et al. 2016); however, saffron is cultivated for its flower. Autohexaploid saffron (6x = 48) corms induced by colchicine germinated but could not establish in the field (Kashtwari et al. 2021).

7.4 Variety Development and Evaluation

7.4.1 Seed Registration, Certification and Protection of MAPs in Turkey

A variety is a plant community of a certain species, developed with a known breeding method, distinguished from others with its unique characteristics, and registered and taken into production. In Turkey, especially in the twenty-first century, there has been a remarkable increase in both the breeding studies and the number of registered varieties due to the interest and demand in MAPs. Ministry of Agriculture and Forestry is the primary government institution for the production, marketing and policy aspects of the agricultural sector with a country-wide network of 81 Provincial Directorates and 887 District Directorates in Turkey.

The 2006 Seed Law and the 2008 Regulation on Registration of Plant Varieties provide the main institutional framework governing variety development, evaluation and release. Additionally, the 2004 Law on Protection of Breeder's Rights of New Plant Varieties, and its accompanying regulations, provide the framework for Plant Variety Protection (PVP). The 2010 Biosafety Law and the 2010 Regulation on GMOs and Products introduced strict control systems over the development of GMOs. Although commercial production of transgenic plants is prohibited, there is no ban on Research and Development (R&D).

The main purpose of the regulations is to make new varieties available to farmers quickly and widely, and to enable private seed companies to further develop new varieties. The regulation is envisaged to determine the procedures and principles regarding the transfer of plant varieties, candidate varieties and breeding materials developed by public research institutions to seed companies, the sale of seed production and marketing rights, and the use of variety development (Bishaw et al. 2021). According to this regulation, seed production and marketing rights of a variety or a candidate variety is sold for a maximum of 10 years. At the end of the agreement, the research institution may re-sell the variety. The breeding material sales are made only to seed companies that are authorized to conduct research by the Ministry, regardless of whether the crops are self-pollinated or not.

Variety release and registration scheme of MAPs in Turkey is presented in Fig. 7.7. Ministry of Agriculture and Forestry has two general directorates responsible for agricultural R&D, both of which play key roles in the seed sector on MAPs. TAGEM (General Directorate of Agricultural Research and Policies) is responsible for agricultural research and the generation of new technologies, while BUGEM

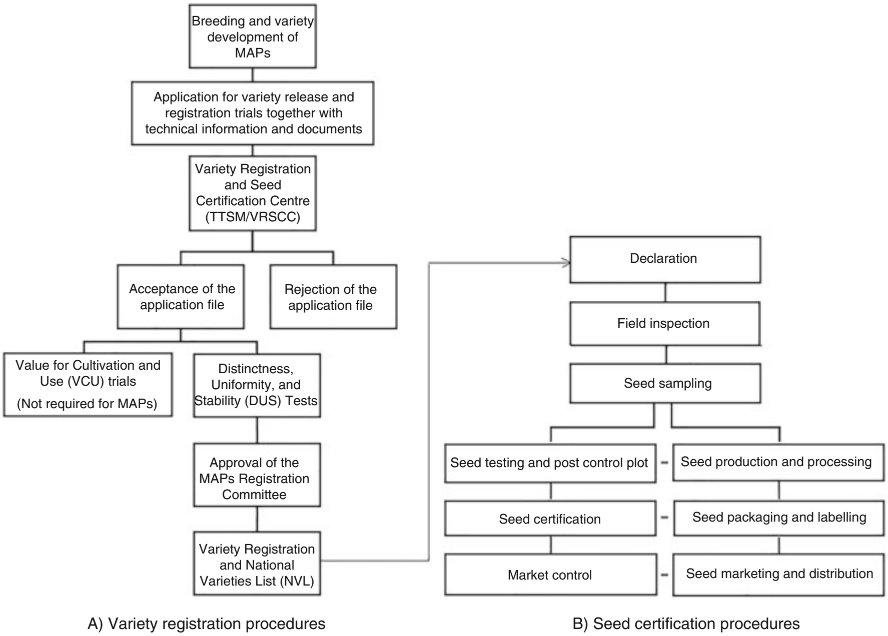

Fig. 7.7 Variety registration and certification procedures of MAPs in Turkey

(General Directorate of Plant Production) is responsible for variety registration and seed certification. In particular, TTSM (the Variety Registration and Seed Certification Centre) is the most important agency related to seed, with responsibilities for overseeing variety registration, including distinctness, uniformity and stability (DUS) and value for cultivation and use (VCU) trials, plant variety protection, maintenance of variety reference collections and seed certification (field inspection, seed testing, control plots). TTSM has overall responsibility for developing policies and regulatory frameworks, standards, procedures and international agreements. It is also a national focal agency for international cooperation with OECD on varietal certification, ISTA (International Seed Testing Association) on seed testing and UPOV (Protection of New Plant Varieties) on plant breeders' rights (TTSM 2021).

Currently, the seed sector in Turkey is organized in 2008 as TÜRKTOB (The Turkish Seed Union) which is the umbrella organization that oversees the seven sub-unions (BİSAB, TSÜAB, FÜAB, FİDEBİRLİK, SÜSBİR, TYAB, and TODAB). According to the Seed Law No 5553 of 2006, all individuals and organizations involved in the seed industry must be members of at least one union and/or sub-union. Two non-governmental organization (NGOs) are formed as TÜRK-TED (Turkish Seed Industry Association) and TÜBİD (Turkish Plant Breeders Association) to contribute to the development of the national seed sector and economy (TÜRKTOB 2021). All these organizations of seed unions are structured under the main roof of BÜGEM, which is affiliated to the Ministry of Agriculture and Forestry. In 2021, there were 247 private research organizations authorized by the Ministry in Turkey working on plant breeding and variety development at varying levels. Of these, 181 were authorized to conduct research on field crops including MAPs (BÜGEM 2021).

The variety registration and release system are governed within the framework of Seed Law No. 5553 and by the regulation on Registration of Plant Varieties (2008). The key element of this regulation is that to register a plant variety, the owner of the variety must apply to TTSM, preparing an application file which consists of application form to be filled for registration, technical information and documents of the variety (morphological, phenological, etc.), receipts of fees paid for variety release and registration trials, and verification of application file for registration from the TTSM. If the registration committee finds any missing technical information or documents, then the committee may reject the variety submitted for registration (Fig. 7.7a). According to the Regulation on Registration of Plant Varieties, a variety can only be registered by an agricultural research institute (ARI), university, an authorized seed producer, or an affiliated individual with a specified level of education and experience.

TTSM is responsible for overseeing variety release and registration. TTSM, with its headquarters in Ankara, undertakes DUS tests. Value for Cultivation and Use (VCU) trials are not required for MAPs. TTSM has one variety testing station based at its headquarters in Ankara. The operational expenses for conducting DUS tests trials are covered by the fees paid by the applicants. The registration or descriptive tests establish the identity or DUS of the variety, based on its morphological characteristics. The application calendar and procedures are available on the

TTSM website. Currently, the new varieties in Turkey are registered and released under three different procedures. DUS and VCU trials are required for regular registration in all field crops (compulsory registration), but only DUS trials are mandatory for vegetables and fruit tree varieties, while DUS testing is optional for ornamentals.

Descriptive trials for DUS are conducted by TTSM in at least one location for two growing seasons. The DUS trial is not necessary if the variety is already registered in another country in accordance with UPOV requirements, TTSM is responsible for preparing the final reports of the trials and presenting the results to the Field Crops Registration Committee for review and approval. A two-thirds majority on the Committee is required to register a new variety and enter it on the National Varieties List (NVL). The organization registering a variety becomes responsible for its maintenance and breeder seed production (Regulation on Plant Variety Registration of 2008). Varieties are registered for a period of 10 years and variety owners can apply for renewal every 10 years. According to the regulation, varieties are removed from the NVL if the registration is not renewed upon completion of its 10-year validity. Registered varieties can also be removed from the list if they fail to meet variety purity tests for three consecutive years.

BÜGEM is a competent authority for plant variety protection (PVP) where application, registration and publication are handled according to the Law No 5042 on Protection of Breeders' Rights for New Plant Varieties enacted in 2004. Applications by the breeder or his/her legal agent or breeding institutions are submitted to BÜGEM and varieties must undergo descriptive trials (DUS). The applicant should provide the mandatory information and documents including botanical description, technical description and geographic origin of the variety. The application for protection will be examined for the novelty and right for prioritization by a committee consisting of three members from BÜGEM, TTSM, and a legal advisor of the Ministry. Upon its approval, the Technical Examination Office of TTSM and the certification directorates will conduct the DUS testing. The final DUS results will be presented to the Plant Breeders' Rights Registration Committee, which is composed of six members representing BÜGEM, TTSM (two members), legal advisor of the Ministry, agricultural college, and public agricultural research institute (ARI). This allows the registration and publication in the Plant Varieties Bulletin published quarterly by BÜGEM, confirming the grant of the protection.

For a variety to be granted protection, it must meet the DUS requirements and an additional criterion for novelty. A variety is not considered novel if it has been traded in Turkey by, or with the consent of, the breeder, for more than one year before the date of the application. Once protection is granted, a variety is protected for 25 years. During this period, the right holder is obliged to maintain the variety and pay the associated fees for PVP rights. The protection entails a transferable and inheritable set of rights to control the use of the variety. It entails the exclusive right to production and reproduction, conditioning for multiplication, offering for sale, selling or other marketing, exporting, importing, and stocking. Right holders may license the variety contractually for use by third parties. After protection for three years, the right holder may be forced into compulsory licensing in cases of public interest, if the variety is not under commercial production. Accordingly, a third party who wishes to make use of a protected variety may apply to TOB to compel the variety owner to enter into an agreement to allow the use of the variety.

There are several regulations pertaining to seed production and marketing as "Seed Law", "Registration of Plant Varieties" and the other related regulations. Seed producer, seed grower and seed dealer can produce seed based on individual or contractual basis. Seed production is carried out by institutes, universities and private seed companies and farmers' cooperatives. Elite seed is strictly produced by the variety owner, whereas original seed is produced either by the variety owner or on license and/ or contract with seed producers. Certified seed can only be produced by registered seed producers/companies who are members of TSÜAB, which produce seed themselves on their own farm or under contract with seed growers. PVP rights are transferred for a maximum of 10 years and are renewable. When production rights are sold to the private sector, ARIs may also transfer the production of elite and original seed to seed companies, optionally retaining a technical supervision role. The seed company is subsequently required to produce and sell the seed according to the terms of the contractual agreement. In Turkey, royalty collection for protected varieties for both the public and private sectors is based on a license agreement between the variety owners and the seed producers (Kashtwari et al. 2021).

TTSM is responsible for seed quality assurance and certification. Furthermore, seed companies are also accredited for seed quality control and certification. The Central Seed Testing Laboratory of TTSM in Ankara was accredited by the International Seed Testing Association (ISTA). TTSM has also five regional seed certification directorates in Antalya, Diyarbakır, İzmir, Mersin and Samsun. In addition, the seed certification and testing directorates (Adana, Adiyaman, Antalya, Beydere, Çayırova, Edremit, Karacabey and Samsun) and provincial directorates of BÜGEM are responsible for seed certification. Seed companies are penalized according to the provisions of Seed Law for any failure to meet the minimum quality standards of the seed classes. In the extreme case, the penalty could be the loss of license by the companies.

In Turkey, three seed classes are recognized: elite seed, original seed, and certified seed. Elite seed forms the basis of a nucleus seed of a variety and is maintained by the breeder. Original seed is the progeny of elite seed (or of itself), and can only be grown by breeders, research institutes, or licensed private companies. Certified seed is the progeny of original seed, which has been certified according to specific procedures, and is produced by public and/or private seed companies under contract with growers or sometimes on own farms. All seed produced in the country from registered varieties whose production is permitted must be certified according to their respective seed classes. Certification involves both field inspection and laboratory seed testing (Fig. 7.7b) under control of TTSM or institutions authorized by TOB.

The field and seed standards for MAPs include land requirement, cropping history and isolation distance, as well as the allowable level of contamination with off-types and other varieties, other crop species, noxious weeds and plants infected with seed-borne diseases. The field inspection establishes the seed class and assesses that planting conditions are appropriate to maintain the identity and purity of the variety. The approved seed production fields will be harvested, processed, packaged, and labelled on a seed lot basis according to the regulations. Seed controllers take samples from these seed lots for laboratory analysis. Laboratory analysis is carried to assess physical purity, germination and seed health. For some MAPs, the seed must have at least 95% physical purity foreign matter including off-types and other varieties must be below 5%, and the germination rate must be above 65% (>70% for Apiaceae and Lamiaceae) for original and certified seed in laboratory standards. Certification is valid for one year, but seed may be sold after the certificate expires, in which case, the seed must be tested again and pass germination tests. TTSM also carries out post-control tests from certified seed samples to test varietal purity. Almost all original and elite seed and certified seed are subject to control plot tests which focus on varietal identity, purity and seed health (Kashtwari et al. 2021).

7.4.2 Registered and Permitted Varieties of MAPs in Turkey

Varieties registered or permitted by TTSM in Turkey are included in one of the groups as field crops, vegetables, fruits and ornamental plants (TTSM 2021). Registered and permitted cultivars of MAPs in the field crops group in Turkey (Table 7.2). Tobacco and poppy breeding studies in Turkey started many years ago and many varieties have been developed in these plants until today. The list of registered and permitted varieties by the Seed Registration and Certification Centre (TTSM) consisted of 42 tobacco, 15 poppies, 7 hop, 7 basil, 6 coriander, 5 quinoa, 5 stevia, 4 phacelia, 4 anise, 3 oregano, 3 lavender, 3 fenugreek, 2 rosemary, 2 cannabis, 2 buckwheat, 2 chufa, 1 cumin, 1 black cumin, 1 Anatolian sage, 1 common sage, 1 mountain tea, 1 lemon balm, 1 saffron, 1 echinacea, 1 buttercup, 1 blessed thistle, 1 caper, 1 ginger and 1 turmeric. Out of a total of 84 registered and permitted cultivars, 43 were registered by Agricultural Research Institutes, 35 by the private seed sector and only 6 by universities (Table 7.2) Sesame, safflower, flax and brown mustard varieties are included in the list of industrial crops. In addition, there are registered and permitted varieties of garden cress, broccoli, celery, arugula, dill, parsley, common purslane, chicory, garlic, fennel and sheep sorrel in the vegetable group list, and blue berries, tea, medlar, cornelia cherry, pitaya, aronia, rosehip, passiflora, frenk grape and carob in the fruit group list. However, many of the varieties currently in the national variety list have problems of uniformity and stability, and it is not possible to reach certified seeds.

7.5 Biotechnology of MAPs in Turkey

Biotechnology can offer very innovative opportunities for the cultivation, production and breeding of MAPs such as genetic engineering, *in vitro* secondary metabolite production, micropropagation, molecular assisted selection (MAS), quantitative trait loci (QTL) mapping.

Improvement of the yield and quality of MAPs through conventional breeding is still a challenge. As an alternative to traditional breeding methods such MAS and QTL mapping are used to create high yielding elite varieties with superior drug quality, adapted to biotic and abiotic stresses in MAPs. Decoding genomes of MAPs greatly facilitated generating large-scale high-throughput DNA markers and identification of QTLs that allows confirmation of candidate genes and use them in MAS breeding programs. Marker assisted selection (MAS) using molecular markers is a very effective method for the rapid and reliable determination of the characters under consideration without being affected by the genotype x environment interaction. MAS provides a great advantage if the feature emphasized in breeding programs cannot be easily distinguished phenotypically or if it appears after the juvenile stage in perennials. With the advances of QTL mapping and genome-wide-association study approaches, DNA markers associated with valuable traits significantly accelerate breeding processes by replacing the selection with a phenotype to the selection at the DNA or gene level (Kushanov et al. 2021).

Recent advances in plant genomics research have generated knowledge leading to a better understanding of the complex genetics and biochemistry involved in biosynthesis of the plant secondary metabolites. This genomics research also concerned identification and isolation of genes involved in different steps of several metabolic pathways. Progress has also been made in the development of functional genomics resources (EST databases and micro-arrays) in several MAPs, which offer new opportunities for improvement of genotypes using perfect markers or genetic transformation. Since the use of transgenic crops is associated with some ethical and biosafety issues, the potential of genomics can also be utilized by developing "cisgenic crops" by transferring the cisgenes from wild strains of the same or related species to cultivated varieties (Kumar and Gupta 2008). Though MAPs have a limited range of genomic sequences available, however recently, next generation sequencing is being widely used to generate a comprehensive transcriptomic resource for these plants. It is anticipated that databases and resources generated from these studies are likely to play a key role towards the study and exploitation of metabolites from MAPs in near future (Tripathi et al. 2016).

Plant cell and organ cultures have emerged as potential sources of secondary metabolites, which are used as pharmaceuticals, agrochemicals, flavours, fragrances, colouring agents, biopesticides, and food additives. *In vitro* micropropagation of MAPs is a traditional technique which is labour-intensive enough and economic assessment indicates a higher cost of resulting plants. This fact is limiting in expanding the use of *in vitro* technology for the propagation of various plant species.

The use of *in vitro* technology for commercial propagation of different MAPs and the production of bioactive compounds from them has become profitable industry worldwide (Máthé et al. 2015; Yancheva et al. 2019). *In vitro* techniques appear as environmentally friendly alternatives for the production of secondary metabolites when natural supply is limited, or chemical synthesis is unviable. In addition, the production of anticancer compounds (camptothecin, podophyllotoxin, taxol, vinblastine, and vincristine) and metabolites from Lamiaceae spp. (phenolics as rosmarinic acid) were selected as examples to be highlighted (Gonçalves and Romano 2018). Thanks to tissue culture (*in vitro*) techniques, germination of seeds with very weak endosperm in artificial media with embryo culture as in salep, obtaining haploid and double haploid plants with pollen or anther culture, production of secondary metabolites with callus and suspension cultures, shoot tip or meristem It is possible to produce plants free from viruses by micropropagation with culture.

In Turkey, important activities are carried out on *in vitro* micropropagation and secondary metabolite production in MAPs especially in the first quarter of the twenty-first century. During this time, many remarkable researches have been conducted on cell and tissue culture (*in vitro*) in MAPs such as *in vitro* seeed and embryo culture in salep orchids and Persian lily (Çağlayan et al. 1998; Çakmak et al. 2016), poliploidy induction in mint and golden berry (Tepe et al. 2002; Çömlekçioğlu and Özden 2019), microprogation in lavender and stevia (Kara and Baydar 2012a, b; Turgut et al. 2018), *in vitro* androgenesis in stevia (Uskutoğlu et al. 2019), secondary metabolite production in hairy root culture of lavandin, echinacea, madder and henbane (Aras et al. 2018, 2019; Demirci et al. 2020, 2021), biotic and/or abiotic stress management (Çoban and Göktürk Baydar 2016). Although commercial production of transgenic plants is prohibited, there is no ban on R&D in Turkey.

Molecular (DNA) markers represent a DNA fragment associated with any gene region of interest in the genome. They are mainly classified as dominant and codominant markers. Dominant markers give a band on the polymorphic band pattern only for those carrying the dominant allele (cannot distinguish between AA and Aa genotypes), but do not give a band for those with recessive homozygous (aa). Whereas codominant markers can distinguish heterozygous individuals (Aa) from homozygous dominant (AA) individuals; On the obtained polymorphic band pattern, it gives one band for AA and aa genotypes and two bands for Aa genotypes. For example, with the help of a codominant marker in cannabis, it is possible to distinguish THC, CBD and CBD + THC chemotypes from each other even when they are still seedlings. Homozygous Bt/Bt genotype containing only THC and homozygous Bd/Bd genotype containing only CBD can be distinguished from the others by giving two bands, while heterozygous Bd/Bt genotype containing CBD + THC can be differentiated from the others (Mandolino and Carboni 2004). RFLP, SSR, STS, SNP, CAPS SRAP and SCAR are codominant markers; RAPD, AFLP, ISSR, DArT and AP-PCR are dominant markers.

Genetic characterization of Turkish populations and local varieties of MAPs was carried out with the help of molecular markers. Here, two studies on the application of molecular markers in the genetic diversities of laurel and oil rose, which Turkey ranks first in world production and trade, will be presented as examples. In a study conducted by Bulut et al. (2018), 95 bay laurel (*Laurus nobilis*) genotypes from flora of Hatay province of Turkey were selected for their superior characteristics and then genetically characterized by 6 SSR markers. As a result of the SSR analysis, a total of 82 alleles were obtained with a mean of 16.4 of 5 polymorphic loci. Generally, a low similarity is determined among the genotypes. The highest genetic similarity was seen in E6 and O6 genotypes with 80%. In the other studies conducted by Ağaoğlu et al. (2000) and Göktürk Baydar et al. (2004), there was no genetic diversity in the oil-bearing rose (*Rosa damascena*) plants grown in the Lake region of Turkey according to the RAPD, AFLP and SSR analyses. Thus, it was understood that all of the oil-bearing roses grown in the region were clonal propagation products of the first planted oil-bearing roses. On the other hand, the phenotypic homogeneity caused by continuous vegetative reproduction makes it possible to produce rose oil with international standards (ISO 9842:2003). Identification of genotypes in *Salvia* is complicated owing to the morphological similarity and common occurrence of natural hybridisation within *Salvia* species (Karaca et al. 2008). Application of PCR-RFLP resulted in species-specific DNA markers, and use of DAMD-PCR resulted in reproducible DNA patterns that are useful in Salvia genetic studies. Multivariate cluster analysis and principal coordinate analysis indicated that there were relationships between DNA marker patterns and essential oil yields at the species level (Karaca et al. 2008). Microsatellite markers were used to study the genetic structure of 48 individuals representing 9 species and subspecies of *Thymus* naturally grown in the Mediterranean region of Antalya (Karaca et al. 2015). It was found that there is a greater genetic diversity at the intraspecific and interspecific level.

7.6 Conclusions

The flora of Turkey has a rich biodiversity in terms of MAPs. Turkey owes its rooted traditional medicine practices to Anatolia's rich floral diversity. MAPs are not the first cultivated plants in Turkey as well as in the world. However, thousands of years ago, as today, people were collecting such plants from nature as wild. Because these people needed not only food, clothing and shelter, but also treatment. Although the emergence of MAPs in the evolutionary concept goes back millions of years like other plants, their cultivation took place in the last few thousand years. Although MAPs have been cultivated in Turkey for centuries, it has developed very rapidly, especially in the first quarter of the twenty-first century. The use of MAPs, especially in the production of pharmaceuticals, perfumery, cosmetics, food and agronomy produce, has led to significant increases in agricultural production. Nature, with its thousands of various plant taxa, will continue to be the biggest and most generous pharmacy of humanity if it is given the respect and care it deserves. The flora of Turkey is very rich in MAPs and is the storehouse of a large number of bioactive molecules that can be included in pharmaceutical, aroma, perfume, cosmetics and dye preparations. However, this richness is not unlimited for economical use. There is also a need for legal regulations and inspections to prevent the possible negative effects of herbal medicines whose efficacy, safety and purity have not been tested and approved on public health. All stages of MAPs production to consumption should be recorded. All production practices, techniques and methods related to MAPs should be recorded in Good Agricultural Practices (GAP), Good Agricultural and Collection Practices (GACP), Good Manufacturing Practices (GMP), Good Laboratory Practices (GLP), Integrated Crop Management (ICM), Integrated Pest Management (IPM), Hazard Analysis and Critical Control Points (HACCP) should be carried out meticulously.

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Chapter 8
Traditional Uses and Cultivation of St. John's Wort (*Hypericum perforatum* L.) in Türkiye

Oya Kaçar and Emine Bayram

Abstract *Hypericum perforatum* L., is a widely known and used species worldwide. Belonging to the Hypericaceae family, it is one of the most prominent medicinal and aromatic plants used to treat mild and moderate types of depression. Its pharmacological effect is due to its content of hypericin and its derivatives. The crude drug of this plant is sourced both by collecting (wildcrafting) from the natural populations and by open field production. Plant breeding is aimed at selecting high quality and high yielding varieties that under appropriate climatic conditions and cultivation technologies can ensure sustainable production.

Keywords St. John's wort · *Hypericum perforatum* L. · Hypericin · Hypericin-derivatives · Cultivation

8.1 Introduction

Hypericum perforatum L., commonly known in Europe as St. John's wort (Gerders 1980) and in Türkiye under local names such as Sarı Kantaron, Binbirdelikotu, Kanotu, Kılıçotu, Koyunkıran, Kuzukıran, Mayasılotu, Yaraotu and Püren (Aydın et al. 1992; Öztürk et al. 1992; Üstün 1998; Baytop 1999), is a medicinal plant belonging to the Hypericaceae (Guttiferae = Clusiaceae)family (Fig. 8.1). In ancient times, physicians, and philosophers such as Dioscorides, Galen, Hippocrates and Pliny mentioned this plant in their works. In recent years, especially in developed countries, Herba hyperici has become one of the pharmaceutical industry's most widely used herbal materials. The antidepressant activity of this plant, which has been used for medicinal purposes for 2000 years, has been proven thanks to extensive clinical trials and its use has become widespread in the world (Wichtl

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Fig. 8.1 *Hypericum perforatum* L. (Photo: Kaçar O)

1986; De Smet and Mohen 1996; Linde et al. 1996). After antidepressant effects of *H. perforatum* L. were discovered in the 1980s, the plant attracted the pharmaceutical industry's attention. In 1984 its use against depression was approved by the German Commission E (Başer 2007). It is reported that the annual sales value of pharmacological products in different forms prepared from the plant exceeds $100 million in European markets and $500 million in the United States while approaching $1 billion worldwide (Solomon et al. 2013). A certain part of this consumed raw material is collected from the flora of different countries, but most of it is also obtained by culturing (Ceylan et al. 2002). Many imported preparations, in which St. John's wort is included in the preparation, find wide use in Türkiye. The plant, which is quite common in the flora of Türkiye, has started to be cultivated in Türkiye, although it is limited on the basis of producers.

8.2 Taxonomic Characteristics

There are about 900–1000 known species in the Hypericaceae (syn: Guttiferae = Clusiaceae) family, in the world. They are usually distributed in the subtropical and temperate belts (Zeybek and Zeybek 1994). These species are woody, shrubby or herbaceous plants with pitch pockets in all vegetative parts, which appear as transparent spots on the leaves. The presence of schizogenic secretory vesicles that secrete balsam (liquid resin) and ethereal oil in their organs and particularly in their flowers is one of the critical characteristics of the family (Zeybek and Zeybek 1994; Seçmen et al. 1995).

The genus *Hypericum*, which is represented by 484 species in the world (Crockett et al. 2011), is reported to be represented by about 100 taxa, in 19 sections, among which 45 taxa are endemic in Türkiye (Eroğlu Özkan et al. 2013). It is observed that this number has reached 119 taxa and 49 endemic species nowadays (URL 2022a). In addition, it was determined that three *Hypericum* species are spread in aquatic environments in Türkiye (Seçmen et al. 1997). The most widely known and used species in the world included in this genus is *Hypericum perforatum* L.. In Türkiye, three taxa of *Hypericum perforatum* species are distributed, namely three *H. perforatum* L., *H. perforatum* subsp. *perforatum* L. and *H. perforatum* subsp. *veronense* (Schrank) H. Linb (URL 2022a).

8.3 Geographic Distribution

H. perforatum L. is a perennial and herbaceous plant with a natural distribution in Europe, Western Asia, North Africa, Western Siberia, Anatolia, Northern Iran, Northern Iraq, Western Syria, Cyprus, and North America (Davis 1967; Walker et al. 2001). In Türkiye, it is found naturally in the Marmara, Black Sea, Aegean, Central and Eastern Anatolia, Mediterranean and Southeastern Anatolia regions (Fig. 8.2) (Davis 1967; URL 2022b).

8.4 Morphological Description

H. perforatum L. is a perennial, herbaceous and rhizomatous plant of 30–90 cm height. Rhizomes can grow up to 0.5 meters long. Roots are formed from the nodes of the shoots spreading on the soil. The root system extends horizontally. Its highly branched stem is green, pale green and has two corners. The leaves of *H. perforatum* L. plants are opposite, entire, and sessile. When the leaves are exposed to light, the schizogenic secretory vesicles that secrete balsam (liquid resin) and essential oil on them are easily seen as bright spots. This is one of the important anatomical features of the plant. Its flowers (corolla) are bright yellow in color and are located at the ends of the branches. There are five sepals and five petals in the flowers. There are black

Fig. 8.2 Distribution areas of *Hypericum perforatum* L. in Türkiye. (URL 2022b)

Fig. 8.3 St. John's Wort leaves (http://www.bio.brandeis.edu/fieldbio/medicinal_plants/images/johns_wort_leaf_full.jpg), Buds and Flowers, Seeds, Capsules. (Photos: Kaçar O)

glandular hairs on the edges of the petals. Its sepals are in the shape of lanceolate and their ends are sharp (Fig. 8.3).

Close inspection of the flowers reveals small black spots which, when crushed between the fingers, release a red pigment that leaves a stain on the hand. This pigment contains hypericin, pseudo-hypericin and hyperforin, the active agents of this medicinal plant known in English as 'St. John's Wort'. The male reproductive organs are numerous and collected together in three bundles. The capsules formed at maturity are three-cornered, oval, lobeless, sticky and length varies between 5.6 and 6.5 mm and width between 2.6 and 3.6 mm. Capsules contain a large number of dark black or brown seeds inside. Each plant can give 15.000–30.000 seeds per year. The seed is 0.5–1 mm long and 0.3–0.4 mm wide with a thousand-grain weight of 0.1–0.15 grams (Fig. 8.3) (Braunewell 1991; Zeybek and Zeybek 1994; Baytop 1999; Marquard and Kroth 2001; Ceylan et al. 2002; Nia 2004; Kaçar and Azkan 2005a; Zeybek and Haksel 2011; Bayram 2020).

H. perforatum L. is a tetraploid plant. The number of chromosomes is $x = 8$ ($2n = 4x = 32$) (Darlington and Wylie 1955). Its fertilization has not been fully clarified. It is noted that self-pollination is excessive.

8.5 Crude Drug Used

The drug Herba Hyperici is defined as the dried, whole, or crushed aerial parts of *Hypericum perforatum* L. collected just before or during flowering (Kroth and Steinhoff 1998). In pharmaceutical applications, the collection of flowering branch tips is preferred. In the Homeopathic Codex, it is stated that all freshly bloomed aerial parts are used (Marburg 1993). The primary sources for the qualification of drug materials are the applicable codices or monograms, such as the Swiss Pharmacopoeia (Ph. Helv.), the German Pharmacopoeia (DAC) and the European Pharmacopoeia (Ph. Eur.). St. John's wort herbage (Hyperici herba) and quantified St. John's wort extract (Hyperi herbae extractum siccum quantificatum) are registered in the European Pharmacopoeia (Başer 2007). In Türkiye, only *Hypericum perforatum* L. is included in the 'Positive Plant List' prepared by the Ministry of Agriculture and Forestry, General Directorate of Food and Control, Department of Risk Assessment (Bayram 2020). However, according to reports, it is collected intensively from the natural flora without distinction of species (Çırak and Kurt 2014).

8.6 Major Chemical Constituents and Bioactive Compounds

H. perforatum L. includes different groups of pharmacological activities such as 0.05–0.3% naphthodianthrones (protopseudohypericin, pseudohypericin, protohypericin and hypericin), 4–6% phloroglucinols (hyperforin, adhyperforin, furanohyperforin), 1–4% flavonoids (rutin, hyperoside, quercitrin, isoquercitrin), xanthones, 8–11% tannins (Hölz and Ostrowski 1987; Nahrstedt and Butterweck 1997; Bilia et al. 2002), 0.05–0.3% essential oil (n-Alkanes, α-Pinene and other monoterpenes) and antibiotic active substances (imanin, novoimanin) (Wichtl et al. 1984; Hölz and Ostrowski 1987).

The most emphasized chemical compound pharmacologically is naphthodianthrones (Patocka 2003). It is known that the antidepressant activity of the plant is associated with hypericin and its derivatives (Butterweck et al. 1998; Porter et al. 1998; Briskin 2000). Protopseudohypericin and protohypericin can be transformed into pseudohypericin and hypericin respectively under the influence of light (Freytag 1984; Kramer and Wiartalla 1992; Gaedcke 1997; Delaey et al. 1999). Pseudohypericin and hypericin are dark red and accumulate in black glands on the edges of leaves and flowers (Osbourn and Lanzotti 2009). *H. perforatum* L. contains about 0.1% of hypericin and hypericin-like substances (Wichtl et al. 1984; Hölz and Ostrowski 1987). According to the German Codex (DAC 1991), the hypericin content in H. perforatum L. should be at least 0.04%, but the total hypericin content should not be less than 0.15% to obtain an extract. Phloroglucinol (hyperforins) derivatives contain hyperforin and adhyperforin molecules that are highly photosensitive and oxidized (Trifunovic et al. 1998; Verotta et al. 2000). Hyperforin is collected in different areas of the leaf (Kootstra et al. 2001).

The hypericin ratio, which is one of the derivatives of the naphthodianthrones group, one of the most important secondary substance groups contained in St. John's wort, varies not only due to genotypic characteristics, but depends also on environmental conditions, plant development period, analyzed plant parts, harvest time, drying method and storage conditions (Bombardelli and Morazzoni 1995; Büter et al. 1998; Jensen et al. 1995; Palevitch 1991; Upton 1997).

8.7 Traditional Use and Common Knowledge

The aerial parts of *Hypericum perforatum* L. are antidepressant due to their hypericin content; sedative, anti-inflammatory, antiulcerogenic and analgesic due to its biflavonoids and hyperforin; diuretic and astringent due to its flavonoids and tannins; and its essential oil is antiphlogistic (Çubukçu et al. 2002).

Products prepared by using the aerial parts, branches, leaves and flowers of St. John's wort are commonly utilized in traditional medicine in Türkiye. The conventional combination and usage functions of these products are outlined below.

St. John's Wort Infusion The flowering branches of the plant are dried in the shade and used as infusion (1–2%) as a chest softener, appetite stimulant, diuretic, and expectorant (Baytop 1999), besides stopping stomachaches and intestinal diseases such as colitis (Sezik et al. 2001; Polat 2010). In addition to these diseases, St. John's wort is also used to treat diabetes (Koçyiğit 2005), rheumatism and menstrual pain (Bulut 2008), cancer (Kızılarslan 2008), as a sedative (Aydın 1990; Baytop 1999; Albayrak 2019; Can 2019), gum diseases, stomach ulcers (Can 2019), and diuretic (Kızılarslan 2008) as herbal tea.

St. John's Wort Decoction The dried above-ground parts of the plant are boiled with water for about 10–15 min, filtered, and then used hot or cold (Çırak and Kurt 2014) to cure stomach disorders (Aktan 2011).

St. John's Wort Tincture 2 handfuls of sun-dried and finely chopped herbs (stem, leaves and flowers) are added to 1 liter of cognac. The bottle is placed in the sun for 14 days and shaken occasionally. It is subsequently filtered, and transferred to dark-colored bottles and stored in a cold place (Çırak and Kurt 2014).

St. John's Wort Oil The most common use of the plant in Türkiye is the application of "St. John's Wort Oil (Oleum Hyperici)" prepared by macerating the flowering branches in olive oil for wound healing purposes (Tanker and Tanker 1985; Mabey et al. 1988; Özyurt 1992; Tanker et al. 1998; Baytop 1999; Mutlubaş and Özdemir 2020). Traditionally, the flowering branch tips of the fresh H. *perforatum* plant are macerated in olive oil in glass jars with lids in sunlight for 15–45 days (Baytop 1999). At the same time, this mixture is used to treat mastitis in animals (Polat 2010).

In the production process of St. John's wort oil; many factors such as the correct harvest time of the plant, the part of the plant used, whether the plant is dry or wet, the proper of the maceration environment (shade / sun), the selection of the oil to be used in maceration, the plant/oil ratio, harvest time, tool equipment feature and hygiene, storage conditions are essential. In the study conducted by Ayran (2021) in Türkiye, it was reported that in order to obtain St. John's wort oil with high hypericin content, it is more appropriate to harvest during the full flowering period and macerate the fresh herbage in a sunny environment in olive oil. In contrast, it is more appropriate to harvest during the full flowering period and macerate in shade conditions to obtain medicinal oil with high total phenol and flavonoid content.

St. John's Wort Extract Instead of tea, the extract obtained from the flowers, leaves and stems of the plant and marketed in capsule form is utilized, particularly in Europe and America. This product is imported with the approval of the Republic of Türkiye Ministry of Agriculture and Forestry and is offered as 300 mg capsules containing 0.3% hypericin (Çırak and Kurt 2014).

Its total extract is included in the composition of preparations used for depression and some nervous disorders (Zeybek and Zeybek 1994). The quality of *H. perforatum* L. preparations depends on many factors, ranging from the selection of seeds, cultivation, harvesting, drying and extraction to the formulation of the medication that reaches the patient.

The antidepressant activity of the plant is associated with hypericin and its derivatives (Butterweck et al. 1998; Porter et al. 1998; Briskin 2000). In nervous disorders, sleep disorders, psycho-vegetative disorders, fear, and nervous restlessness (Marburg 1993) Herba Hyperici and Flores Hyperici extracts have euphoric effects on depressive patients (Zeybek and Zeybek 1994). *H. perforatum* is currently used successfully treating mild to moderate depression. In comparison to synthetic drugs, it does not have the serious side effects such as insomnia, weight loss, and sexual dysfunction (Müldner and Zöller 1984; Okpanyi et al. 1987). In addition to depression, the plant is also used in situations such as fear, menopausal stress, excitement, insomnia, excessive sleep, and anxiety (Maisenbacher et al. 1995).

Studies have shown that the alcohol extract of the plant has hepatoprotective effect (Öztürk et al. 1992) and a broad-spectrum antibacterial effect against gram-positive and gram-negative bacteria such as *Staphylococcus aureus*, *Streptococcus mutans*, *Proteus vulgaris*, *Escherichia coli* and *Pseudomonas aeruginosa* (Murrey 1995; Cecchini et al. 2007). Although it is also known that hypericin has a strong antibiotic effect (Tanker and Tanker 1985), it also has significant antioxidant activity (Güzel et al. 2019). It is known that plant's essential oil is antihelmintic (Tanker and Tanker 1985), irritant and slightly aromatic (Newall et al. 1983; Tanker and Tanker 1985).

The only serious side effect of *Hypericum perforatum* L. due to its hypericin content is photosensitization has only been reported in albino animal species and some humans with sensitive skin (Southwell and Campell 1991; Tükel and Hatipoğlu 2001). Since the flowers and leaves of *H. perforatum* contain substances that increase photo-sensitivity, skin diseases, which are characterized by oedema in the mouth and genital area, debility, and sometimes result in death, occur in animals that eat the plant, especially animals with white hairs. This illness is called as "Hypericismus disease" (Tanker and Tanker 1985; Özyurt 1992; Zeybek and Zeybek 1994; Tanker et al. 1998; Baytop 1999; Uzun 2009).

8.8 Ecological Requirements

It has been recorded that the plant can be found at altitudes of 1000–1200 meters and has even reached up to 3600 meters in Afghanistan (Meusel et al. 1978). In Türkiye, *H. perforatum* is naturally distributed in mesophytic areas from sea level to 2500 m (Davis 1967). In plant collection programs conducted in Türkiye, the plant was found between 65 and 1880 m (Ceylan et al. 2002; Kaçar and Azkan 2005b). St. John's wort is a very cold-resistant plant.

Regarding soil, St. John's wort has no specific requirements. It develops on loamy-sandy, in soils that are medium or rich in organic matter. It can also grow in poor soils, but prefers soils free of weeds, rich in humus, neutral or alkaline. In medium or heavy soils, the pH should be above 6.5. In light soils, the pH can start from 6.0. St. John's wort is an accumulator plant that accumulates particularly cadmium (Cd), a toxic heavy metal, within its body. It is used as a phytoremediation plant in areas contaminated with heavy metals. Therefore, cadmium-poor soils should be preferred. Cadmium taken from the soil accumulates mainly in the upper parts of the flowering branches of the plant (Plescher 1997). The limit for cadmium in the plant is 0.5 mg/kg (Dachler and Pelzmann 1999). In a study conducted in Germany, it was reported that flowering branches had relatively high Cd uptake regardless of Cd content in the soil and different sources. In contrast, Cd uptake by generative parts varied according to origin (Gaudchau et al. 1996), a strong positive correlation was found between Cd content in the soil and Cd uptake by plants, the degree of Cd uptake varied among plants of different origin (Schneider et al. 1996). As a conclusion of these studies, the Cd concentration of raw materials should be determined in materials collected from nature and cultivation should be avoided in such soils.

8.9 Cultivation of St. John's Wort in Türkiye

The raw material demand of *Hypericum perforatum* L. for the market is met both by collecting from the flora and by cultivation (Ceylan et al. 2002; Kaçar 2003). In Europe, the first agricultural research on this species started in Germany, in 1981 and in Switzerland, in 1994 (Bomme 1983; Bomme 1997). Presently, it is cultivated, in large areas in Germany, Switzerland, Poland, Slovakia, Finland, Ukraine, Hungary, USA, Canada, South America, especially in Chile (Galambosi 1993; Bomme 1997; Plescher 1997; Zeybek and Haksel 2011).

In Türkiye, the first research on its culture started in 1989, at the Ege University, Faculty of Agriculture, Department of Field Crops, where a comprehensive project was carried out with the support of TUBITAK to identify chemotypes in the flora of the Aegean Region, to elaborate their production techniques, and to determine their agronomic characteristics and quality criteria (Ceylan et al. 2002). St. John's wort plant does not have a widespread cultivation area in Türkiye it is generally sourced from wildcrafting. As the crude drug is popular trade item, large scale production of St. John's wort is subject to further development.

8.9.1 Seeding Materials

There are many registered varieties of St. John's wort in the world. These varieties are Authos, Hyperimed, Hyperixtrale and Motiv in Germany, Topaz in Poland, Uperikon, Hypera and Gold in Slovakia. The most cultivated variety in the world today is the 'Topaz' variety developed in Poland. The proportion of hypericin in this variety is high and ranges from 0.15% to 0.24% (Dachler and Pelzmann 1999). There are no registered varieties in our country yet. The seed must be free from disease factors. Seeds can remain for 10 years or more, capable of forming a new plant in the soil. St. John's wort is a plant whose germination power increases in the light. The seeds show exogenous and endogenous dormancy (Çırak et al. 2004). Dormancy can be eliminated by proper storage, washing of seeds, high germination temperature, light during germination, pre-germination (Braunewell 1991; Zeybek and Zeybek 1994; Baytop 1999; Marquard and Kroth 2001; Ceylan et al. 2002; Nia 2004; Zeybek and Haksel 2011). In order to break dormancy and reduce germination, inhibiting secretions leaking from the capsule, it is recommended to wash the seeds with hot water at 40 °C and to apply 50 ppm GA, and in the absence of light, to apply 0.01 mole KNO_3 (Çırak et al. 2004). The International Seed Testing Association (ISTA) has determined germination temperature of 20–30 °C, as seed test conditions for *Hypericum perforatum* L. and stated that the first count should be made on the fourth-seventh day and the last count on the 21st day (ISTA 2014).

8.9.2 Agricultural Technology (Production Techniques)

Production in *H. perforatum* L. can be started from both generative and vegetative propagation (Braunewell 1991). Presently, the most frequently applied methods are: Direct seed sowing, production by transplants and vegetative propagation.

Direct Sowing into the Open Field Since St. John's wort seeds are exceedingly small (1000 grains weighing 0.1 g), the soil needs to be well prepared for direct seed sowing. A good emergence cannot be guaranteed, even though there is a good soil preparation. Sowing in the fall is generally recommended. It takes about four weeks for the seed to germinate in the soil. However, if the weather is warmer or the cultivated area is covered, then germination will take place in a shorter time. When sowing, the seed should be sown very shallowly and pressed down. The number of seeds varies between 50–200 g per 1000 sq. m. The row spacing is approximately 40–50 cm (Marquard and Kroth 2001).

Production by Transplants Success is higher in production by seedling. This method is applied by first obtaining seedlings from seeds and then transplanting them into the field (Fig. 8.4). However, germination of seeds varies according to the storage condition of the seed, germination temperature, light intensity at germination and the priming applications (washing the seeds, gibberellic acid treatment, etc.) (Crompton et al. 1988; Jensen et al. 1995; Pluhár et al. 2000). Plant dormancy can last up to eleven months depending on the origin. According to the ecological conditions of the relevant region, the sowing should be done between October and December. Sowing on seedbeds should be done as broadcasting sowing and with the calculation of 4–5 g of seeds per square meter. After sowing, the seeds are covered with a thin layer of manure (farmyard manure 0.5 cm thick). The germination temperature varies between 20 and 25 °C. Homogenous light conditions favor the rapid germination of the seeds (Bomme 1997). The emergence takes place about a week. In some cases, plants can be transplanted into small pots, after the emergence.

Fig. 8.4 Germination of seeds and young seedlings. (Photos: Kaçar O)

If the plants are cultivated in greenhouses, the seedlings should be aclimatized to the external conditions, at least a week before they are transplanted into the field. While transplanting into the field, the row spacing approximately is 40–50 cm and intra-row spacing is 25–30 cm. In this case, there are about 8000 plants per 1000 sq. m. The transfer of seedlings to the open field takes place in March–April, depending on the ecological conditions (Bayram 2020).

Vegetative Propagation Vegetative propagation is practiced in small areas and during plant breeding (Bomme 1997; Marquard and Kroth 2001). Production with vegetative parts is preferred against the possibility that some traits may not be passed on to the next generation due to genetic divergence in production with seed and when rapid production is required. For this purpose, stem cuttings of 5 cm length are taken from the shoots of the mother plant, in spring. These cuttings are treated with a rooting stimulant hormone and planted 2 cm apart, in a medium prepared with some materials such as soil, sand, peat, perlite, coco-peat and vermiculite, etc. In this case, 1200 cuttings can be found per square meter. If the environmental conditions are suitable (cuttings covered, temperature of 20–25 °C, additional light, and sufficient fertilization), almost 100% of the cuttings will root. A period of about six weeks is needed for a good rooting and tillering. In addition, rooted cuttings are taken from the existing plants in the field at the end of March and the first week of April and and these cuttings are planted in the field (Nia 2004; Nia and Bayram 2005).

8.9.3 Plant Care Processes

Fertilization In determining the amount of fertilizer to be applied soil analysis results, ecological conditions of the region, fertilization time and the type of fertilizer to be given play a very crucial role. According to studies by Braunewell 1991; Lurtz and Plescher 1997 on the hypericin rate and yield in St. John's wort, phosphorus fertilizers had an increasing effect especially on the active substance rate, whereas a decrease in hypericin rate was observed with the increase in the amount of nitrogen fertilizers. In addition, the increase in the amount of nitrogen fertilizer caused an increase in fungal diseases, increased lodging, delayed flowering date and as a result, decreased yields. The average amount of mineral fertilizer to be given to St. John's wort is 10 kg of nitrogen, 4 kg of phosphorus and 11 kg of potassium per 1000 sq. m under German conditions (Lieres 1989; Bomme 1997). Under the ecological conditions in Bornova, ammonium sulphate fertilizer (6 kg pure nitrogen) and TSP (Triple super phosphate) fertilizer (6 kg pure phosphorus) were applied before planting (Nia 2004). In the second year of vegetation, half of the nitrogen fertilizer was applied in spring, when the plants started to green up and the other half was applied after the first harvest (Fig. 8.5). If organic fertilizer is to be used, it is recommended that it is either applied at least three months before sowing or, even better, applied in the pre-planting stage (Bayram 2020).

Fig. 8.5 Fertilization and flowering St. John's wort field. (Photos: Kaçar O)

Irrigation and Weed Control To guarantee the yield of St. John's wort, it is necessary to pay attention to soil moisture from sowing or planting. In Türkiye, according to the ecological conditions of the region, the plants should be provided with enough water during the vegetation period. The water content of the field capacity should not fall below 25%. During the vegetation period, mechanical control of weeds should be conducted when necessary. Hand tools or hoeing machines can be equally used for mechanical weed-control. However, no herbicides application is recommended to eradicate weeds (Bayram 2020).

8.9.4 *Harvesting*

St. John's wort can be harvested from June to September. The effect of ontogenetic variability, especially on the proportion of active substances in the plant, is observed. Therefore, it is crucial to determine the appropriate harvest time. The aerial parts of the plant should be collected during the period flowering and full bloom. The most significant proportion of active substances in St. John's wort is in the period of full flowering. According to some researchers, the most suitable mowing time is the period when 70% of the flowers have finished blooming (Schneider and Marquard 1996; Bomme 2000; Marquard and Kroth 2001) (Fig. 8.6). It has also been determined that hypericin and pseudohypericin production started to decrease rapidly after the flowers opened and pollination occurred (Benigni et al. 1971; Branther et al. 1994). Buds and flowers have higher levels of hypericin than capsules (Kaçar et al. 2008), leaves (Çırak and Kurt 2016), stems (Cirak et al. 2007a) and the whole plant (Shabani et al. 2019).

In general, under Türkiye conditions, St. John's wort can be harvested once, in the first planting year, and twice, in the second year. The highest naphthodianthrones (hypericin and pseudohypericin) and flavonoid contents and highest yields have been found in the upper 30–60 cm of the plant (Berghöfer and Hölz 1986). For producing a good quality drug and extract from St. John's wort, 20–30 cm of the

Fig. 8.6 General view of the plant at harvest time and the harvest. (Photos: Kaçar O)

upper part of the flowering plant should be harvested. In St. John's wort, it has been reported that the hypericin content is higher in the flowering upper part of the plant (Bomme 1997; Southwell and Bourke 2001; Pluhár et al. 2001), and that the part of the plant in the area of the flowers contains 90% of the hypericin content of the whole plant (Fröbus and Plescher 1995). For this reason, the yield of top drug herbage is vital for obtaining pharmaceutical-quality drug and extract (Zeybek and Haksel 2011). In the study conducted by Kaçar and Azkan (2004), a significant relationship was determined between the number of buds and hypericin ratio and it was revealed that the number of buds should be high in the density of flowers in the part of the plant called top drug herbage. It has been stated that the abundance of branches with many buds and flowers is important in obtaining quality drugs. Therefore it should be considered as a selection criterion in breeding studies (Pluhár and Bernáth 2000; Kaçar and Azkan 2004; Sun et al. 2019). It was found that the amount of hypericin in the plant was positively correlated with the density of secretory vesicles (glands) on the leaf, while the leaf area and the amount of hypericin were negatively correlated (Çırak et al. 2007b). Harvesting machine can be used for harvesting. In small areas, manual harvesting is possible. Particular care should be taken to ensure that there is no loss in the process of machine harvesting. It is accepted that the most important agronomic criteria for St. John's wort harvesting are plant height, top drug herbage yield and hypericin ratio (Çakmak and Bayram 2003).

8.9.5 Diseases and Pests

St. John's wort is especially susceptible to fungal diseases. It is not suitable for cultivation on heavy and clay soils. It is susceptible to the disease called Anthracnose caused by the fungus *Colletotrichum gloeosporioides* (Plescher 1997). Typical

Fig. 8.7 *Hypericum perforatum* L. plants infected with *Colletotrichum gloeosporioides*. (Photos: Kaçar O)

symptoms of anthracnose in the field are browning, stem lesions, and reddening of infected plants (Debrunner and Rauber 2000) (Fig. 8.7).

For this reason, it needs to take four to five years to replant St. John's wort in the same place. New plantations should never be established in the area where St. John's wort was previously located (Bayram 2020). In addition to *Colletotrichum gloeosporioides*, fungal diseases such as *Pythium* spec. and *Rhizoctonia* spec., happening especially in the seedling stage, and sawflies (Tenthredinidae) can cause damage to the plant (Plescher 1997).

8.9.6 Drying

St. John's wort should not be left in bulk for more than four hours after harvesting. Drying should be started immediately after harvesting. The drying temperature should be between 40–60 °C (Dachler and Pelzmann 1999). Some researchers have emphasized that the drying temperature should not rise above 40 °C (Sezik et al. 2004; Zeybek and Haksel 2011). It should also be noted that the temperature should not rise above 50 °C in the storage environment after drying. In a study conducted with the microwave drying method at different energy levels, it was found that the most appropriate technique for preserving the hypericin content of St. John's wort flowers is 850 W microwave power, drying time (150 s) and energy consumption (0.06 kWh) (Alibas and Kacar 2016).

8.9.7 The Yields

The yields of St. John's wort are rather variable. Yields show great variation according to ecological conditions, cultivation technique, plant age, variety, and especially harvest height. In the first year, development is relatively slow, plants are less productive, as they have fewer flowers and branches (Büter et al. 1998) Yield values increase with plant age (Pluhár et al. 2001; Kordana and Zalecki 1997) (Figs. 8.8 and 8.9). A study conducted in Poland, reported that hypericin rates

Fig. 8.8 *Hypericum perforatum* L. growth during the first and second years. (Photos: Kaçar O)

Fig. 8.9 *Hypericum perforatum* L. cultivation. (Photos: Bayram E)

were low in the first year and increased – by approximately 50% – in the second year (Kordana and Zalecki 1997).

In studies conducted with different cultivars and populations in different ecologies in Türkiye, top drug herbage yield varied between 880–4605 kg/ha (Geren 2003; Bayram et al. 2002; Bayram et al. 2004; Nia and Bayram 2005; Kaçar and Azkan 2007; Kaçar et al. 2011).

8.10 Conclusions

The sustainable supply of *Hypericum perforatum* L., that has a natural distribution in Türkiye and is traded as a medicinal plant, is critical. The protection of its genetic resources has therefore come to the forefront of studies. As a result of recent research, it has become possible to prevent the destruction of the natural flora by collecting crude drug in a sustainable way and to produce a standard and homogeneous product, by cultivation. In Turkey, the expansion of field production of St. John's wort has become necessary, especially in view of the increasing demand on high-quality products. For this reason, by accelerating breeding, it is important to secure appropriate propagation materials and to deploy good agronomic methods (Good Agricultural Practices or organic agriculture), to teach and support producers and research. The aim is to grow both efficient and high- quality products. It is anticipated that the production of standardized products with high added value, will contribute to the national economy for the benefit of both producers and consumers. Ultimately, St. John's wort is an essential medicinal herb whose sustainable production in Türkiye should be further enhanced.

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Chapter 9
Turkish Oregano (*Origanum* spp.): Biodiversity, Cultivation, Traditional and Commercial Uses

Çiğdem Sönmez

Abstract Different genera and species containing thymol and carvacrol in their essential oil are classified under the name of "Kekik" in Turkey. It is divided into two groups, as oregano and thyme, in the international commerce. Today, most of the *Origanum* species are cultivated under field conditions but it can also be gathered from nature. The main region where *Origanum* species are naturally distributed is the Mediterranean Region. It is also distributed into many parts of the world, though in different ways. Turkey has the largest share in the world's oregano trade. *Origanum* species have been used for many different purposes since ancient times and they have preserved their important place among medicinal and aromatic plants even today. Due to the strong antibacterial, antifungal and antioxidant effects of their essential oils, they are used for many different purposes in the spice, food and pharmaceutical industries.

Keywords *Origanum* · Essential oil · Carvacrol · Tyhmol

9.1 Introduction

Different plant species with thymol and carvacrol as their main essential oil components are known as "Kekik" in Turkish because they have similar aroma and flavor. There are about 61 species with such characteristics, and they belong to the Lamiaceae and Verbenaceae families worldwide. The most important genus in the Lamiaceae family is *Origanum*. *Origanum vulgare* and *Origanum onites* appears to be economically important species in this genus. Also, *Lippia* and *Lanata* species from the Verbenaceae family are known as oregano. It is known that oregano consists of two groups: Mediterranean oregano and Mexican oregano. Mediterranean oregano is *Origanum* spp., Mexican oregano is *Lippia* sp. forms. The species known as oregano with economic importance are *Origanum vulgare* (Greek

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oregano), *Origanum onites* (Turkish oregano), *Thymbra capitata* (Spanish oregano), *Lippia origanoides* Kunth (Mexican oreganus). Turkey has the largest share in the world's oregano trade. Mainly *O. onites*, *O. vulgare* subsp. *hirtum*, *O. minutiflorum* Schwartz & P. H. Davis, *O. majorana* L. and *O. syriacum* L. *subsp bevanii* Greuter&Burget. In addition to these, *T. capitata*, *T. spicata* L. and *T. sintenisii* Bornm. & Azn., *Satureja cuneifolia* Ten., *S. hortensis* L., *S. montana* L., *S. spicigera* and *Thymus eigii* Jalas are exported species (Başer 2001).

9.2 Taxonomic Characteristics, Geographical Distribution

There is not a definitive consensus on the taxonomy of *Origanum* spp. and it is still a matter of debate. It consists of 49 taxa and 44 species, according to the morphological features of the *Origanum* genus and classification of the chemical content of essential oils. Iestwaart's classification is still widely accepted today, and it is used in the classification of species belonging to the *Origanum* genus (Table 9.1). These sections are as follows; Sect. Amaracus (Gleditsch) Vogel, Sect. Anatolicon Ietsw., Sect. Breviflametum Ietsw., Sect. Longitubus Ietsw., Sect. Chilocalyx (Briq.) Ietsw., Sect. Majorana (Mill.) Benth., Sect. Campanulaticaly x Ietsw., Sect. Elongataspica Ietsw. Sect. Origanum, and Sect. ProlaticorollaIetsw. It is stated that with the discovery of new species, the number of species increased to 44, and the number of hybrids increased to 20 with natural and artificial hybrids. In general, the chromosome number of *Origanum* species and their hybrids is $2n = 30$. There are 21 *Origanum* species in Turkey and out of 13 hybrids 12 are endemic (Arabacı et al. 2021; Genç et al. 2020: Narini 2014; Kintzios 2004).

Origanum dubium Boiss. is grown in the wild flora of Turkey, Greece and Cyprus. *O. dubium* is composed of carvacrol, linalool, and linalool carvacrol chemotypes, as well as the thymol chemotype. Recently, Lukas et al. (2013) reported a new basis about the taxonomic uncertainties concerning section Majorana. They assessed the taxonomic status of *O. onites, O. syriacum, O. dubium* and *O. majorana* and discuss evolutionary relationships in section Majorana by considering molecular, morphological and phytochemical evidence. According to their results, "cymyl" chemotype of *Origanum majorana* L. is classified as *Origanum dubium* Boiss (Turgut et al. 2017).

Nearly about 70% of *Origanum* species are endemic, spreading from the Azores to Taiwan. Most of the species belonging to the *Origanum* genus originate from the Mediterranean region. 75% of these are located in the Eastern Mediterranean Region. In addition, these species spread from coastal regions to high mountains, from east to west in different regions of the world. The distribution table of the Origanum section is given below (Henry et al. 2020; Skoula and Harborne 2002; Iestwaart 1980) (Table 9.1). Observing the distribution of the sections, it is seen that Turkey, Greece and Aegean islands are rich in species diversity.

Table 9.1 Sections of *Origanum* species (Iestwaart 1980)

Section	sp/spp/ssp	Distribution
Amaracus Bentham	*O. boissieri* Ietswaart	Turkey
	O. calcaratum Jussieu	Greece – Aegean Island, Greece-Crete
	O. cordifolium Vogel	Cyprus, Syria
	O. dictamnus L.	Greece-Crete
	O. saccatum Davis	Turkey
	O. solymicum Davis	Turkey
	O. symes Carlström	Greece – Aegean Island
Anatolicon Bentham	*O. akhdarense* Ietswaart et Boulos	Libya
	O. cyrenaicum Beguinot et Vaccari	Libya
	O. hypercifolium Schwarz et Davis	Turkey
	O. libanoticum Boissier	Lebanon
	O. pampaninii Ietswaart	Libya
	O. scabrum Boissier et Heldreich	Greece, Greece-Crete
	O. sipyleum L.	Turkey, Greece – Aegean Island
	O. vetteri Briquet et Barbey	Greece – Aegean Island
Brevifilamentum Ietswaart	*O. acutidens* Ietswaar	Turkey
	O. bargyli Mouterde	Turkey, Syria
	O. brevidens Dinsmore	Turkey
	O. hausskenechtii Boissier	Turkey
	O. husnucan-baserii H. Duman, Z. Aytaç et A. Duran	Turkey
	O. leptocladum Boissier	Turkey
	O. rotundifolium Boissier	Turkey, Georgia
Longitubus Ietswaar	*O. amanum* Post	Turkey
Chilocalyx Ietswaart	*O. bilgeri* Davis	Turkey
	O. micranthum Vogel	Turkey
	O. microphyllum Vogel	Greece-Crete
	O. minutiflorum Schwarz et Davis	Turkey
Majorana Bentham	*O. majorana* L	Turkey, Cyprus, Greece – Aegean Island
	O. onites L.	Turkey, Greece, Greece – Aegean Island, Greece-Crete, Egypt-Sinai
	O. syriacum L	Turkey, Cyprus, Syria, Lebanon,Israel, Jordan, Egypt-Sinai
	O. syriacum L. var. syriacum	Israel, Jordan, Syria
	O. syriacum L. var. *bevanii* Ietswaart	Turkey, Cyprus, Syria, Lebanon
	O. syriacum L. var. *sinaicum* Ietswaart	Egypt-Sinai

(continued)

Table 9.1 (continued)

Section	sp/spp/ssp	Distribution
Campanulaticaly x Ietswaart	*O. dayi* Post	Israel
	O. isthmicum Danin	Israe-N. Sinai
	O. jordanicum Danin and Künne	Jordan
	O. petraeum Danin	Jordan
	O. punonense Danin	Jordan
	O. ramonense Danin	Israel-Negev
Elongataspica Ietswaart	*O. elongatum* Emberger ex Maire	Morroco
	O. floribundum Munby	Algeria
	O. grosii Pau et Font Quer ex Ietswaart	Morroco
Origanum	*O. vulgare* L	Azores-Taiwan, N. Africa-Scandinavia
	O. vulgare L. ssp. vulgare	Britian-Scandinavia-Taiwan
	O. vulgare L. ssp. glandulosum Ietswaart	Algeria, Tunisia
	O. vulgare L. ssp. *gracile* Ietswaart	Turkey-Afganistan-S. Siberia
	O. vulgare L. ssp. *hirtum* Ietswaart	Turkey, Balkan
	O. vulgare L. ssp. *virens* Ietwaart	Azores, Madeira, Balearic Israel, Portugal, Spain, Morroco
	O. vulgare L. ssp. viride Hayek	Corse-China
Prolaticorolla Ietswaart	*O. compactum* Bentham	Spain, Morroco
	O. ehrenbergii Boissier	Lebanon
	O. laevigatum Boissier	Turkey, Cyprus

Abbreviations in the Table: *sp* species, *spp* genres, *ssp* subspecies

9.3 Botanical Characteristics

The underground parts of *Origanum* species have a woody structure. The roots of many species, especially those grown in the Eastern Mediterranean, are thick and woody. Above ground parts have a bushy form. The height of the branches varies according to the species, and in some species, it is 10–30 cm tall. Most often the branch height is 30–60 cm, although in some species it can be 60 cm or taller than 1 meter. Stems usually have lateral branches. Except for a few species, all stems are hairy. The leaves are sessile except for a few species. Mostly, the leaves are of similar length, but in certain species they may be larger. Leaf lengths vary between 2 and 40 mm, and widths vary between 2 and 30 mm. There are two types of glands in the leaves, petiolate and non-petiolate. These glands also occur on stems, bracts, calyces, and corollas. The leaves of *Origanum* species may differ in size, shape and thickness, as well as the density, type and size of glandular and non-glandular hairs covering their surfaces. While the glands are numerous in vegetative organs, their density decreases in generative organs. In the glands, thymol and cavracrol are secreted from the monoterpenes, which are the main components of the essential oil. There are morphological and chemical varieties of *Origanum* species, including carvacrol, thymol, linalool and p-cymene (Dirmenci et al. 2018; Kintzios 2002; Ceylan 1997; Iestwaart 1980). *Origanum syriacum* var. *bevanii* species is 65–70 cm long, the essential oil rate varies between 3–5% and the main component of the essential oil is cis-sabinne hydrate, γ-terpinene, carvacrol and thymol. *Origanum onites* can grow in regions up to 1–400 meters altitude in the Mediterranean climate (Fig. 9.1). The plant can reach up to 1 m in height and the essential oil rate is between 2% and 5%. Carvacrol, thymol and α-terpinene components are noteworthy as the main components. Some chemotypes have very high levels of linalool. *Origanum vulgare* subsp. *hirtum* is a shorter plant (60–65 cm) than *O. onites*. Its main essential oil component is similar to *O. onites* and its ratio is 3.6–5.7%. The seeds are very small, thousand seeds weigh between 0.2 and 0.3 g. *O. minutiflorum* is an endemic species for Turkey. The essential oil ratio is the same as *O. onites* and contains 40–80% carvacrol, 25% thymol, 13–8% terpinene and 6% p-cymene as the major component. The *O. dubium* formerly called *O. majorana* species is 20–80 cm tall, the Turkish type has a high essential oil content (6.5–7.7%) and is cultivated for essential oil production. Carvacrol ratio varies between 78% and 90% (Alekseeva et al. 2020; Bozdemir 2019) (Fig. 9.2).

Fig. 9.1 Natural *Origanum onites* plants in Perge ancient city, Antalya

Fig. 9.2 *Origanum onites* field in Denizli Province

9.4 Ecomonic Characteristics

O. majorana L. is cultivated in France, Greece, Hungary, the United States, Egypt, Germany and other Mediterranean countries. *O. vulgare* L. and *O. syriacum* L. are commercially grown in Israel. In addition, *O. vulgare* L, *O. heracleoticum* L. and *O. majorana* are cultivated in Albania. Turkey has the largest share in the world's oregano trade (Trumpy 2012). The species with thymol and carvacrol in their essential oil are called "kekik". The Oregano species exported from Turkey are *O. onites* (İzmir oregano, Turkish oregano), *O. vulgare* subsp. *hirtum* (Istanbul oregano, black oregano), *O. minutiflorum* Schwarz & P.H. Davis (Sütçüler oregano, Yayla oregano), *O. dubium* formerly called *O. majorana* L. (White oregano, Alanya oregano) and *O. syriacum* L. subsp. *bevanii* Greuter&Burget (Mountain oregano, Syrian oregano, Israel oregano), *Thymbra capitata* (Spanish oregano), *T. spicata* L., and *T. sintenisii* Bornm. & Min. (Sharp oregano), *Satureja cuneifolia* Ten. (Sater), *S. hortensis* L., *S. montana* L., *S. spicigera* (K. Koch) Boiss. (Trabzon oregano) and *Thymus eigii* (Zohary& Davis) Jalas (Sönmez 2019; Tonçer et al. 2009, 2010; Schulz et al. 2005; Kintzios 2002; Başer 2001; Azcan et al. 2000). Although several *Origanum* species (mainly *O. onites*) are cultivated in Turkey, there are also natural gatherings. Analysing data of the last ten decade, it is seen that the production of oregano increased from 7771 ha in 2011 to 19,957 ha, in 2021 (Fig. 9.3). One of the reasons for this increase may be the high profit margin compared to other products.

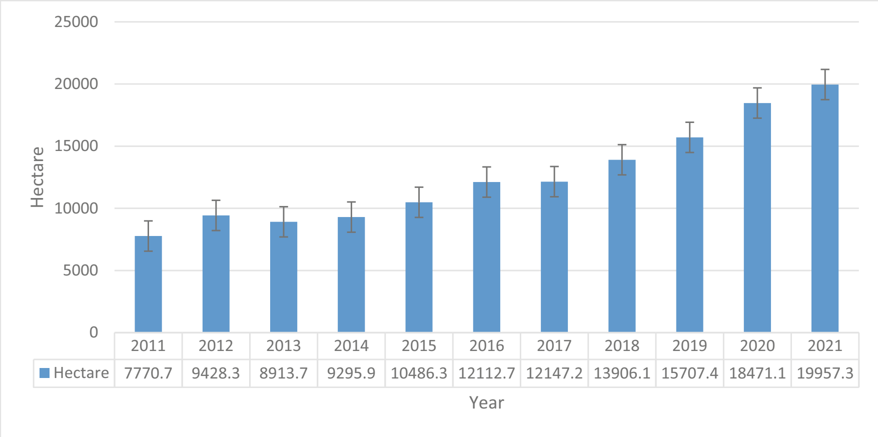

Fig. 9.3 Changes in the territory of Turkish Origano production in the period 2011–2021. TURKSTAT, Crop Production Statistics, 2022

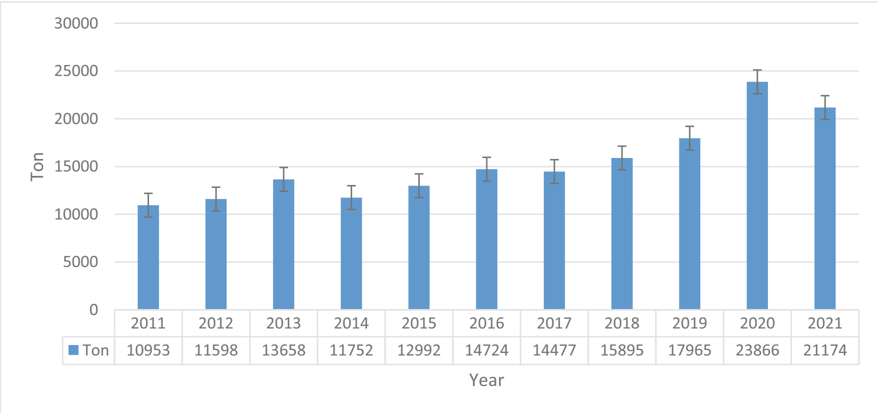

Fig. 9.4 Changes in Turkish Origano production in the period 2011–2021. TURKSTAT, Crop Production Statistics, 2022

Oregano production also increased from 10,953 tons in 2011 to 21,174 tons in 2021. It can be seen that there has been a steady increase over the years (Fig. 9.4). Oregano is mainly cultivated in Denizli (85%) and followed by Manisa (4%) and Uşak (4%). One of the reasons why Turkey has a leading position in the oregano trade is the quality.

In Turkey, studies on cultivar breeding of *Origanum* and *Thymus* species were carried out and eight commercial varieties were developed by institutions and companies. Six out of these varieties generate from *Origanum* species with high yield and quality and two from *T. vulgaris* L. (Table 9.2). More information on these varieties can be found below (Table 9.2). With these varieties, significant

Table 9.2 Turkey's registered oregano and tyme varieties

Variety name	Registerated year	Species	Institution/Company
Ceylan-2002	2002	*Origanum onites* L.	Ege University, Faculty of Agriculture
Tayşi-2002	2002	*Origanum onites* L.	Ege University, Faculty of Agriculture
Winter	2015	*Thymus vulgaris* L.	Anadolu Seed Company
Timo	2015	*Thymus vulgaris* L.	AG Seed Company
Tınmaz-2015	2015	*Origanum vulgare* subsp. *hirtum*	Republic of Turkey Ministry of Agriculture and Forestry, Atatürk Horticultural Central Research Institute
Başer-2015	2015	*Origanum vulgare* subsp. *hirtum*	Republic of Turkey Ministry of Agriculture and Forestry, Atatürk Horticultural Central Research Institute
Oğuz-2012	2018	*Origanum onites* L.	Republic of Turkey Ministry of Agriculture and Forestry, Aegean Agricultural Research Institute
Tekin-2017	2020	*O. onites* × *O. syriacum*	GAP International Agricultural Research and Training Center

Bozdemir (2019)

developments have been achieved in the cultivation of high yield crops with the standard quality demanded by the industry.

Due to the open pollination of the plants, the cultivars were developed using the clone selection method, which necessitates vegetative propagation by preventing the propagation of plants using seeds. Tekin-2017 is a commercial variety obtained through hybridization of *O. nites* and *O. syriacum* species.

9.5 Cultivation of Turkish Oregano

Origanum species are widely traded in the world and *O. onites* L. is the first species cultivated under field conditions. The general principles of Oregano cultivation such as; seed sowing, seedling production, tillage, sowing and planting methods, fertilization, irrigation, weed control, harvest time and method are similar. It is possible to propagate perennial *Origanum* species vegetative and generatively. Since the seeds are very small and germination is very slow, there are some difficulties in sowing directly into the field. Therefore, it is not recommended. The suitable best time for seed sowing and vegetative reproduction in Mediterranean climate conditions is October–November. Seedling pads to be planted are filled with 1/3 sand, 1/3 soil and 1/3 mature animal manure. Then, planting the seeds in specially prepared seedling pads and transplanting the seedlings to the field is the most applied and recommended method. It is important that the seed material is clean and mature in order to obtain well-developed smooth seedlings. Ripe seeds retain their ability to germinate for 2–3 years (Ceylan 1997). Seed Test Association (ISTA) reported that the seeds of *O. vulgare* and *O. majorana* species started to germinate in seven days at 20–30 °C, and germination was completed in 21 days (ISTA 2014). 1–2 g of seeds is sufficient for approximately 1 m^2 of area. Seedlings should be irrigated regularly, ventilation and weed control should be proper. Plants should be transferred to the field in early spring, approximately 4–5 months after sowing. Old stems or young stems can be used in vegetative production. By cutting the stems, hormones such as IBA (Indole Butyric Acid) that will increase rooting can be applied. In the Mediterranean climate zone, October–November is the best time for bud cuttings. The rooted seedling transferred to field conditions in the spring before the weather gets too hot. Although *Origanum* species can grow in different soils, the most suitable conditions are clay-loam, alluvial, well-drained, soils with a pH of 6–8. For young plants propagated from seed or cuttings, plant spacing varies according to the mechanization conditons, but it is sufficient to plant 14,000–15,000 (plants/ha) plants per hectare. Under irrigated conditions it is possible to harvest more than once. While *O. onites* L. are adapted to arid conditions, *O. vulgare* subsp. *hirtum*, on the other hand, are better adapted to moist soils. Irrigation is required in order to obtain yielded products of standard quality in field conditions. Irrigation amount varies according to climate and soil conditions. The plants should be irrigated after each harvest and during the flowering period. Nitrogen fertilization increases the yield and can be applied two or three times (50–150 kg/ha). Fertilizer should be applied for the first time in the spring, the second fertilizer after the first harvest, and the third time following the second harvest. Phosphorus and potassium fertilizers are recommended during planting and in the spring. Although green herb yield and drug herb yield are low in the first harvest year, yields increase in the following years. Under Aegean Region conditions, average green herb yield is 15,000 kg/ha, drug herb yield is around 5000 kg/ha. Yields vary according to the years, regions and cultivation technique. Seed should be harvested when the seeds are fully ripe (Alekseeva et al. 2020; Harini 2014; Ceylan 1997).

Twenty years ago, 80% of the traded oregano were collected from natural flora. However, these figures are reversed due to the success story in Denizli Province. After Turkish tobacco law comes into force in 2002, tobacco production area in Denizli were sharply declined. Therefore, tobacco producers started *O. onites* cultivation as an alternative crop. In fact, *O. onites* was naturally grown and wild collected in that area. Oregano farmers in Denizli generally use their own seedlings obtained from seeds and cultivated without irrigation as a perennial crop (Fig. 9.2). Oregano plants are harvested by cutting in the flowering stage and then they are dried under sun. The average dry leaf yield in Denizli is 150 kg/da. After that, dry leaves are marketed as drug (Folia Origani) and after steam distillation as carvacrol rich essential oils (4–7%) (Baydar and Arabaci 2013). Turkey provides more than 50% of the world's exported oregano (Origanum types). Turkey produces 21,000 tonnes dried oregano leaves per year and earns 64 million USD export income (TURKSTAT 2022). Denizli has become the centre of oregano production in Turkey with %85 of Turkey's oregano production.

9.6 Traditional Uses and Usage Areas

According to mythology, *Origanum* was taken from the depths of the ocean by Aphrodite, the goddess of love, and brought to the heights of the mountains, where the sunlight shone the brightest (Gezgin 2007). The earliest records of the use of *Origanum* were found in Hittite tablets from 1200–1600 BC. Some sources claim that Oregano was transported to North America by European colonies. Hippocrates describes him as the prince of herbs. Oregano plants have been associated with love, protection, purification, healing and happiness, and religious traditions and myths (Meyers 2005). It has been used in many areas because of the scent. It is known that they were used as incense in temples and as a repellant to insects in homes during the Ancient Greek period. In ancient Greek and Roman times Origanum spp. was also used in alcoholic beverages and to give flavor to cheese. In addition, in Egypt, they were aware of the antiseptic and preserving properties of these plants and they were used in the mummification process. The earliest records of the use of oregano for healing date back centuries. Early writers such as Theophrastus, Mithradates, Pliny, Dioscorides, and Galen mentioned these plants (Bozdemir 2019; Gezgin 2007; Başer 1997).

Since ancient times, *Origanum* species, classified among medicinal plants, have been used as a spice in the kitchen, fragrance in perfumery and raw material in the pharmaceutical industry due to their pleasant odour and benefit to human health. Such qualities are due to the type of plant, the climatic conditions of its location and the essential oil content. Other metabolic chemicals are important compounds such as fixed oils and flavonoids. Carcavrol and sabinene hydrate are two chemicals related to taste in oreganos used for seasoning in kitchens. Carvacrol is the key ingredient responsible for the harsh and pungent aroma of *Origanum* species such as *O. vulgare* subsp. *hirtum*, *O. onites*, *O. minutiflorum* and *O. syriacum*. Sabinene hydrate has a sweet aroma and is highly prevalent in *O. majorana* and its hybrids and subspecies of *O. vulgare*. *O. majorana* was used during the Renaissance in salads and in the servings of eggs, rice, meat and fish. *Origanum* species are used in herbal teas and alcoholic and non-alcoholic beverages. In folk medicine, oreganos are herbal remedies used for respiratory problems, cough, stomach problems, painful menstruation, urinary tract diseases, diuretic, rheumatism, muscle pain. (Alekseeva et al. 2020; Bajer 2019; Faydaoğlu and Sürücüoğlu 2011; Conforti et al. 2011; Üçer 2010; Baytop 1999; Başer 1997; Asımgil 1993). Tymol, found in *Origanum* species, is characterized by a thyme-type aroma. Other chemicals are linalool, gamma-terpinene, p-cymene and terpinene-4-ol, which are essential oil components (Meyers 2005).

9.7 Chemistry and Modern Medicine Aproaches

The essential oils of *Origanum* are rich in terpenic substances. The monocyclic monoterpenes carvacrol and tymol are the main components in commercialized *Origanum* species. In addition, methyl ethers and acetates of γ-terpinene, α-terpinene, p-cymene, p-cymenene, carvacrol and thymol, terpinen-4-ol, p-cymen-8-ol, p-cymen-7-ol, thymo -quinone and thymohydroquinone are components found in different proportions. Apart from these, thujene, sabinene, camphene, α-pinene, β-pinene, borneol, cis-sabinene hydrate, trans-sabinene hydrate, cis-sabinene hydrate acetate, trans-sabinene hydrate acetate, cis-sabinol, trans-sabinol, camphor and Isoborneol are bicyclicmonoterpene compounds contained in these plants. Sesquiterpenes commonly isolated from these plants are β-bisabolene, β-caryophyllene, aromandrene, germacrene, α-humulene, β-bourbonene, β-cubene, α-muurolene, γ-muurolene, α-copaene, β-caryophyllene γ oxide, −cadinene, α-cadinol, germacrene-D-ol and bicyclogermacrene. In *Origanum* species, ursolic and oleanolic acids are the main triterpenoids. The most common phenolic compounds isolated from *Origanum* species are hydroquinone, hydroquinone monomethyl ether, and glucoside arbutin. In addition, these plants are characterized by phenolics such as p-hydroxybenzoic, vanillic, syringic, protocatechuic acids, hydroxycinnamic acids, caffeic and cinnamic acids, ester forms of rosmarinic acid, chlorogenic acid. Many flavonoid group substances such as; apigenin, genkwanin, chrysin, neglectein, mosloflavone, apigenin 7-O-glucuronide, isovitexin etc., have also been determined in *Origanum* species (Marelli et al. 2018; Asensio et al. 2015).

Thymol and **carvacrol** have antifungal and antibacterial properties and are present in different proportions in *Origanum* species. It has been stated in various sources that there is an increase in the amount of tymol and carvacrol in plants grown in arid conditions and especially exposed to water stress. The essential oils of *Origanum* genus have an antimicrobial effect on microorganisms such as *E. coli*, a subspecies of *Salmonella enterica*, *Salmonella enteritidis*, *Pseudomonas aeruginosa, Enterococcus faecalis*, *Salmonella enteritidis*, *Staphylococcus aureus*, *Bacillus subtilis* subsp. *spizizenii*, *Staphylococcus aureus*, *Candida albicans* etc. and stop their development. It is thought that *Origanum* essential oil phenolics penetrate the phospholipid layer in the cell walls of bacteria, damage the cell wall and cytoplasmic membrane, bind to proteins and interfere with their normal functions. Some compounds such as butylatedhydroxytoluene (BHT), propyl gallate (PG), butylatedhydroxyanisole (BHA), tertiarybutylhydroquinone (TBHQ) are commonly used as synthetic antioxidants. However, due to the toxic effects of these synthetic antioxidants, there is an increase in interest in natural ones. It was determined that the antioxidant activity of *Origanum* species is quite high following the extraction with different solvents. Thus, species of *Origanum* genus containing antioxidant compounds are important for pharmacology and food industry. Studies on the effectiveness of *Origanum* species on different cancer types are still ongoing (Alekseeva et al. 2020; Hijazeen 2018; Beltran and Esteban 2016; Busatta et al. 2007).

9.8 Conclusions

Origanum species have been used throughout human history, in folk medicine, ethnobotonically, against many infectious diseases and in pain relief. In addition to the production of food, spices, fragrances, alcoholic and non-alcoholic beverages, scientific research has proven that these plants have strong biological activities. Due to their content of phenolic compounds, *Origanum* species, whose biological activity has been determined, have the potential to be used as an alternative to synthetic antioxidants. Various research projects on origanums are aimed at finding solutions to protect human and animal health and to cure current problems. Species with proven pharmacological effects are preferred for use in the pharmaceutical industry. For such purposes, instead of sourcing *Origanum* species from their wild populations, the cultivation of sustainably cultivated, registered varieties is preferably, as they produce reliable standard quality plant materials.

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Chapter 10
Traditional Medicinal and Aromatic Trees in Türkiye: Laurel (*Laurus nobilis* L.), Sumac (*Rhus coriaria* L.), Hawthorn (*Crataegus* spp.) and Carob (*Ceratonia siliqua* L.)

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Abstract Türkiye is one of the gene centers of medicinal and aromatic trees such as laurel, sumac, hawthorn, and carob. Laurel leaves, with their antiseptic and antibacterial properties and sumac extracts, with their antiviral, antibacterial, antifungal properties, and DNA-protective effects are very popular. The flower, leaf, and fruit extracts of the hawthorn are used for cardiovascular, hypertension, and diabetic diseases. Carob products for hemoglobin, cough, diabetes, and gall bladder diseases. Oleic acid and lauric acid are obtained from bay laurel berries. The main component of bay laurel leaf essential oil is 1,8-cineole. Since sumac oil has a high monounsaturated fatty acid content, it is more resistant to oxidative deterioration and can be stored for a longer time. Hawthorn fruits, leaves, and flowers contain a number of chemical constituents, such as flavonoids, oligomeric proanthocyanidins, triterpene acids, organic acids, sterols, and cardioactive amines. The dry matter of the carob fruit contains a high amount of sugar (more than 50%). In the future, it is expected that the interest will increase in the extracts and drugs of these species, as they are rich sources of bioactive compounds that have positive effects on human health.

Keywords Essential oil · Fixed oil · Lauric acid · Flavonoids · Oxidative deterioration

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10.1 Introduction

Various woody medicinal plant species have been used as major sources of medicine throughout human history in both traditional healthcare systems and the pharmaceutical industry. In general, the roots, stems, branches, buds, leaves, flowers, seeds, fruits, resins, sap, charcoal and tars of the trees are used as raw material and medicine according to their types and characteristics. Although primarily herbaceous plants come to mind as medicinal and aromatic plants, in Anatolia, woody medicinal plants have also been widely used since ancient times, in both traditional medicine and pharmaceutical industry. Among the woody medicinal plants that grow naturally in Turkey, laurel, hawthorn, sumac and carob are the most widely used and traded. In recent years, there has been a significant increase in the use of these plant species and studies are continuing intensively to cultivate them.

Laurel is an evergreen tree that has been the subject of legends for centuries in Anatolia, whose origin goes back thousands of years. It is characterized as a symbol of wisdom, immortality and vitality, due to its ever-greenness and longevity. The fruits and leaves of the bay laurel are used for many different purposes. Fruit fixed oil is extracted by traditional methods from laurel fruits collected by the villagers from the forests. This fixed oil is widely used especially in the production of laurel soap, as well as a skin moisturizer in the cosmetics industry. Traditionally it was used for rheumatism, skin rashes and earaches. The essential oil containing bay leaves containing are collected and dried in spring. These dried leaves are consumed as a spice. The essential oil containing high amounts of cineole and α-terpinyl acetate is obtained by distillation from bay leaves and used in different fields such as medicine, cosmetics etc.

Sumac (Rhus spp.) is a perennial, healing, flavoring and curative wild plant that belongs to the Anacardiaceae family. It is distributed naturally in Mediterranean countries, North Africa, South Europe, Afghanistan and İran and can grow in marginally low agriculture capacity areas such as roadsides, trails, shoulders, bushes and forests. As for Türkiye, Sumac is densely found in the coastal regions of Mediterranean, Aegean, Marmara and Black Sea. Sumac plants grow in groups or as individual plants in these areas. (Dalby 2003; Nayebpour and Asadi-Gharneh 2019; Rayne and Mazza 2007; Ünver and Özcan 2006). Sumac is used as a spice, as a dye, and in medicine. (Baytop 1984; Gök et al. 2020; Güner 2012; Kızıl and Türk 2010; Kurt et al. 2014; Tiryaki 2010; Tuzlacı 2006, 2011).

There are three known domestic species of sumac in Türkiye, *Rhus coriaria* L. (Derici sumac), *Rhus cotinus* L. (Boyacı sumac) and *Rhus chinensis* L. The most common species of sumac in Türkiye is *Rhus coriaria* L. which spreads in the 500–2000 m altitudes. (Ayhan and Altınkaynak 2020). Sumac is traditionally used for many purposes in Türkiye. It is a very popular condiment used as a major souring agent in salads and meat to add a lemony taste. Sumac fruits were used in folk medicine to treat several diseases that include diabetes, diarrhea, urinary system issues, ulcer and liver disease. Powdered fruits were used to stimulate perspiration and reduce cholesterol. Sumac leaves and bark, which contain large amounts of tannins, were also used for centuries in tanning fine leather at the industrial level. (Altınkurt and Heper 1970; Baytop 1984; Gök et al. 2020; Özcan and Hacıseferoğulları 2004).

Crataegus species are native to Africa, America, Europe, and Asia and the natural products are widely used in traditional medical treatment. In these treatments, tinctures, tablets, teas, and fruit extract prepared from *Crataegus* leaves, flowers, and fruits are used (Edwards et al. 2012). *Crataegus* may improve coronary artery blood flow and the contractions of the heart muscle, and therefore are used widely in cardiovascular disorders like arrhythmia, myocardial infarction, and congestive heart failure. *Crataegus* extracts prevent the elimination of plasma lipids such as total cholesterol, triacylglycerides, and LDL and VLDL fractions. These extracts may be employed as an anti-inflammatory, gastro-protective, antimicrobial agent and used as a hepatoprotective agent (Kao et al. 2007). These also inhibit the angiotensin-converting enzymes and reduce the production of the potent blood vessel-constricting substance angiotensin II, hence acting as a hypotensive and diuretic, lower blood pressure in some individuals with high blood pressure but should not be thought of as a substitute for cardiac medications for this condition (Wu et al. 2017).

Türkiye has more than 30 hawthorn species (Donmez and Ozderin 2019) which are called “alıç”, a word that means “small plum” in terms of the size and acidity of the fruit. The most common hawthorn species in Anatolia is *C. monogyna*, however, *C. azarolus* and *C. orientalis* species are also frequently encountered (Caliskan et al. 2016). Hawthorn plants are grown for fruit consumption in Hatay province, the eastern Mediterranean region of Türkiye. However in different regions, flowers and leaves are collected from nature and used for medicinal purposes (Calışkan et al. 2018).

The carob tree (*Ceratonia siliqua* L., Fabaceae) is a native evergreen plant of the Mediterranean climate area including the West and South Anatolia of Türkiye. The non-fleshy and bean-like fruits, called ‘*carob pods’,* are a traditional part of the Mediterranean diet, and the plant has been cultivated in the Agean and Mediterranean regions for centuries for its edible fruits. According to FAO data for 2020, the current world production of carob pod is 49,693 tons per year (FAO 2022) and Türkiye meets 46% of this production with 18,806 tons. Carob fruits (pods) are mostly consumed as a snack in Türkiye. The pods are beneficial against digestive issues, gastritis, lung and liver problems, and gum and tooth issues, while lowering cholesterol and developing muscles. Generally, carob fruits have been used in industries such as pharmaceutical, food, textile, and cosmetics (Morton 1987; Pazir and Alper 2016).

10.2 Bay Laurel (*Laurus nobilis* L.)

10.2.1 Morphological Description and Geographical Distribution of Bay Laurel

Bay laurel is one of the trees that is the symbol of the Mediterranean vegetation. It is a dioecious shrub or tree which can grow up to 15–20 meters in suitable conditions. The trunk has a dark gray, almost black smooth bark. Fresh shoots are green, then later red, black and hairless. Its leaves are simple and elliptical, with a special scent, the tip is pointed or blunt, the leathery upper surface is glossy dark green and the lower surface is dull light green. Leaf lengths vary between 5 and 10 cm. The flowers of the laurel are located in the axil of the leaf, in small lateral bunches. Male flowers are dark yellow, clustered and more plentiful, while the female flowers are light green or yellow-like in color, less frequently on the branches. The periphery of the flower is greenish in color and is in four parts. There are usually 10–12 stamens in male flowers, and 4 stamens in atrophied form in female flowers. Its olive-like fruits are green in its first formation and take on a shiny dark black color as it matures in late September and October. The root system is strong (Cengiz 1979; Zeybek and Zeybek 1994; Anşin and Özkan 1997; Baytop 1999; Yazıcı 2002) (Fig. 10.1).

Bay laurel, originating from Asia, is widely found in Türkiye, Greece, Italy, Spain, Portugal, France, Yugoslavia, Syria, Morocco, Algeria, Mediterranean Islands, California, Mexico and Canary Islands. There are about 2200 species in the tropics and subtropics. Among them, *L. nobilis* L. is a typical small tree that grows mainly on the Mediterranean coasts, Aegean, Marmara and Black Sea coasts and inland parts of these coasts in Türkiye (Davis 1982; Baytop 1999; Şafak and Okan 2004) (Fig. 10.2).

10.2.2 Traditional Use and Herbal Drugs

Laurel is a plant grown for both its leaves and berries. Bay laurel leaves contain essential oil, tannin and bitter substances.The fixed oil obtained from its berries has an important place in soap making. Its leaves are used as a spice and essential oil is

Fig. 10.1 Male flowers, female flowers and mature berries of *Laurus. nobilis*

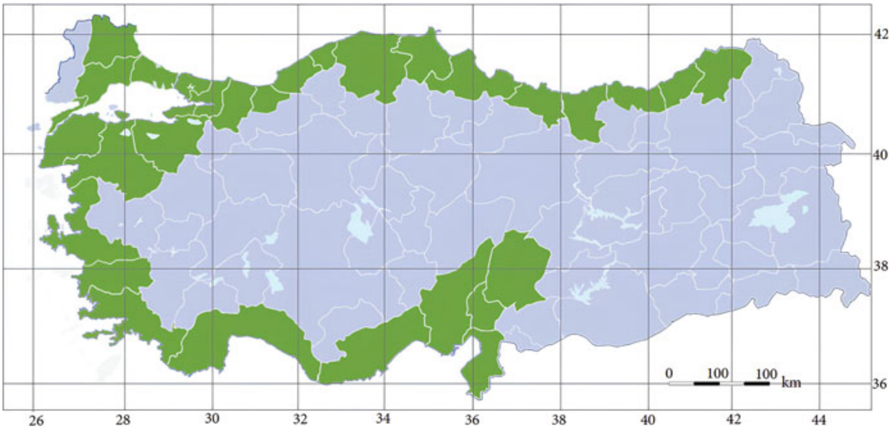

Fig. 10.2 Distribution of *Laurus nobilis* in Turkiye. (Anonymous 2012)

Fig. 10.3 Extraction of bay laurel oil by using the traditional method

extracted from its leaves. In general, one kg of dry leaves is obtained from two kilograms of fresh bay leaves, and 1 kg of oil is obtained from 10 kg of berry (Göker and Acar 1983).

Dating back to mythological ages, laurel is known as a symbol of beauty and fragrance. Laurel fixed oil is traditionally obtained by boiling berries with water in cauldrons (Fig. 10.3). While the average oil rate in the berry is 20%, only around 10% of the oil is obtained with this traditional method, in which the essential oils (1–4%) in the fruit are largely destroyed. Although laurel fixed oil is generally obtained by traditional methods, there are also various mechanical and chemical methods. The oil ratio of laurel berry varies between 13.05% and 38.04% according to extraction methods, genotypes and locations (Yazıcı 2002; Ayanoglu et al. 2010, 2019; Karık et al. 2016; Koçer and Ayanoglu 2021). It consists of 95% fatty acids and 5% essential oils and melts at 30 °C. The oil is mostly used in soap production, as well as a skin moisturizer in the cosmetic industry. Soap made with laurel oil is very useful for skin and hair health (Anonimous 2012). It is known to be used as a medicinal herb for rheumatism, skin rashes and earaches. In the medical literature, it is stated that bay leaf has antioxidant (Simic et al. 2003), analgesic (pain reliever), anti-inflammatory (Sayyah et al. 2002), anticonvulsant (antiepileptic) (Sayyah et al. 2003) and antifungal (Rodilla et al. 2008) effects.

Türkiye is one of the few countries that export the highest quality bay leaves and meets approximately 90% of the world's laurel needs (Şafak and Okan 2004). Bay leaves are harvested between May and October, when their unique aroma is highest. Dried leaves with aromatic odor are used as a flavoring in the food industry. The leaves are ground and used as a seasoning in various dishes, soups, sauces, and especially in the fish and meat-based canning industry. In addition, bay leaves are used in the leather industry and in the packaging of dried figs to prevent infestation. The essential oil obtained from its fresh and dried leaves is widely used in the food, perfumery, medicine and beverage industries (Rivera and Obon 1995; Şahin et al. 2008; Ayanoglu et al. 2010). The amount of essential oil in laurel and the physico-chemical structure of the oil vary depending on the region where it is grown, the time of harvest and the age of the shoots. The amount of essential oil is higher in young shoots than in old shoots. In addition, the volatile oil rate is higher in low altitude coastal areas (Acar 1988; Ceylan and Özay 1990).

Recently, interest and orientation towards natural dyestuffs instead of synthetic dyestuffs has been increasing. The anthocyanin in the laurel (*Laurus nobilis* L.) fruit is used as a natural dye in the food, pharmaceutical and cosmetic industries (Hammer et al. 1999; Driver and Arroy 2001; Longo and Vasapollo 2005; Patrakar et al. 2012).

10.2.3 Major Chemical Constituents and Bioctive Compounds of Bay Laurel

Oleic acid, lauric acid, palmitic acid and linoleic acid constitute 95% of the oil obtained from bay laurel berries. Proportionally, approximately 65% of laurel oil consists of unsaturated and 35% saturated fatty acids. Although there are great variations between genotypes in terms of fatty acid compositions, the approximate average values of the four main components of laurel grown in Türkiye are oleic acid 38–42%, lauric acid 16–24%, palmitic acid 15–18% and linoleic acid 20–23% (Ayanoglu et al. 2010; Karık et al. 2016; Ayanoglu et al. 2019; Koçer and Ayanoglu 2021). Lauric acid, which makes laurel oil valuable, is found in the endocarp. Bay fruits also contain anthocyanins (Yazıcıoğlu and Karaali 1983; Zeybek and Zeybek 1994; Baytop 1999; Longo and Vasapollo 2005).

Although it varies according to the region where it grows in Türkiye, dried bay leaves usually contain 1–4% essential oil. However, in selection studies, it was determined that the essential oil ratios of some genotypes increased up to 7%. The main components of laurel essential oil are 1,8-cineole, transsabinene hydrate, α-terpinyl acetate, methyl eugenol, sabinene, eugenol and α-Pinene (Ceylan and Özay 1990; Kılıç et al. 2004; Ayanoglu et al. 2010; Uyar 2014).

In studies, the ratios of 1,8-cineole (eucalyptol) and α-terpinyl acetate, two important components of the essential oil, varied between 36.93–76.15% and 4.04–37.05%, respectively (Özcan and Chalchat 2005; Ayanoglu et al. 2010; Uyar 2014; Karık et al. 2015).

10.3 Sumac (*Rhus coriaria* L.)

10.3.1 Morphological Description and Geographical Distribution of Sumac Species

Sumac is a shrub 1–3 meters in height as shown (Fig. 10.4). The single leaves are feathery with 5–15 leaflets (Başoğlu and Cemeroğlu 1984). Sumac fruit is spread across the regions from the Islands of Canary and Madeira to North Africa, from South Europe to Afghanistan. Its natural habitats are bushes, shores and rocky areas, and wild forms are found in Aegean, Mediterranean, Black Sea, East and Southeast Anatolian Regions of Türkiye (Baytop 1984).

The flowers of the plant are in the form of clusters, and the flowers are actinomorphic, hermaphrodite or monosexual. Male and female flowers are usually on separate trees. Male flowers are yellow-green. The female flowers are red in color. The flowers, which open in June–July, are located in green-yellow colored, hairy, upright clusters of 15–20 cm. The fruits and seeds ripen from September to

Fig. 10.4 *Rhus coriaria* L.

November (Ayhan and Altınkaynak 2020). The fruits are 4–7 mm. in size, round or slightly flattened lentil-shaped, and single-seeded. It has a flat, kidney-shaped, gray-brown, extremely hard stone core. The fruit flesh, which contains a thick juice with a sour and slightly spicy flavor, surrounds the core. When ripe, the fruits are dark red in color and hairy on top. (Başoğlu and Cemeroğlu 1984).

10.3.2 Traditional Use and Herbal Drugs

Conventionally, the decoctions made of the roots and leaves are used in gastricism, the decoction made of ripe fruits is used to ease passing kidney stones. The fresh leaves of the plant are laid flat in the sole of the shoe to prevent leather crevices and the fruits are chewed like gum to heal mouth sores and abdominal cramps (Güner 2012; Tuzlacı 2006; Tuzlacı 2011). It is known that sumac is also used in treatments of dysentery, conjunctivitis, liver diseases and anorexia as well as treatment of hair loss, and dermotherapy such as burns and dermatitis (Ali-Shtayeh et al. 2013). Regular consumption of sumac creates protection against atherosclerosis, oxidative stress that is caused by high fat food and liver enzymes (Setorki et al. 2012). In Azerbaijan, the fruit of sumac is preferred because of its laxative effects and is also used in hypertension and diabetes treatments (Hasanova et al. 2000). In Iran, sumac is used in the treatment of diarrhea (Zhalel et al. 2018). From 1990 to 2010, the exportation of the extracts made from sumac, used as a herbal tanning material, and the dyeing, ink manufacturing, and veterinary industries demonstrates the economical significance of sumac (Kurt et al. 2014; Kızıl and Türk 2010; Tiryaki 2010). The compound that causes the red coloring of the sumac fruit is an anthocyanin compound. Because of this compound, the usage of sumac should be closely monitored during pregnancy and lactation (Shabbir 2012; Kacergius et al. 2017).

10.3.3 Major Chemical Constituents and Bioactive Compounds of Sumac

There have been studies to determine the essential oil ratios of the sumac grown in different provinces of Türkiye. Güvenç and Koyuncu (1994), have observed 15% and 20% essential oil ratios in the pericarps of the samples collected from Artvin and Mersin, while Güvenç and Koyuncu (1994) have 7.4% from Mersin (Büyükeceli-Gülnar); Doğan and Akgül (2005) 10–15% from Şanlı Urfa (Birecik), Malatya (Darende) and Kahramanmaraş; Ünver and Özcan (2006) 37.25% in pericarps from Mersin (Mut), and 13.77% from Hatay samples. According to the literature reviews, this variation of the essential oil ratios in sumac is caused by factors such as different species, environmental effects, soil properties and climate differences (Ünver and Özcan 2006). The free oil acidity, peroxide analyses to determine the essential oil quality that Hosseini et al. (2020) conducted on the sumac samples from different regions of sumac observed free oil acidity between 2.60–3.15% and peroxide values at 5.70–6.50 meqO_2/kg.

Fixed oils, obtained by processing oilseeds, are very important in terms of health as well as in human nutrition. Fatty acid ratios and fatty acid compositions determine the physical and chemical properties of oils. The positive effects of especially high oleic acid content on shelf life, oxidation stability and human health (cancer, cardiovascular diseases) have been determined by studies. For this reason, it is thought that the use of sumac oil in the diet can create a healthy composition for nutrition (Kızıl and Türk 2010; Duru and Bozdoğan Konuşkan 2014).

Since sumac oil has a high monounsaturated fatty acid content, it is more resistant to oxidative deterioration and can be stored for a longer time. It has been stated that sumac oil can be a good product especially when mixed with olive oil and used in salads and meals, thus contributing to the shelf life of olive oil (Kızıl and Türk 2010). Doğan and Akgül (2005) determined the fatty acids of sumac samples collected from Birecik, Darende, Kahramanmaraş and Şanlı Urfa to be as oleic (34.00–40.35%), linoleic (33.31–35.83%), palmitic (20.75–25.60%) and linolenic (1.55–2.99%). Nayebpour and Asadi-Gharneh (2019) reported the main fatty acid compositions of sumac samples grown in Iran to be as oleic (40.45%), linoleic (27.22%), palmitic (24.94%), stearic (2.74%) and linolenic (1.65%).

10.4 Hawthorn (*Crataegus* spp.)

10.4.1 Morphological Description and Geographical Distribution of Hawthorn Species

Hawthorn is mainly multi-branched ranging from shrubs to small trees, even normal sized trees can reach a height of up to 10 m. While the plants of the *Crataegus azarolus* are mostly in the form of trees, *C. monogyna* mainly forms plants in the form of shrubs. The fruit and leaf characteristics of the hawthorn species are commonly used for the identification of the species. The leaf area of *C. azarolus* varies between 3 cm^2 and 12 cm^2 in the plants in the natural population (Serçe et al. 2011), and the leaf area exceeds 30 cm^2 in the cultural forms. Hawthorn flowers mainly contain 5 petals and 5 sepals and 15–20 male flowers. There is one female organ within a flower and the female organ has 2 or 3 parts (Calışkan et al. 2018). *C. orientalis* is a shrub or small tree usually 3–5 m tall. The fruits are reddish-orange and the leaves are obovate-oblong and deeply 3–7 lobed (Eraslan and Kültür 2019). *C. monogyna* mostly has single-seeded, small red fruits (Serçe et al. 2011).

Currently, more than 30 *Crataegus* species have been identified in Türkiye, including C. *monogyna* Jacq., *C. tanacetifolia* (Poir.) Pers, *C. pentagyna* Willd., *C. azarolus* L., *C. orientalis* M. Bieb., *C. rhipidophylla* Gaud., and *C. laevigata* (Poir) DC. Dönmez (2004) indicated that some species and their hybrids are located

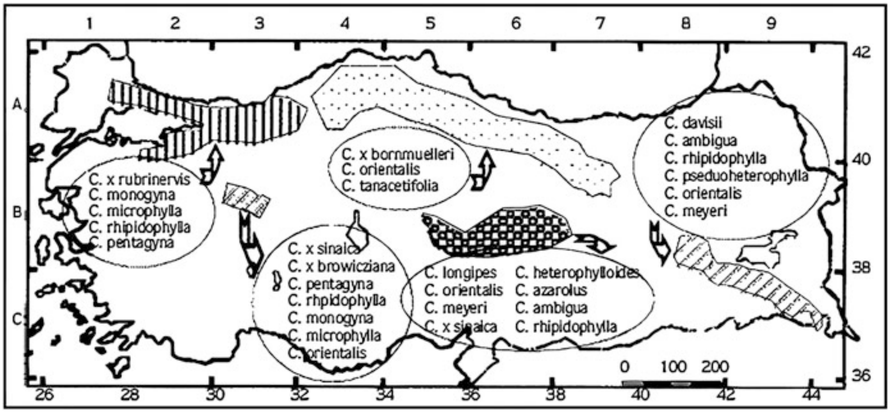

Fig. 10.5 Distribution of some *Crataegus* spp. in Türkiye. (Dönmez 2004)

in various geographic regions (Fig. 10.5). Currently, *C. monogyna* Jacq. is widespread in Türkiye, while other *Crataegus* species are mainly distributed in the temperate zone areas of Türkiye. Furthermore, some species such as *C. azarolus* and *C. orientalis* are distributed in low altitude (300–500 m) areas of subtropical conditions in Türkiye (Caliskan et al. 2016).

10.4.2 Traditional Use and Herbal Drugs

In Türkiye, the leaf, flower, new shoots, and plant roots of the *Crataegus* species (especially *C. monogyn*a) have been used in traditional medicine for various diseases such as cough, flu, asthma, stomach ache, rheumatic pain, nephritis, hemorrhoids, and cardiac diseases. The flowers and fruit of the hawthorn plant treat cardiovascular, hypertension, and diabetic diseases. Hawthorn vinegar is produced in some local areas of Türkiye, and the fruits and flowers of hawthorn are consumed as tea (Caliskan et al. 2016). Üçer (2011) stated that the leaves and thin branches of the hawthorn tree are boiled in water and drunk on an empty stomach in the case of diabetes. Tea made from hawthorn leaves boiled in water may also open the vocal cords.

The active ingredients of extracts and drugs prepared from hawthorn leaves, flowers, and fruits differ from each other. Leaf/flower drugs should contain 1–4% oligomeric procyanidins (predominantly catechin and epicatechin monomers) and flavonoids varying between 0.3% and 2.5% (content not less than 1.5% on hyperoside). Hawthorn fruit drugs should contain oligomeric procyanidins between 0.4–2.9% and flavonoids ranging between 0.05–0.15% (Zeybek and Hkasel 2010). The contents of these drugs in Türkiye are basically similar to the properties stated in the hawthorn extracts in the European Pharmacopoeia. In addition, hawthorn drugs are standardized to contain 4–30 mg of flavonoids or 30–160 mg of procyanidin (Heinrich et al. 2004). Currently, the dry extracts of hawthorn leaves and flowers and the drugs obtained from the flowers, leaves, and fruits are available in places selling medicinal plants and in pharmacies in Türkiye.

10.4.3 Major Chemical Constituents and Bioactive Compounds of Hawthorns

Hawthorn fruits, leaves, and flowers contain a number of chemical constituents, such as flavonoids (0.1–1% in fruits, 1–2% in leaves, and flowers), oligomeric proanthocyanidins (1–3% in fruits or leaves with flowers), triterpene acids (0.5–1.4% in fruits), organic acids (2–6%), sterols, and a small amount of cardioactive amines. The flavonoids and proanthocyanidins are the two primary bioactive components (Chang et al. 2002). The total flavonoid contents of some *Crataegus* extracts in Türkiye are mentioned in Table 10.1 The total flavonoid content varies significantly depending on hawthorn species and which parts of the plants are used such as fruit, flower, and leaf extracts. In general, the flowers and leaves of *C. monogyna* and *C. orientalis* contain a high amount of phenolic compounds and the amount of quercetin is higher in the flowers and the amount of rutin is higher in the leaves (Caliskan et al. 2012; Çınar et al. 2020). According to the Council of Europe, the leaf and flower material of hawthorn must contain a minimum of 1.5% flavonoids (The Council of Europe 2004). In general, it is clearly seen

Table 10.1 Total flavonoid contents of some *Crataegus* extracts in Türkiye

Species	Concentration (mg/g)			Reference
	Fruit	Flowers	Leaves	
C. monogyna		0.83	1.26	Meriçli and Melikoğlu (2002)
C. tanacetifolia		0.58	0.68	
C. orientalis		0.63	0.98	
C. stevenii		1.39	0.89	
C. microphylla		1.28	2.04	
C. microphylla		2.58	1.83	Melikoglu et al. (2004)
C. aronia var. aronia			9.13	Orhan et al. (2007)
C. monogyna			24.95–28.60	
C. pseudoheterophylla		7.8	5.5–7.58	
C. monogyna	17.60			Bardakcı et al. (2019)
C. orientalis	20.05			
C. pontica	18.78			
C. rhipidophylla	13.69			
C. turcicus	23.87			
C.orientalis	0.75	42.89	15.59	Çınar et al. (2020)
C. azarolus	1.95	16.29	19.43	
C. sinaica	4.83	27.19	45.40	
C. monogyna	5.95	20.86	36.45	

Table 10.2 Main bioactive compounds extracted from *Crataegus* species in Türkiye

Species	Bioactive compounds	Plant part	Reference
C. microphylla	Hesperetin and hyperoside	Flower/ leaf	Melikoglu et al. (2004)
C. davisii	Hyperoside, vitexine-2″-rhamnoside, vitexine-4″-rhamnoside, rutin and quercitin	Leaf	Sozer et al. (2006)
C. monogyna	Vitexine-2″-O-rhamnoside and hyperoside	Leaf	Orhan et al. (2007)
C. aronia	Vitexine-2″-O-rhamnoside and hyperoside		
C. pseudoheterophylla	Vitexine-2″-O-rhamnoside and hyperoside		
C. folium	Catechin, ferulic, coumaric, caffeic and gallic acid	Leaf	Demiray et al. (2009)
C. monogyna	Qercetin and rutin	Leaf/ flower	Keser et al. (2014)
C. monogyna	Catechin, chlorogenic, caffeic and rutin	Fruit	Gurlen et al. (2020)
C. tanacetifolia			

that the flavonoid content in flowers, leaves and fruits of *C. monogyna* is higher than other species. However, the fruits of *C. turcicus* and the flowers and leaves of *C. sinaica* are rich in total phenolics. The results showed that flavonoid contents of all of the extracts met the requirements of *Crataegus* species (Table 10.1).

Vitexin, hyperoside, rutin, quercetin, chlorogenic acid, and caffeic acid are the main bioactive compounds detected in *Crataegus* species from Türkiye (Table 10.2). The total content of phenolics is higher in the leaves and flowers than in the fruits. Vitexine and hyperoside compounds are most abundant in the leaves (Sozer et al. 2006; Orhan et al. 2007) and catechin, chlorogenic, caffeic, and rutin are also included in the fruit extracts (Gurlen et al. 2020). In addition, the biochemical compound contents of the *Crataegus* species may differ based on genotype, plant parts, and developmental/ripening stage. The action of these compounds on the cardiovascular system has led to the development of leaf and flower extracts, which are widely used in Europe.

The leaves, flowers, and fruits of hawthorn species have rich content in terms of volatile compounds. These volatile compounds may differ according to hawthorn species and plant parts (Özderin et al. 2015; Dursun et al. 2021). Özderin et al. (2016) reported that a total of 81 volatile components were detected in leaves and flowers of different hawthorn species. Benzaldehyde, butyraldehyde, and 2-hexenal components were identified at the highest ratios. In addition, Dursun et al. (2021) indicated that the highest amount of esters along with the occurrence of butyl butanoate was determined in over-mature hawthorn fruit (*C. azarolus*) in comparison with immature and mature ones. Two esters butyl hexanoate and hexyl hexanoate were dominant volatile organic compounds of hawthorn fruit at all maturation stages and butyl butanoate appeared only at over mature fruit as the dominant compound.

10.5 Carob Tree (*Ceratonia siliqua* L.)

10.5.1 Morphological Description and Geographical Distribution of Carob

Carob is mainly called 'keçi boynuzu' and 'harnup' in Turkish. Carob trees that are maintained in nature can even reach 10–15 m. The carob pod is light to dark brown, oblong, flattened, straight or slightly curved, with a thickened margin, and ranges from 10 to 20 cm in length and 1.5–2 cm in width. The unripe pod is green, moist, and very astringent, but the ripe pod is sweet (Morton 1987). Its leaves are 3–5 cm long and elliptical, while its flowers are small and greenish-red (Şahin and Taşlıgil 2016). Carob fruits start maturing around June–July and are harvested between September and November–December, in the Mediterranean region of Türkiye. Tunalıoğlu and Özkaya (2003) indicated that the carob tree starts producing fruits between 5 and 10 years of age, and becomes commercially mature at 15 years. The carob tree lives for 300–400 years and its average productivity varies between 90–115 kg/year (Taşlıgil 2011).

Türkiye is the origin area of the carob and it spreads naturally in the coastal part of the Mediterranean and Aegean regions in Türkiye (Fig. 10.6). Natural populations are encountered in the forested areas of the coastline starting from Urla (İzmir) to Samandağ (Hatay). It has a dense population, especially in Alanya (Antalya) and Silifke (Mersin).

The carob populations are located between 200 m and 800 m above sea level in this region (Şahin and Taşlıgil 2016). Additionally, carob orchards are being established in Antalya, Mersin, Adana, Muğla, and Osmaniye provinces. Pekmezci et al. (2008) reported that different types of carob are grown in Türkiye, namely 'Etli', 'Sisam' and 'Yabani'.

Fig. 10.6 Distribution of some carob cultivation areas in Turkiye

10.5.2 Traditional Use and Herbal Extracts

Carob pods are mainly consumed as a snack in Türkiye. One of the traditional ways of consumption of carob in Türkiye is pekmez (molasses). Due to its beneficial effects on health, the production amount and consumption of molasses increases every year. The natural molasses obtained from the fruits of carob in the Antalya province is used in hemoglobin, cough, sperm enhancer, diabetes, and gall bladder diseases (Yıldırım and Kargıoğlu 2015).

The compounds of carob also reduce the blood glucose response by inhibiting the activity of the amylase enzyme, resulting in a slowing of starch digestion. Since carob flour is rich in fiber, polyphenol, and tannin content, it can be included in diabetic-friendly foods. Additionally, studies have shown that consuming 15 g of carob fiber or 10 g of carob flour in a daily diet reduces total cholesterol and LDL cholesterol in individuals with hypercholesterolemia (Ekiz et al. 2019).

Carob gum (E-410, also called carubin) is the refined endosperm of the seed of the carob pods by extraction of the seeds with water or aqueous alkaline solutions. The gums are a versatile material used for many applications: they are excellent stiffeners and stabilizers of emulsions, and the absence of toxicity allows their use in the textile, pharmaceutical, biomedical, cosmetics, nutrition sciences, and food industries (Karababa and Coskuner 2013).

10.5.3 Major Chemical Constituents and Bioactive Compounds of Carobs

Carob fruits consist of 90% fruit pulp and 10% seeds, and 91% of the fruit is dry matter. The dry matter of the fruits contains more than 50% sugar (Tunalıoğlu and Özkaya 2003). Carob pods contain nutritionally important amino acids (aspartic and glutamic acids, alanine, valine, etc.) and minerals (K and Ca) that play a significant role in human health (Ayaz et al. 2007). Ayaz et al. (2007) reported that sucrose (437.3 mg/g dry weight), glucose (395.8 mg/g dry weight), and fructose (42.3 mg/g dry weight) were the major sugars and gallic acid (3.27 mg/g dry weight) was the most abundant phenolic acid in the Anatolian carob pods. Pazir and Alper (2016) showed that carob fruit is a natural source of dietary fiber (258.3 g/kg) and total phenolic content (3944.7 mg/kg), therefore making carob pulp an excellent source of bioactive compounds with rich phenolics.

Simsek and Artık (2002) indicated that carob is a good mineral and energy source of molasses. The molasses contains 62–69% total sugar, 40–44% sucrose, 11–13% glucose, 11–12% fructose, 71–72% total soluble solids, and 05–07% acid. The studies on the carob pods showed that Turkish carob pods are very rich both in sugar content and their compounds compared to Greek and Bulgarian carob pods (Vekiari et al. 2011; Fidan et al. 2016). In addition, Fidan et al. (2016) reported that the Turkish carob pods and syrups are a source of prebiotics, because of the presence of 1-kestose (0.5 g/100 g DW), a fructooligosaccharide.

Carob also contains a compound named D-pinitol, a carbohydrate that has an insulin-like effect. Tetik et al. (2011) stated that when carob fruit is compared with other plants for D-pinitol concentration, it has some advantages such as cheap raw material, an easy extraction method, and rich D-pinitol levels. The highest D-pinitol content was in wild-type carob pods (84.59 g/kg) compared to the cultivated carob pods (61.88 g/kg) (Turhan 2014). This compound which is naturally found in carob pods increases the interest in this fruit (Pazir and Alper 2016). According to EFSA, per capita dietary fiber intake is below the recommended consumption (25 g/day), and therefore, it is of great importance to include in the diet new ingredients, such as carob pulp, that may help reach this objective (EFSA 2022).

10.6 Conclusions

Türkiye is one of the few countries that exports the highest quality bay leaves and meets approximately 90% of the world's bay leaf requirements. *Laurus nobilis* is gaining importance both due to the active ingredients of its fruits and leaves, and also because of its increasing usage day by day. *Rhus coriaria* has been widely used for many years in Anatolia, especially in the Mediterranean, Aegean and Southern Anatolia regions, for different purposes. It has an important place in the Turkish cuisine, as a spice: in salads and adding a lemony taste to meat dishes. In recent years, besides its traditional use in the treatment of some diseases, its use by the pharmaceutical industry has been increasingly studied.

The information presented in this review on the different pharmacological properties of *Crataegus* species found in Türkiye can provide the incentive for favorable evaluation of the use of its various species in medicine. *C. monogyna* flowers, leaves and fruits are rich in bioactive components and this species is widely used in traditional medicine in Türkiye.

The cultivated and wild types of carob pods are a rich source of sugars, phenols, and D-pinitol.

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Chapter 11
Turkish Soaproot (Radix Gypsophylae)

Ekrem Sezik

Abstract In Türkiye soaproot is a herbal drug obtained from 7 plant species belonging to 2 genera: *Gypsophila bicolor*, *G. graminifolia*, *Ankyropetalum gipsophiloides*, in Eastern Anatolia, *G. arrosti var*. nebulosa, in inner West Anatolia and G. perfoliata var. anatolica, *G. eriocalyx*, in Central Anatolia. Soaproot water and soaproot dry extract are still obtained by using the plant material imported from Afghanistan and used for different purposes. A small amount of soaproot from *G. bicolor* and *G. arrostii var*. nebulosa roots are also commercially available. In the present chapter information about the sources of Turkish soaproot is reviewed, with reference to benchmark studies on the Turkish soaproot.

Keywords Turkish soaproot · Çöven · *Gypsophila* · *Gypsophila* root

11.1 Introduction

Soaproot (Radix Gypsophilae) is an important herbal drug of both medicinal and economic importance. In general, soaproot denotes the woody roots of some perennial species of the family Caryophyllaceae belonging to the following genera: *Gypsophila* L., *Saponaria* L., and *Ankryopetalum* Fenzl. Sometimes soaproot is mixed with roots of other plant species and sold as soaproot of lower quality. In the followings information about the sources of Turkish soaproot is reviewed, with reference to benchmark studies on the Turkish soaproot.

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11.1.1 Research on Turkish Soaproot

The first publication about Turkish soaproot belongs to T. Baytop (1954, 2021). In this publication, it is mentioned that Turkish soaproot is not obtained from *Saponaria paniculata*, but from *Gypsophila arrostii* Guss. around Beyşehir (Konya). T. Baytop explained that *G. venusta*, which is found in the same region, is also used to obtain soaproot, but in small quantities.

The most comprehensive study on Turkish soaproot has been published by Sezik (1982). This study contains the following detailed information: the regions where soaproot is obtained from in Anatolia, description of the *Gypsophila* species used, the morphological and microscopic characteristics of the roots complemented with pictures and hand drawings of the different soaproots. The assays determining their quality (Hemolysis and foaming indices), a method developed to obtain crude saponins, saponin contents of the soaproots, and identification of soaproots by TLC, were also provided.

Koyuncu et al. (2008) added some more information about the species used obtaining soaproot in Eastern Anatolia. In this article, pictures facilitate the identification of soaproot from *G. bicolor*. In addition, it is also mentioned that soaproot is obtained from the roots of *Gypsophila graminifolia* Bark and *Ankyropetalum gipsophiloides*Fenzl. Importantly, with this publication, 2 more species were added to the soaproot sources in Eastern Anatolia. This publication contains no information about the morphological and anatomical features, identification by TLC, quality values (saponin content, hemolysis and foaming indices) of these 2 soaproot varieties. Importantly, in this publication it was also mentioned that root collection had destroyed the natural resources. This seems to be underpinning the information received from some companies, mentioning that large quantities of soaproot were imported from Afghanistan.

In the doctoral thesis prepared by M. Inan at Çukurova University, the cultivation of different *Gypsophila* species in Çukurova was studied (Inan 2006). *G. pallida* Stapf., *G. paniculata L., G. bicolor, G. arrostii* var. nebulosa were introduced into cultivation, while *G. bitlisensis Bark. G. pilosa Hudson, G. ruscifolia* Boiss. could not be cultivated.

As a result of different criteria evaluated in cultivation trials, it was concluded that *G. pallida* is the most suitable species for cultivation in the Çukurova Region, nonetheless since 2006, *G. pallida* has not been found in cultivation, in Çukurova Region.

According to Inan (2006) soaproot was imported from Uzbekistan and there was no domestic production. Minor amounts of Van soaproot are available in the market. *G. arrostii* var. nebulosa was cultivated in a small area, in Isparta and most of the commercially available soaproot is occasionally obtained from this species.

İmportant information from previous studies and especially from Sezik's detailed study are summarized in our review so that the following information on Turkish soaproot is up-to-date.

11.1.2 Soaproot as Important Turkish Import and Export Item

In Türkiye, soaproot (Radix gypsophilae) is used both domestically and as an export item, in significant quantities. As this drug has been sourced from nature for some 30 years, it is interesting to compare statistics about exports between 1972 and 1979 (Table 11.1) and 2004—2019 (Tables 11.2 and 11.3). Between 1972 and 1979, an significant portion of the export was directed to Germany (E.Merck Company) to obtain "*Saponinum purum album*" and to be used in the production of "halva" to the Balkan and some Middle East countries. Exports decreased after 1985 due to the use of other surfactants instead of "*Saponinum purum album*" (Sezik 1982).

Soaproot was exported in annual amounts of up to 450 tons between 1972 and 1979.

It is seen that after 2004, soaproot was in significant quantities (Tables 11.2 and 11.3), while in the same years, soaproot was exported also in large quantities: this fact seems to indicate that soaproot was sold in the form of reexport.

11.2 Turkish Soaproot Production Regions

The words "çöven" and "çöğen" are the Türkish equivalents of soaproot. Local or market names in Turkish are also frequently attached.

Important soaproot obtaining regions and description of plants used as soaproot are the following:

11.2.1 Eastern Anatolia

Gypsophila bicolor (Freyn et Sint) Grossheim. Turkish name – "Van çöveni" (Van soaproot), "Van malı" (Van goods) and "birinci kalite" (first quality. Grows in districts and villages around Van, and in areas close to the lake shore) (Sezik 1982).

Table 11.1 Import and export values (Sezik 1982)

years	kg	Turkish Lira	US dollars
1972	204.100	571.365	–
1973	451.030	2.407.475	–
1974	417.295	3.174.240	231.586.-
1975	410.350	4.195.469	290.660.-
1976	393.520	3.374.607	212.974.-
1977	305.800	3.406.355	193.283.-
1978	429.650	8.079.723	347.382.-
1979	276.265	19.109.713	436.783.-

Table 11.2 Import and export values (Metin et al. 2012)

2004		2005		2006		2007		2008		2009		2010		2011	
Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$
Import															
116	29	486	171	306	115	550	212	484	200	293	150	758	460	350	228
Export															
85	80	92	66	153	61	102	55	56	108	199	132	202	163	107	81

Table 11.3 Import and export values 2015–2019 (Boztaş et al. 2021)

2015		2016		2017		2018		2019	
Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$	Tons	1000$
Import									
591	521	551	535	884	884	563	323	668	425
Export									
449	653	302	426	577	683	369	386	123	185

G. graminifolia Bark. Turkish name: Başkale çöveni (Başkale soaproot), Dağ çöveni (mountain soaproot) (Koyuncu et al. 2008).

This species grows around Başkale (Van), in a mountainous area. It has a narrow area of distribution and is collected in autumn (September–October). Koyuncu et al. give the following information about this species in their publication: "*between 1995 and 2001, 200 tons of "dağ çöveni" were collected from this region per year and therefore natural habitats of the species were destroyed.*"

Ankyropetatalum gypsophiloides Fenzl. Turkish name: Siirt çöveni (Siirt soaproot), helva çöveni (halvah soaproot) (Koyuncu et al. 2008).

The roots were collected from Batman and Siirt and used by local halvah producers. Koyuncu et al. gives the following information: "*Most of these halvah producers have closed down recently and only a few have remained using soaproot and using soaproot juice, which is delivered from İstanbul in a ready form. Therefore, soaproot has not been collected in these regions for a couple of years*".

11.2.2 Inner-West Anatolia (Sezik 1982)

Gypsophila arrostii Guss. var. *nebulosa* (Boiss. et Held.) Bark. Turkish names: Konya çöveni (Konya soaproot), Beyşehir or Isparta çöveni (Isparta or Beyşehir soaproot) was obtained around Konya (especially Beyşehir), Isparta, Burdur, Elmalı and Denizli.

Due to the development of agriculture in the region and the decrease in the availability plant raw materials, only a few species are available in the market from cultivation.

11.2.3 Central Anatolia (Sezik 1982)

In this region, 2 species of *Gypsophila* are used to obtain soaproot: *Gypsophila eriocalyx* Boiss., *G. perfoliata* L. var. *anatolica*.

Çorum-Yozgat Region (*G. eriocalyx*): Turkish names: Çorum çöveni (Çorum soaproot), Yozgat çöveni (Yozgat soaproot) and üçüncü kalite (third quality). Was obtained Çorum, Ankara (especially around Keskin), Kırşehir and Sivas provinces.

Niğde Region (*G. perfoliata* var. *anatolica*). Turkish names: Niğde çöveni (Niğde soaproot), üçüncü kalite (third quality) was obtained from in a narrow region (around Bor) in Niğde province.

11.3 Crude Drug Used for Obtaining Soaproot

There are no significant differences between regions in obtaining soaproot. The process of soaproot production is generally the following: Roots are dug from the soil in a period starting immediately after the rainy season (May) and extending until the time of the plant's fruiting (end of July). Villager collectors of soaproot recognize the plant even when the first leaves of the plant appear on the soil surface: they dig the soil and collect the roots. Tools such as picks, hoes and shovels are used to dig. As a next step, the roots are washed, cleaned and dried in heaps in the sun (Sezik 1982).

11.3.1 Van Soaproot

Van soaproot (Fig. 11.1) generally consists of similar, long, cylindrical, slightly curved, straight or slightly bent dirty yellow pieces. Small amounts of small, curved root pieces can also be found in the mixture. Roots are 0.8–4 cm in diameter and 4–35 cm in length. The ends of the drug are boardered either with a flat or slightly

Fig. 11.1 Van soaproot

inclined surface or there are thick and prominent stem residues. The surface of the roots is longitudinally irregularly corrugated. The grooves are sometimes cut with transverse lines or round bubbles. These transverse bubbles are more prominent than the Isparta-Beyşehir soaproot. Soil fragments are seen. Roots are uniquely scented. The structure of the roots is hard, hard to break, dusty broken, sneezing when broken.

The cross section is ovate, the edges are wrinkled. Root layers are noticeable due to differences in color and structure. They are seen as follows: Cork (dirty yellow), bark (white), vascular bundles (yellow), pith (white). In the pith, year rings can be distinguished.

11.3.2 Isparta – Beyşehir Soaproot

This soaproot is a mixture of long, cylindrical, slightly curved or twisted dirty yellow pieces that look generally similar to each other (Fig. 11.2). Thin and short roots are rare. Sometimes 50–60 cm long pieces can be also encountered. Roots are usually 1.3–2.8 cm in diameter and 15–30 cm in length. The ends are either born without breaking and end with a sloping surface or there may be stem residues. The surface of the roots is cut with irregular grooves longitudinally, and sometimes with transverse stripes. The cork layer has fallen partly and the spilled parts are white. Roots have an unique odor. They do not have a characteristic taste; their structure is hard. The drug is difficult to break, the break surface is dusty, the dust is muffling,

Fig. 11.2 Isparta – Beyşehir soaproot

the fracture surface is slightly inclined. Cross section ovate, wrinkled. Root layers can be distinguished macroscopically.

The cross section is ovate, the edges are wrinkled. Root layers are noticeable due to differences in color and structure. They are seen as follows: Cork (dirty yellow), bark (white), vascular bundles (yellow), pith (white), In the pith, year rings can be distinguished.

11.3.3 Çorum-Yozgat Soaproot

Çorum-Yozgat soaproot (Fig. 11.3) is a mixture of irregular or regular root pieces and contain neat or irregular pieces that are cut to length. Irregular pieces can be thick, large and of various shapes, they can have lateral roots. Their ends do not have any fixed features. Regular pieces are 1.6–1.7 cm in diameter, 7–13 cm in length and The tips are almost flat (because it is broken apart by sharp tools when removed from the ground) or very little rough. The inner surfaces of the longitudinally cut smooth or irregular pieces are white, dusty and yellow in places. The outer surfaces of all roots are brownish dirty yellow, longitudinally striped, transversely by the merging of small bubbles. It carries a series of bubbles in lines. Roots have a distinctive light smell, bland taste and hard structure. However, they can be broken with cutting tools, the surface of the break is fibrous and dusty, the powder is not very musky.

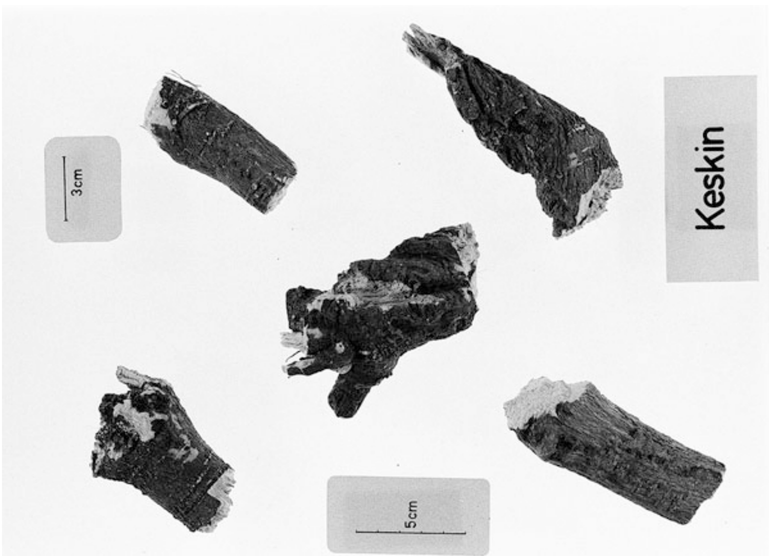

Fig. 11.3 Çorum –Yozgat soaproot

The cross section is circular; the edges are almost straight. The layers can be easily separated. They are seen as follows: Cork (dirty yellow), bark (white), vascular bundles (yellow), pith (white), In the pith, year rings can be distinguished.

11.3.4 Niğde Soaproot

This soaproot is a mixture of irregular, long, cylindrical, curled parts or whole roots. Roots are brownish, longitudinally deeply corrugated, transverse bubbles are rarely seen on the surface(Fig. 11.4). Soil fragments are evident in the grooves. In some parts of the surface, the cork layer may be shed as dots. Roots 0.3–1 cm in diameter, 3–17 cm in length, with smooth ends or stem residues. It has a peculiar smell, tasteless, hard, easily breakable structure. Fracture is less dusty; fracture surface is almost flat.

The cross section is convoluted; the base is flat or almost round. The layers are not as well differentiated macroscopically as other soaproots: cork (brown), bark (white), vascular bundles (yellow), pith (white). Year rings are not distinguished.

Fig. 11.4 Niğde soaproot

11.3.5 Soaproot Water Extract

Roots are freed from foreign materials and brought to a size suitable for extraction in special mills (Figs. 11.5 and 11.6). Roots are extracted with appropriate proportion of water: the resulting liquid is filtered, the roots are squeezed through a press, and the resulting liquid is added to the mother solution. It is concentrated to the appropriate concentration, the resulting liquid is rested for 12 h, and filtered again if necessary. This extract is filled into plastic containers and the growth of microorganisms is prevented by using pasteurization technique. Two types of soapwort water are produced: Helvalık (for halvah) and Lokumluk (for Turkish delight). The most important difference between these 2 types is that the brix values are different. Soaproot water extract is mostly used in the production of tahini halva in Turkey and adjacent countries. In Turkey, besides Tahini halva, it is used for various halva types (cevizli helva-halva with walnuts, köpük helvası - foaming halva), desserts (kerebiç) and whitening grape molasses.

11.3.6 Powdered Soaproot Extract

Soaproot juice extract is evaporated in a spray drier to obtain an extract with 4% moisture. This extract is used by diluting with water.

Fig. 11.5 Mills for powdering soaproots

Fig. 11.6 Powdered soaproots for extraction

Table 11.4 Quality features of Turkish soaproots (Sezik 1982)

Gypsophila species	Hemolytic Index	Foaming index	Crude saponin %
bicolor	6.667–6.925	9.000–10.000	20–25
arrostii var. nebulosa	5.295–6.667	9.600–10.034	19–22
eriocalyx	3.385–3.659	1.800–2.000	10–14
perfoliata var. anatolica	9.778–10.000	4.650–5.000	15–19

11.4 Turkish Soaproot Used for Obtaining Crude Saponin

In some studies carried out after Sezik on *Gypsophila* roots, the "raw saponin extraction method" developed by Sezik (1982) were used. But, incorrect and irrelevant sources were cited. To correct this error, the method of obtaining raw saponin developed by E. Sezik has been included in our article (Table 11.4).

"The powdered and weighed material is extracted with petroleum ether (40–60^{o}) in the Soxhlet device. The petroleum ether extract is separated; the material is left to dry in the open air. The material is extracted with ethanol (80^{o}) in the Soxhlet device for 8 h. The extract is taken and the extraction process is carried out under the same conditions. It is repeated one more time. The ethanolic extracts are combined and concentrated at low pressure. The concentrated extract is dropped into acetone cooled in a salt-ice bath and mixed continuously. The saponins precipitate, centrifuged for 15 min, the precipitate is separated, dissolved in a small amount of ethanol. The precipitation and centrifugation processes are repeated. The precipitate is washed with cold acetone, dried in a vacuum oven, and weighed."

11.5 Present Status and Origine of Soaproot in Turkey

Currently, very low amounts of soaproot are obtained from resources in Turkey. Roots imported from Afghanistan are used by 2 companies (Kalealtı Ticaret, İstanbul Tarım). Companies sell the roots as chopped (Fig. 11.7), concentrated aqueous solution or dry extract. Condensed aqueous solution is available in the market with the Turkish name "Çöven suyu" (soaproot water) and the dry extract "Çöven ekstraktı tozu" (soaproot extract).

Features related to the products are available on the websites of the companies. Our research on soaproots used by Kalealtı company continues. Our preliminary findings are given in the article.

Roots are still imported from Afghanistan mostly via Uzbekistan. Morphologically, the roots are, however, not homogeneous. Some of them are very long and big (Figs. 11.8 and 11.9). Some may belong to *Acontophyllum gypsophiloides* which grows in Uzbekistan and Afghanistan. However, this finding is not definitive.

Fig. 11.7 Chopped soaproots prepared from Afghanistan soaproot

Fig. 11.8 Soaproot imported from Uzbekistan

Fig. 11.9 Soaproot imported from Afghanistan

11.6 Information from Soaproot Producing Company-Websites

Information to be obtained from soaproot producing-company website are contradictory. In the website of one of the companies (İstanbul Tarım – www.istanbultarim.com), *G. bicolor* is featured as the marketed plant species. It claims to have obtained both soaproot and soaproot extract from *G. bicolor* roots, however this does not seem possible, as generally *G. bicolor* roots are rather scarce in the market. Similarly misleading is the information contained in the web-site of the company Kalealtı Ticaret (http://www.kalealti.com), where the following statement can be read: “Roots obtained from different regions of Anatolia are used”. The truth, that both water and dry extracts of *Gypsophila* were obtained from roots imported from Afghanistan, was confirmed in a personal communication from this company (Kalealtı Ticaret).

11.6.1 **Gypsophila arrostii *Cultivation***

Ramazan Koltuk (Isparta) has been cultivating *G. arrostii* var. nebulosa on an area of 70 decares, for 20 years. Cultivation is started from seeds and the roots are removed from the soil when the plants are usually 2 years old. The extent of cultivation is variable due to the demanding high agricultural inputs and the availability of cheap Afghan soaproot. In other words, it is not possible to speak about a continuous production.

11.7 Conclusions

The most detailed study on Turkish soaproot published by Sezik (1982) provides detailed information on soaproot obtaining regions, the *Gypsophila* species used, the morphological and microscopic characteristics of the roots, pictures and hand drawings of the soaproot, the assays determining their quality (Hemolysis and foaming indices), a method developed to obtain crude saponins, saponin contents of the soaproots, and identification of 4 soaproots by TLC. After Sezik, a study on Eastern Anatolian soaproots was published by Koyuncu et al. (2008). In this publication information on obtaining soaproot from *G. bicolor*, photos of the production and the 2 plants used for obtaining soaproot in Eastern Anatolia is given. Following the study of Koyuncu *et al,* two more species were added to the list of Eastern Anatolian soaproots: there is no information about the amount of saponins and the quality determining values of these soaproots.

Domestication trials on *Gypsophila* species aimed at cultivating every soaproot species have not been successful. Only *G. pallida* cultivation trials have yielded promising results in the Çukurova region, in 2006. Remarkably, since then the stage of regular production has not been reached. Information on *G. arrostii var. nebulosa* cultivation are given above.

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Chapter 12
Traditional Farming of Apiaceae Species in Türkiye: *Pimpinella anisum* L., *Foeniculum vulgare* Mill., *Cuminum cyminum* L.

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Abstract The plant family Apiaceae (Umbelliferae) comprising 466 genera and about 3800 species is represented in Türkiye by 101 genera belonging to 485 species. Included in 511 taxa comprising 181 endemics, 7 monotypic genera: the ratio of species endemism in the family is 37.3%. Apiaceae species are annual or perennial plants that contain essential oils and resins and some alkaloids. The phytochemical diversity of Apiaceae was early discovered by man due to their odors and flavours that have led to a wide range of uses: foods, beverages, flavourings, remedies and industrial uses. In contrast, many Apiaceae species, like hemlock water-dropwort (*Oenanthe crocata*), poison hemlock (*Conium maculatum*) and water hemlocks (*Cicuta* spp.) are strongly toxic. Some species are also known to cause dermatitis when the damp skin is exposed to bright sunlight (*Heracleum* spp., *Pastinaca* spp.). Cultivated members of the Family are grown on more than 1.2 million ha worldwide, their annual production is about 25 million tons. The present chapter focuses on the

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traditional farming practices of cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* Mill.), anise (*Pimpinella anisum* L.), and dill (*Anethum graveolens* L.) that are the most frequently cultivated species.

Keywords Aniseed · Fennel · Cumin · Uses · Essential oil · Cultivation · Anethol · Cumin aldehyde · Fixed oil · Polyphenols

12.1 Introduction

The plant family Apiaceae (Umbelliferae) comprising 466 genera and about 3800 species is represented in Türkiye by 101 genera comprising 485 species. Included in 511 taxa comprising 181 endemics, 7 monotypic genera: the ratio of species endemism in the family is 37.3%.

The use of anise, fennel and cumin as both medicine and food has been widespread in Anatolia, since ancient times. The name of cumin (kamunum) is mentioned as a spice on the clay tablets found in Kültepe near Kayseri (74–1719 BC) (Kırıcı 2015). There are medicinal uses of anise, fennel and cumin plants in the book called "*De Materia Medica*" written by Dioscorides (129–210 CE), who was born in Anavarza, located in the south of Türkiye (Kahya 2019). Todate, these species have maintained their importance as spices and medicines, and their commercial values are increasing year-by-year.

In Türkiye, the cultivation area of anise amounts to 73.735 ha, and the seed-production is 314.999 tons. Türkiye ranks second after India in the total production of four Apiaceae species, i.e.: anise, badian, fennel, coriander (FAO 2022). Cumin has also an important place in the world trade. India is the world's largest cumin producing country with 646.9 million dollars worth (315.2 thousand tons) of exports, in 2020 (Comtrade 2022a, b). Türkiye produced 13.9 thousand tons of cumin, in 2020 (TUIK 2022).

The present chapter reviews the current knowledge on the traditional cultivation and use of three important Apiaceae species, such as *Pimpinella anisum*, *Foeniculum vulgare* and *Cuminum cyminum.*

12.2 Aniseed (*Pimpinella anisum* L.)

Pimpinella anisum L. (Photo: Kirici S)

Anise (*Pimpinella anisum* L.) is an annual plant belonging to the Apiaceae family, and its seeds (fruits) have been used in the pharmaceutical, food and beverage industries for many years (Özcan and Chalchat 2006).

Anise is an annual plant cultivated in Southern and Western Anatolia in Türkiye. Anise cultivation area and yield are not stable based on different growth factors. The reasons for the limited agriculture and the low anise production are: the farmer cannot find high quality and efficient certified seeds, the generally small family farming practices, the insufficient information about production techniques, fertilization and pest and disease control, and low purchase prices for anise (Bayram 1992). A large proportion of anise-seed produced in Türkiye is used in the production of the alcoholic beverage called "raki. TEKEL the raki producing company was sold, in 2004, decreasing the production of anise (Boztaş and Bayram 2020). Due to similar reasons, the extent of anise production has decreased in Türkiye after 2000. By the year of 2021, the cultivation area has decreased to 11.071 ha and the production has decreased by 35% compared to the previous year, decreased to 6.936 tons (TSI 2022) (Fig. 12.1). Main producing areas are in Burdur, Denizli, Antalya, Muğla, Afyon, Bursa, Antalya, and less in Konya, Balıkesir, Eskişehir, Uşak, İzmir, Kütahya and Ankara.

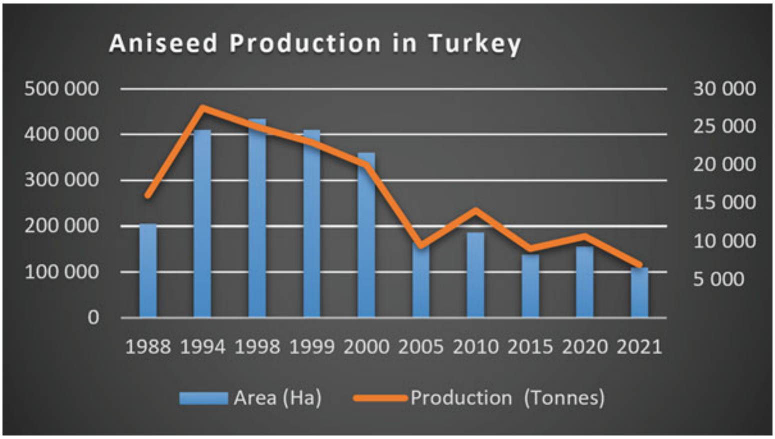

Fig. 12.1 Production amount and areas of aniseed in different years (TSI 2022)

12.2.1 *Taxonomic Characteristics*

The gene center of anise is around the Eastern Mediterranean, however, some researchers argue that it is in the Mediterranean region and even Asia Minor, while some argue that it is in the Far Eastern Countries. However, its natural occurrence in Türkiye, Greece, Sicily and Egypt confirm the first view (Hegi 1965). According to botanists anise was first domesticated in Egypt, and the plant, which was transcribed as "inst" in ancient Egyptian records, is identified as anise by egyptologists. Its fruits mentioned in the "Hearst Papyrus" dated to 1200 years (Uhri 2011), are known also as aniseed and were used as traditional medicine in China as early as in the fifth century (Sun et al. 2019). In the Cronquist (1968) system *P. anisum* L. is ranked to the division Magnoliophyta, class Magnoliopsida, subclass Rosidae, order Apiales, family Apiaceae (also known as Umbelliferae). Globally, there are 150 *Pimpinella* species in the genus (Ghosh et al. 2019). Castro and Rosello (2007) reported the chromosome number as $2n = 18$ and 20 in *P. anisum* L. Türkiye is a rich country for *Pimpinella* genus represented by 27 taxa. Five of the annual, biennial and perennial species are endemic (*P. flabellifolia*, *P. anisetum*, *P. cappadocica* var. *cappadocica*, *P. isaurica*, *P. anthriscoides* var. *cruciata*). *Pimpinella anisum* has different common names in the various countries, e.g.: Anis vert (France); Anise seed (Japan); Anise and Star anise (the USA); Annesella (Italy); Anisa, Badian, Kuppi, Muhuri, Saunf and Sop (Iran and India); Boucage anis, Petit anise (North Africa), and anise (England) (Sun et al. 2019). In Türkiye, the economically important *P. anisum*; although it is called Anason in general, it is also locally called Enisen, Ezanteri (Gümüşhane), Ezeltere (Endemic *Pimpinella anisetum* Boiss.'Sivas), Ezenere (Eğridir-Isparta), Ezertere (Pınarbaşı-Kayseri), Ezertere (Sivas), Mesir otu (Karamanlı) -Burdur) (Başer 2007; TUBIVES 2022).

12.2.2 Crude Drug Used

Anise fruits, which are commercially called "seeds", are used as flavorings and crude drug. The essential oil from anise fruits is used in food processing, perfumes, toothpaste, and also, anise root oil is used in medicine (Orav et al. 2008). Anise seeds have stomachic, appetizing, carminative, sleep-inducing properties. Its essential oil has antispasmodic, antioxidant, antimicrobial, insecticidal and antifungal properties, and cold treatment and mild expectorant (Ceylan 1987; Özcan and Chalchat 2006; Tepe et al. 2006; Haşimi et al. 2014; Mohamed et al. 2015). Anise is approved by the German Commision E for the treatment of dyspeptic complaints and loss of appetite and inflammatory states of the mouth and pharynx (Capasso et al. 2003). It is also used in bread, cake, pastry, sauce, confectionery and spice mixes. Young green leaves are used in salads and soups. Its essential oils are used in the food industry, pharmacy, cosmetics and perfumery (Baytop 1984; Ceylan 1987).

12.2.3 Major Chemical Constituents and Bioactive Compounds

Anise seeds contain 2–6% essential oil, 30% fatty oil, flavonoids, proteic substances and caffeic acid derivatives (clorogenic acid) (Capasso et al. 2003). The amount of aniseed essential oil and its components varied greatly according to the regions where it was grown (Table 12.1) Anise essence obtained from anise fruits (Fructus Anisi or Anisi fructus) with 2–4% efficiency by steam distillation contains 80–95% phenylpropanoid named 'trans-anethole'. Anise essential oil, which is 13 times sweeter than sugar and rich in 'trans-anethole', crystallizes below 15 °C (Başer 2007). The essential oil is a clear, colourless or pale-yellow liquid, obtained by steam distillation of dry ripe fruits (Lawless 2002); it varies between 1.5% and 6% v/w and contains mainly trans-anethole (80–95%) (Anonymous 2012). In contrast to the essential oil of anise, oil does not contain appreciable amounts of fenchone, but contains much smaller amounts of estragole (Mahboubi and Mahboubi 2021).

Aniseed flavoured distilled spirits are produced in different Mediterranean countries, and are known under various names such as anis, arak, pastis, ouzo, sambuco and zivania; Raki, a traditional Turkish alcoholic beverage, also belongs to this group. It is the second most produced alcoholic beverage in Türkiye (Yucesoy and Ozen 2013). The main component that gives anise its distinctive smell is anethole. The sweet taste of anise is due to this substance. Because of this feature, trans-anethole is used in the production of toothpaste and adds sweetness to the paste (Fidan and Şahin 1993). Trans-anethole and estragole are effective in raki quality (Cabaroglu and Yilmaztekin 2011). According to USDA limit physico-chemical and proximate composition of anise seed (g/100 g), 9.54 for moisture, 6.95 for ash, 17.60 for protein, 14.6 for crude fiber, 15.90 for fatty oil, 50.02 for carbohydrate and 337 (kcal/100 g) for food energy contents which have indicated good quality seeds

Table 12.1 Variability of the aniseed essential oil content and some main components in different countries

Esential oil content (%)	Chemical composition	Country	References
1.3–3.7	trans–anethole 78.63–95.21%, methyl eugenol 0.09–2.44%, anisaldehyde 0.01–5.76%	Turkiye	Arslan et al. (2004)
2.49 (wild)	methyl chavicol 2.0%, bicyclogermacrene 12.0%, (E)-anethole 94.2%,	Turkiye	Tabanca et al. (2006)
2.8–4.8	(E)-anethole 84.8–92.6%	Turkiye	Özel (2009)
1.0–5.36	trans-anethole 76.9–93.7%, 0.4–8.2%, trans-pseudoisoeugenyl 2-methylbutyrate 0.4–6.4%, p-anisaldehyde tr-5.4%, methylchavicol 0.5–2.3%	Estonia	Orav et al. (2008)
1.3–4.8 (wild) 3–5	trans-anethole 85–96%	Turkiye	Başer and Kırımer (2014)
3.24–3.73	trans-anethole 82.1%, γ-himachalene 7.0%	Germany	Ullah et al. (2014)
2.0	methyl chavicol 1.7%, (Z)-anethole 0.1%, (E)-anethole 97.9%, 4 γ-himachalene 0.3%	Italy	Iannarellia et al. (2018)
1.30–3.47	trans anethol 85.62–94.99%, methyl chavicol 1.52–2.57%	Turkiye	Doğan et al. (2018)
0.81	E-anethole 93.0%, γ-himachalene 2.85%, Methyl chavicol 1.13%	Saudi Arabia	Figueredo et al. (2020)
1.74–7.69	trans-anethol 84.61–97.0%, pseudo-2-eugenyl-2-methyl butyrate 0.71–12.43%, pallylanisole 0.14–2.08% and methyl eugenol 0.14–0.50%	Turkiye	Karik (2020)
4.16–5.19	E-anethole 88.65–88.90%, limonene 5.40–5.55%	Greece	Katsoulis et al. (2022)

as well as good nutritional source (Ghosh et al. 2019). The crude oil yields of aniseed were determined as 22.07%, and the main fatty acid components of aniseed were oleic acid (6Z-octadecanoic acid- petroselinic acid-C18:1) with 70.82% and linoleic acid with 23.34% (C18:2) that grown in central Türkiye (Çelik and Ayran 2020).

12.2.4 Morphological Description

Pimpinella anisum L. is an annual long day plant (Rudorf 1958). The thin and weak roots are shallow. The stem is erect, 30–60 cm tall, rounded and branched at the top. The leaves show three different shapes depending on their position on the plant. The lower leaves are long petiolate; their shape is rounded heart-shaped. Its edges are more or less deeply toothed. The middle leaves are in three or five parts and narrow towards the foundation. The upper leaves are short-stalked, usually narrowly lanceolate, and three-part (Fig. 12.2). The plant branches in the last third of the topsoil

Fig. 12.2 Aniseed lower, middle and upper leaf and flower clusters and fruits (left photo: Bayram E) and vegetatif period (right photo: Kırıcı S)

(Heeger 1956; Ceylan 1987). At the end of the branches there are sparse umbella type flower clusters containing of 8–15 radiant branches (Fig. 12.2).

Anise flowers are small. There are no bract-leaves or one bract leaf is present. Sepals (calyx) are very small and have 5 teeth. The petals (corolla) are 5 pieces, 1.0 to 1.5 mm. long and white in color. The ovary (ovarium) has two stigmas and two eyes. The male organ (stamen) is 5 pieces, they are in two bags (Heeger 1956; Melchior and Kastner 1974; Sauer et al. 1996; Ceylan 1987). Anise is a foreign pollinated plant, the pollinator is honey and wild bees and insects. In many sources, it is stated that it is a species with a high foreign fertilization rate and shows a genetically heterogeneous structure.

The fruit (seed) is short hairy, elliptical, or pear-shaped, 2-part, 3–5 mm long and 1.5–2 mm wide. Its color is grayish green or grayish brown, bearing a small piece of stem and 2 short pistils at the upper end. There are 5 or more longitudinal veins on the fruit. (Heeger 1956; Melchior and Kastner 1974; Baytop 1984; Sauer et al. 1996). Anise seeds are schizocarp; each seed consists of two parts called mericarps. During harvest, the seeds are schizocarp. Dried seeds in later periods can be divided into two by storage, transportation, unloading and similar applications. The weight of 1000 grains is 1–1.5 g in small fruits and 2.5–3 g in large fruits if the fruit is divided into pieces (Ceylan 1987). In schizocarp seeds, the weight of a thousand grains varies between 4.01 g and 5.46 g (İpek et al. 2004). Germination in anise seeds is completed in 21 days at 18–20 °C.

12.2.5 Geographical Distribution

Aniseed can grow naturally in the world; Southern and Central Europe, Western, Easthern and Central Russia, Cyprus, Syria, Egypt and Türkiye (Davis 1972). As a spice plant, anise ranks second after cumin in terms of the planting area in Türkiye.

Anise grown in Türkiye is usually known by the name of the cultivation area, such as Cesme Anise, Burdur Anise, and Denizli Anise.

The production of anise is still frequently carried out by using landraces. The seeds used in production are composed of very mixed populations. Therefore, the anise industry experiences certain difficulties in obtaining products of standard quality. *Pimpinella anisum* landraces of Turkish (16) and different origins (Cyprus, Syria, and France) were to identify genetic variation using RAPD and ISSR markers. The highest genetic similarity values of Syrian and French landraces were probably associated with their resemblance in the amplified region. The results also showed that the foreign anise landraces were closely grouped with the indigenous landraces. The Eskisehir-Cesme and Syria-France landraces were also located in the same cluster in RAPD-based and combined dendrograms and were observed as genetically close landraces. These results concluded that the accessions from diverse geographical regions could be genetically similar (Akcali Giachino 2020).

12.2.6 Ecological Requirements vs. Cultivation

Anise is a slow growing annual herb which is cultivated throughout the world. For cultivation a warm, sunny and dry autumn is ideal to produce economical yields and high quality essential oil. The temperature during the growing season should be quite uniform without very hot periods, particularly following precipitation. When the fruits are near maturity, alternate wet and dry conditions change it to brown color. The anise cultivated field should be protected from wind to save the plants from lodging (Heeger 1956). The reported life zone for anise cultivation is 8–23 °C with 1000–1200 mm annual precipitation produce excellent crop, and 2000 mm rainfall is suitable, and a soil pH of cultivated field range from 6.3 to 7.3 (Simon et al. 1984). Anise is damaged by the climate with high humidity, very hot weather, long-lasting drought, precipitation during the flowering, and dry and hot winds. It requires sunny and dry weather conditions especially during flowering, grain setting and seed maturation periods.

Anise is a plant that is grown in Aegean, Marmara and Southern Anatolian Regions of Türkiye and loves heat and moderate humidity. Although it likes humid and rainy weather conditions during germination and first development periods, it requires dry weather conditions especially during flowering and seed setting periods. During these periods, rainy, cold and humid weather adversely affects fertilization, and the seed retention rate is low. The anise plant, which likes the regions with hot and regular rainfalls in terms of climate, is adversely affected by sudden weather changes, and changes in fruit color (brown or darker color) may be encountered due to precipitation or drought. This situation directly affects fruit quality (Dumanoğlu et al. 2020).

Anise particularly likes light to medium soils rich in lime and nutrients. Cold, heavy and moist soils are not suitable for anise cultivation. Weather, soil structure, topography, the condition of the land to the prevailing winds are the factors that affect the cultivation of anise. The seeds purity for sowing should beat least 90% and germination rate at least 70%. The germination ability of aniseseeds decrease rapidly when using inadequate conditions of storage. The best seeds for cultivation will come from the previous year harvest, since the germination ability decreases depending on the storage period, it is foreseen to use fresh seeds (Akıcı 2016).

The field where anise will be planted should be plowed deeply once or twice in fall, and once exposed before planting if necessary. After the pre-sowing plow, the seed bed is prepared by surface processing with a disc harrow or similar tool. A well-prepared seedbed is necessary for the germination and emergence of anise seeds. Anise planting in Türkiye is done between the end of January–March and April according to the region and planting conditions. Early sowing is done in dry conditions. Even sowing at the end of November has produced positive fruit yields (Heeger 1956; Tayşi et al. 1977; Fazecas et al. 1985). Seed yield varies greatly according to planting time. The earlier the planting is done, the higher the yield is received. However, it is important to determine the planting time by taking into account the changes in climatic conditions in recent years.

There are two types of sowing in anise, scattering and drilling. In recent years, drilling in rows has become widespread. However, the scattering sowing metod is still applied in small anise production areas. When sown by scattering, a homogeneous germination cannot be achieved in the field, however, more seeds are used and it is more difficult to fight weeds. Seed rate has important effect on yield and yield components such as the number of branches, fruits and fruit size (Tunçturk and Yildirim 2006). Sowing in rows is carried out with a seeder and approximately 15–20 kg of seeds are planted per hectare. The spacing between rows is usually 30–40 cm and the planting depth varies between 1–3 cm. Anise agriculture has undergone little change in Turkey. In 1948, it is recommended that anise should be planted in 30–40 cm rows in March and May, 14–20 kg ha^{-1} for scatter sowing and 10–15 kg ha^{-1} for sowing with seeder. Thus, they stated that 600–1500 kg ha^{-1} of seed yield and 1600–3000 kg ha^{-1} of straw can be obtained (Ekimci 1948). Depending on the climatic conditions, the seeds germinate 2–3 weeks after planting and emerge on the soil surface. In case of rain before exiting, a cream layer may form on the soil surface depending on the soil structure. Anise is very sensitive to the "cream layer" of the soil. Therefore, the "cream layer" must be broken to ensure the establishment of anise plants. Since anise grows very slowly compared to weeds during the germination and at the first development period, weed control is very important and should not be neglected. Hoeing is done 2–3 times during a vegetation period according to the density of weeds. In anise, the first hoe should be done when the plants have 3–4 leaves, and the second hoe should be done when the plants are 10–15 cm tall. If necessary, tillering is also made and it can be appropriate to remove weeds, once more. In recent years, the use of pre-planting herbicides in the weeds control has become widespread (Tepe et al. 1994).

More specifically, N and P fertilization affect plant growth and the quantitative yield of anise essential oil, reduced N intake affects anise, as with various other medicinal and aromatic plants, in terms of growth and productivity, P affects metabolic processes, improves fertility, stimulates flowering, helps seed growth, and accelerates ripening (Katsoulis et al. 2022). One of the applications that directly affects the yield and quality of anise is fertilization.The amount of nitrogen fertilizer is very important in terms of yield and quality. Care should be taken during adding nitrogen to the anise field, because it can result in too-exuberant growth of weeds as well poor fruit setting and storing conditions. High doses of nitrogen cause an increase in the vegetative part of the plant and the total number of branches, on the other hand, a decrease in the fruit setting rate, a decrease in the essential oil ratios and flower drop. As a pure active-substance anise should be fertilized with 50 kg of N, 50–70 kg of P and 80–100 kg of K per hectare. However, when 60 kg of nitrogen is applied per hectare, a decrease in grain yield has been determined (Bayram 1992). Generally; 40–50 tons ha^{-1} farm manure is given. Since the soils have different nutrient contents, soil analysis must be done before fertilizer applications.

Anise plants can be grown without irrigation in places where rainfall is sufficient. However, if the precipitation is not sufficient during the anise growing period, the irrigation will significantly increase the grain yield. According to the climatic conditions, irrigation is done 1–3 times during the vegetation period. Anise can be watered 10 days before the flower. Irrigation during the grain setting period provides a minimum of 20–40% increase in yield. Water is not given over the period of full flowering. The first irrigation should be given when the plants are 10–15 cm tall under irrigated conditions; first irrigation is done after weeding and first hoeing, second irrigation is done before flowering, third irrigation is done after flowering. If anise grown in irrigated areas is combated with powdery mildew (for example, with aqueous or powdered sulfur), the yield will increase and the quality will increase. In a study conducted on anise, it was determined that irrigation, especially in critical ontogenetic periods (two-leaf period, stem lift and the beginning of flowering in the main umbrella), increased seed yield and essential oil ratio (Waly et al. 1981). Inanise, it has been determined that high irrigation water and increasing doses of nitrogen fertilizers increase fruit yield, while low irrigation water and excess doses of nitrogen fertilizer cause depression in yield (Tayşi et al. 1977).

It is very important to determine the appropriate harvest time in anise farming. Harvesting is difficult because the umbels mature progressively, and fruits ripenis uneven within each umbel (Stephens 1997). The most suitable harvest time for anise is when the seeds on the main umbrella begin to turn brown. The highest yields of seeds, essential oil and (E)-anethole were obtained from the fourth harvesting stage when the main umbel was completely matured (Özel 2009). Harvest time may change from early July to August depending on the climatic conditions. Harvesting is done by hand plucking or reaping, as well as by machinery in the recent years. Machine harvesting is not recommended as the plant will lie down due to sparse planting in barren areas. Harvested plants are dried in bunches, the threshing of the dried plants is carried out by hand pounding or by threshing machines. It is further dried in the sun for one day to reduce humidity. Then it is filled in bags and stored. Early or late harvesting affects the quality negatively. Harvested anise should not be exposed to rain. In such cases and in late harvests, the grains become black, and their quality decreases.

The seed yield of aniseed varies between 450–1.100 kg ha^{-1}: it may noticeably vary depending on ecological conditions such as temperature, precipitation, soil fertility, growing technique and quality of the seed used. Planting space and seed rate are important factors in determining the microenvironment of the anise field (Arslan et al. 1999; Ullah et al. 2014). The optimization of these factors can lead to a higher yield, as they favorably affect the absorption of nutrients and exposure of the plants to the light.

12.2.7 Selection of Planting Materials

Anise cultivation is started from seeds. Although Türkiye is an important producer of anise, there are not enough varieties to grow. There are 5 varieties of anise in Türkiye, 2 of them are developed by the public sector and 3 by the private sector. Anise producers usually obtain the seeds they need from their blended products of the previous year or from anis producing farmers. The seeds should have a solid appearance, and should be disease-free, free of weeds and foreign materials, high germination vigor, not more than one-year-old, containing less than 10% moisture, with a unique taste and smell, and greenish gray color (Anonymous 1987). Figure 12.3 shows that plants isolated during flowering using the "phenotypic repetitive selection" method in anise (Bayram 2019).

Fig. 12.3 Anise plants isolated in bloom. (Photo: Bayram E)

12.2.8 Traditional Use and Common Knowledge

Aniseed, which has a history of 500 years in our geography, is a great traditional and folkloric element. In Turkish folk medicine this plant, and especially its seeds, have been used to alleviate the spastic conditions of infants and adults, to increase milk secretion and to have a widespread use as carminative, appetizers, sedative, antispasmodic and antibacterial, besides it is also included in many pharmacopoeias (Baytop 1984; Arslan et al. 2004; Tabanca et al. 2006; Salim et al. 2016). In folk medicine, it is also known to be used internally for whooping cough, colic-like pain, menstrual disorders, liver disease, tuberculosis, and dyspeptic complaints. It is also used in homeopathy for shoulder pain and lumbago (Gurkan et al. 2007). Recipes made with anise are given in herbalists (aktars) in Türkiye; for example, a decoction of 50 g aniseed in half a liter water is taken for cold in the bowels, it is good for indigestion. Also one teaspoon of aniseed drug is infused with one glassful of water and filtered, 10 drops of this filtrate is added to one spoonful of mother's milk, and given to babies three times a day after feeding for gas pain. Besides, prepared panason tea with aniseed (ingredients: one part anise, 2 parts *Matricaria* and 2 parts *Mentha piperita*) are used for gastric pains and common cold (Başer et al. 1986). In additon, it is used to increase the milk of breast feeding, by boiling 30 g of anise leaves in one liter of water and drinking 3 tablespoons before meals. Its use is common among the people to relieve gas pains. In indigestion and as a carminative, it is drunk by adding honey or sugar to sweeten herbal tea obtained by adding 1 teaspoon of anise to 1 glass of hot water. In addition, anise is used in the production of drinks (raki, anizet). 0.5–1 g powder once or twice a day, or 1–2% infusion can be prepared and drunk 2–3 glasses a day (Baytop 1984; Asımgil 2009; Kullu 2020).

12.2.9 Modern Medicine Based on Its Traditional Medicine Uses

Traditionally, the aniseeds are used as carminative, diuretic, sedative, appetizers, increase milk production, sedative, antispasmodic and antibacterial (Baytop 1984). Antimicrobial properties of anise seed oils were investigated. The antimicrobial activity determined by disc diffusion method against the gram-negative bacteria, namely *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, the gram-positive bacteria namely *Staphylococcus aureus* ATCC 25923, *Streptococcus pyogenes* ATCC19615 and *Candida albicans* ATCC10231 as the yeast. Anise essential oil showed weak antimicrobial activity against test microorganisms Studies carried out by Ghosh et al. (2019) showed that antimicrobial activity of the two essential oils of aniseed which collected from the local market Dhaka and Bangladesh Spice Research Centre (BSRC), Bogra showed moderate activity against Gram-positive, Gram- negative bacteria and fungi compared to the standard antibiotic ciprofloxacin. Mohamed et al. (2015) reported that the aqueous decoction of *P. anisum* seed showed no activity against both gram positive and gram-negative bacteria, but the petroleum ether and chloroform extracts were found active against *Pseud. aureginosa* and the two fungi, *Candida albicans* and *Aspergillus niger*.

On the other hand, Iannarellia et al. (2018) have evaluated the anti-inflammatory activity and the effect on mucin secretion of aniseed essential oil in primary airway bronchial and tracheal epithelial cells (HBEpC and HTEpC, respectively) in a model of lung inflammation induced by lypopolysaccharide (LPS). The data obtained for 0.3% of aniseed essential oil contained a very high level of (E)-anethole (97.9%). At non-toxic doses, it significantly decreased the expression levels of IL-1 and IL-8 and increased the Muc5ac secretion in LPS-treated HBEpC and HTEpC lines. These results provide new evidence supporting the ethnobotanical use of aniseed in the treatment of respiratory diseases. In particular, aniseed essential oil showed a significant anti-inflammatory effect on both HBEpC and HTEpC cells together with mucus hypersecretion. Similarly, in the monographs, it is stated that the essential oil of anise and its aqueous and ethanolic extracts have bronchodilator effects, and this relaxant effect is due to the inhibition of muscarinic receptors. Also, the essential oil and trans-anethole have estrogenic effects, inhibit apoptosis induced by TNF (Tumor necrosis factor), thereby inhibiting inflammation and its role in the suppression of carcinogenesis. However, it is recommended not to apply the treatment for a long time in terms of medical use (Anonymous 2007; Somer 2011).

The anise plant is used against diseases and pests that occur during agricultural production such as red spiders, aphids, whiteflies and storage pests (Doğan et al. 2018; Baydar 2021). The essential oil of aniseseed growing in Türkiye has antifungal activity against *Alternaria alternata, Aspergillus niger* and *Aspergillus parasiticus* mycelial, suggesting the potential use of some oils as antifungal preservatives in food (Özcan and Chalchat 2006). Tunç et al. (2000) studied the fumigant activity of the essential oils of *Pimpinella anisum* and *Cuminum cyminum*, against eggs of two storage insects; the exposure to anise and cumin essential oil vapors resulted in 100% mortality of the eggs. Since anise pulp contains 23% oil and 18% protein, it is a sought-after product as animal feed (Hoppe 1975). Çiftci et al. (2005) indicated that anise is an annual herb indigenous to Iran, India, Türkiye, and many other warm regions, and it could be considered as a potential natural growth promoter for poultry.

12.3 Fennel (*Foeniculum vulgare* Miller)

Foeniculum vulgare. (Photo İnan M)

Foeniculum vulgare Mill is a spice that has annual, biennial and perennial forms, and contains essential oil (Miraldi 1999). Traditionally, different plant parts have been used for various stomach ailments and against obesity (Gàmiz-Gracia and Castro 2000; Yamini et al. 2002; Choi and Hwang 2004; Rahimmalek et al. 2014). Although the natural growth areas of fennel are the Mediterranean regions and the European contries, it is commercially cultivated in many countries of the world (Miraldi 1999; Kırıcı et al. 2010; Diao et al. 2014). Due to the presence of different proportions of essential oil in all organs of the plant, it has found its place in many fields such as vegetables, spices, aromatics, cosmetics, medicine, food industry and, livestock sector (Makukha et al. 2018). Two types of fennel are cultivated in the world: bitter (var. *vulgare*) and sweet (var. *dulce*) fennel. All of the fennel produced in Türkiye are sweet fennel, those that grow naturally are bitter fennel. Fennel production area in Türkiye has increased by 113% in the last 5 years and reached 33.857 da, the production amount in this area has been 4.738 tons (TUIK 2022).

12.3.1 Taxonomic Characteristics

Fennel is classified only as *Foeniculum vulgare* Mill., as a species belonging to the *Foeniculum* genus of the Apiaceae family. All fennel plants, both naturally growing and cultivated, belong to the *Foeniculum vulgare* Mill. species. It has two subspecies: ssp. *piperitum* and ssp. *vulgare* (Muckensturm et al. 1997). *Foeniculum vulgare* ssp. *vulgare* has three varieties: var. *azoricum* (perennial), var. *dulce* (annual or biennial) and var. *vulgare* (perennial) (Miraldi 1999; Piccaglia and Marotti 2001; Khammassi et al. 2018).

Foeniculum vulgare Miller ssp. *vulgare* var. *azoricum* (Mill.) Thell., is defined as vegetable fennel, *F. vulgare* Mill. ssp. *vulgare* var. *dulce* (Mill.) Thell. as sweet fennel, and *F. vulgare* Miller ssp. *vulgare* var. *vulgare* as bitter fennel (Miraldi 1999; Shalaby et al. 2011; Raal et al. 2012; Khammassi et al. 2018).

12.3.2 Crude Drug Used

Fennel fruits, which are commercially called "seeds" are used as flavorings and crude drug. The fruits have stomachic, carminative and milk enhancing effect, whereas the leaves are used as a healing agent, and the roots as a diuretic. The 2% infusion prepared from its fruits is also effective in preventing gas formation, especially in infants (Baytop 1984). They are also used as flavoring agents in food products such as liqueurs, bread, pickles, pastries and cheese (Akgül 1993; Telci et al. 2009; Kırıcı et al. 2010). It has also used aperitif, anti-inflammatory, antimicrobial, antiseptic, antispasmodic, carminative and diuretic (Lawless 2002). Both fruits and essential oils of ripe fennels are used in cosmetics and pharmaceutical products (Barrahi et al. 2020).

12.3.3 Major Chemical Constituents and Bioactive Compounds

There are numerous studies on the essential oil and its components in fennel seeds. Some of the results of these studies are summarized in Table 12.2. Although the main component of the essential oil is trans-anethole, there are studies stating that estragole as the main component (Table 12.2) (Khammassi et al. 2018; Barrahi et al. 2020). Similarly, components such as fenchone, estragole, and limonene stand out as the second and the third most abundant components.

Studies on different subspecies (sweet and bitter fennel), geographical regions, cultivated or collected from natural habitats, as well as the time of seed harvesting (early period, ripe) have established the variability of essential oil components. Muckensturm et al. (1997) reported that fennel subspecies are divided into 3 chemotypes in terms of essential oil components as anethole, estragole/anethole and estragole chemotype. Kalleli et al. (2019) reported that the main component of seeds obtained from Tunisia was trans-anethole (63.41–78.26%) and estragole (44.72–88.92%), from France. In some studies, conducted on other plant organs (leaf, upper part of the plant, umbrella) other than the seed, it has been reported that the main components show similar changes (Muckensturm et al. 1997; Rahimmalek et al. 2014; Sharapov et al. 2017; Zolotilova et al. 2021).

Table 12.2 Essential oil contents and components obtained in studies with fennel seeds in different countries

Source	Esential oil content (%)	Chemical composition	Country	References
Natural	3.03–3.46	*trans*-anethole (1.4–94.6%) estragole (1.4–93.9%) fenchone (0.7–10.4%)	Italy	Miraldi (1999)
Natural	2.5	(e)-anethole (69.4%)fenchone (11.0%) limonene (10.0%)	Iran	Yamini et al. (2002)
Natural	2.4–6.4	*trans*-anethole (85.07–90.38%) fenchone (2.11–4.06%) estragole (1.24–3.25%)	Iran	Salami et al. (2016)
Cultivated	0.8–1.42 (FS)	*trans*-anethole (70.6–77.4%) fenchone (4.96–6.18%) methyl chavicol (2.81–3.16%)	India	Kapoor et al. (2004)
Natural	3.8	*trans*-anethole (70.1%) fenchone (6.9%) methyl chavicol (4.8%)	Pakistan	Gulfraz et al. (2008)
Cultivated	5.8	*trans*-anethole (84.1–87.9%) methyl chavicol (4.2–5.5%) limonene (2.96–4.69%)	Turkiye	Telci et al. (2009)
Cultivated	1.7–6.4	*trans*-anethole (11.3–91.77%) fenchone (0.83–29.04 (%) estragole (1.66–45.89 (%)	Turkiye	Kırıcı et al. (2010)
Cultivated	1.48–2.97	(e)- anethole (50.3–75.9%) limonene (5.8–18.2 (%) fenchone (3.44–14.62%)	Egypt	Shalaby et al. (2011)
CF	0.5–5.1	*trans*-anethole (34.8–82%) estragole (2.4–17.0%) limonene (0.8–16.5%)	DC	Raal et al. (2012)
CF	1.74	*trans*-anethole (68.53%) estragole (10.42%) limonene (6.24%)	China	Diao et al. (2014)
Natural	1.20–5.06	estragole (66.09–85.23%) fenchone (5.18–23.09%) limonene (4.30–10.25%)	Tunisia	Khammassi et al. (2018)
Cultivated	3.24–5.26	*trans*-anethole (36.31–78.26%) estragole (4.67–88.92%) L-fenchone (2.82–12.09%)	Tunusia	Kalleli et al. (2019)
Natural	2.82	estragole (44.38%) fenchone (11.73%) limonene (8.29%)	Morocco	Barrahi et al. (2020)
Cultivated	4.67–7.04	anethole (73.2–75.9%) fenchone (10.40–12.70%) methylchavicol (3.0–3.5%)	Russia	Zolotilova et al. (2021)
Natural	2.33–2.92	anethole (30.00–89.50%) fenchone (3.40–10.90%) α-terpineol (42.20–56.50%)	Montenegro	Božovic et al. (2022)

FS fresh seeds, *DC* different countries (Estonia, Norway, Austria, Moldava, Turkiye), *CF* commercial fruit

12.3.4 Morphological Description

It is stated that there are significant differences in the morphological characteristics, essential oil content and components of plants collected from nature and cultivation (Shahat et al. 2011; Kırıcı et al. 2010). In natural habitats, fennel can grow up to 2–2.5 m in height, have a hairless, bright-striped body, consist of 12–25 flowers in an umbrella shape, form schizocarpic fruit with yellow flowers, and may have a thousand seed mass between 1.5–6.1 g (Kırıcı et al. 2010; Božovic et al. 2022). The key herbal characteristics is erect, glabrous, glaucous perennial with sturdy, terete, finely ridged, branched stems, 1–1.8 m, strongly smelling of aniseed or licorice. Basal leaves triangular or triangular-ovate, 3–4-pinnate up to 30 × 15 cm (or more); ultimate segments filiform, up to 40 × 0.5 mm; petioles broad, sheath-like; cauline leaves few, like basal but smaller. Rays 8–15, unequal, 10–40 mm. Bracts and bracteoles absent, pedicels 1–7 mm. Flowers 18–25 per umbellule and petals are yellow. Fruit ovoid-oblong, 4–4.5 × 0.5 mm, glabrous, with prominent ridges (Davis 1972) (Fig. 12.4).

12.3.5 Geographical Distribution

Fennel can grow naturally in the world; Western, Southern and Central Europe, North Africa and Mediterranean Coasts and, from Southwest Asia to Nepal (Davis 1972). It is cultivated in many Mediterranean countries, Europe, Asia, America and Africa (Kapoor et al. 2004; Datiles and Popay 2015; Moosavi and Seghatoleslami 2016). India, Russia, Mexico, Iran, China, Pakistan, Argentina and Indonesia are at the top fennel cultivating countries (Makukha et al. 2018).

Fig. 12.4 Fennel plants clusters and fruits (left photo: İnan M, right photo Kırıcı S)

12.3.6 Ecological Requirements and Cultivation

Fennel is a plant that can be adapted to different ecological conditions in the world and spread naturally. It is known that fennel grows naturally in all Mediterranean climate having countries. It can spread along the streams and roadsides, fertile and unproductive non-agricultural areas, irrigation canal edges, coasts close to the sea and altitudes between 0–2600 m. It shows good growth, especially in humid-temperate and sunny seasons. Fennel can be grown in many different soil types such as moist, loamy or loamy-clay soils with a pH between 6.3 and 8.3, with low salt content and well-drained soils. Fennel prefers conditions where precipitation is between 500–2000 mm and temperature is between 6–24 °C (Datiles and Popay 2015; Dheebisha and Vishwanath 2020).

It can be grown in summer or winter in different countries of the world. Fennel is cultivated for two different purposes the tubers of *F. vulgare* ssp. *vulgare* var. *azoricum*, which forms a tuber near the soil surface, are consumed as vegetables, while *F. vulgare* ssp. *vulgare* var. *dulce* and var. *vulgare* are grown to produce seeds.

Tuberous fennel (var. *azoricum*), which is used as a vegetable, is usually planted as an annual, either directly in the field in the first spring, or the seeds are sown in the seedling pads in the early spring, and the seedlings obtained from those are planted in the ground. If it is planted as seeds, the space between the rows is 45–50 cm, above row spacing is 10–15 cm, and the sowing depth is 1 cm. If it is planted as seedlings, it should be planted in the greenhouse 4–6 weeks before the last frost date and turned into seedlings (Adams and Drost 2020). Tuber yield and quality are quite high in the field when planted from mid-April to the end of May in Czech Republic conditions (Koudela and Petříková 2008) and in April under Polish conditions (Błażewicz-Woźniak 2010).

Sowing time and planting technique of production as seed vary depending on ecological factors. It is reported that production can be made even with claws in the root zone of fennel in regions with mild winters (Oguz et al. 1999). Fennel seeds can be planted directly in the field if the soil is well tilled and processed for sowing. This is important for a uniform germination. The seeds germinate in 8–10 days at temperatures between 16–18 °C, the germination time may vary depending on the ecology, sowing time and sowing depth (Dheebisha and Vishwanath 2020). As a matter of fact, it is reported that germination takes place in 20 days (Kırıcı et al. 2010) after sowing in January in Southern Türkiye (Mediterranean Climate), and in 21–31 days after sowing in March under Ukrainian conditions (Makukha et al. 2018). It is reported that better results were obtained in October under Pakistan (Ayub et al. 2008) and Egypt (Shalaby et al. 2011) conditions and in March under Iranian conditions (Moosavi and Seghatoleslami 2016). Again, although it varies according to the ecological regions, the distance between the rows and above varies between 25–70 × 15–40 cm. In studies conducted in different countries; Türkiye (Kırıcı et al. 2010; Telci et al. 2009; Özel et al. 2019) 40–70 × 15–30 cm, Egypt

(Shalaby et al. 2011) 60 × 40 cm, Iran (Moosavi and Seghatoleslami 2016) 50 cm, Ukraine (Makukha et al. 2018) 45 cm, India (Dheebisha and Vishwanath 2020) 20–25 × 45–60 cm, Russia (Zolotilova et al. 2021) 60 cm above row spacings were used. There are studies on the "between-row-spacing" that results in higher seed yields in dense plantings (Khorshidi et al. 2009; Özel et al. 2019). Considering these distances, the number of seeds to be used per hectare varies between 5 to 20 kg ha^{-1}.

An appropriate fertilization amount and time should be determined depending on the soil conditions, planting period (summer-winter) and water availability. In order to provide the nutritional needs of the plants, fertilization should be done with 40–50 kg ha^{-1} phosphorus and 40–100 kg ha^{-1}nitrogen as pure effective substance. Phosphorus and half of the nitrogen fertilizers should be given just before planting, at the last tillage or during the planting. The remaining half of the nitrogen should be given from the moment the plants begin to establish a root system, until the inititation of flowering (Ayub et al. 2008; Kırıcı et al. 2010; Makukha et al. 2018; Özel et al. 2019; Dheebisha and Vishwanath 2020). If irrigation is available, a good seed yield is obtained when the plants are irrigated every 10 days during the summer season (Kouchaki et al. 2006).

If fennel seeds are used as a spice, they must be harvested before the seed color turns to fully brown. Consumers especially prefer dark green color whose seeds are highly attractive. For this reason, when the seeds are dark green, without waiting for the umbrella to mature, the umbrellas are harvested by hand and dried in a shade and airy place to preserve, their color and quality. Umbrellas harvested at this stage should not be kept in high piles since the humidity is high. When the moisture content in the seeds falls below 10%, they should be threshed, and the seeds are cleaned from other plant residues and presented to the market. If the seeds are not to be used as a spice but as a flavoring in the industry, the seeds in the umbrellas should be harvested when they turn to brown. The essential oil content and components will be at the highest level in fully matured seeds. However, at this stage, it is very important to harvest the seeds in the umbrellas before they start to spill in order to prevent yield loss.

12.3.7 Traditional Used and Common Knowledge

Fennel, which is named according to the region in herbalists such as mayana, şumra, arapsaçı, meleture, irziyan, raziyane, isra, sincibil, sincilip, rezdene, yellow ot rezyane and malatura; used for dizziness and flatulence, condiment and carminative. Its stem, fruit, leaves, seeds, and whole plant itself are medicinally used in different forms in the treatment of a variety of diseased conditions. Also fennel used for atheroma and in vascular occlusion, it must be used for at least 20 days. It is included in the composition of teas prepared as a dewormer and for kidney and bladder stones and sands. Fennel can be used as an eyewash for tired, sore eyes (Mabey et al. 1988; Aksakal 2006). It is also included in mixtures prepared to calm the nerves of the puerperium and strengthen their bodies. For this, 15 different plant and seed parts, including fennel are pounded and mixed with molasses (Başer et al. 1986). Fennel is also used in the kitchen in foods such as pasta, bread, soup, meatballs, pickles, salads, and locally in sugary and floury products such as holiday buns. In addition to these, anise type is used instead of anise in the production of some alcoholic beverages (Akgül 1993). In addition, the young leaves of the plant are consumed as food in the Aegean region of Türkiye (Baytop 1984).

12.3.8 Modern Medicine Based on Its Traditional Medicine Uses

Fennel is among the main herbal medicines supported by the German Commission E for the treatment of indigestion complaints. The oil obtained from its fruits, containing anethol, fenchone and estragole, is taken as a daily dose of 0.1 ml and 0.6 ml or 5–7 g crude drug (Capasso et al. 2003). In Mediterranean region, fennel used to cure gastrointestinal and neurological disorders, kidney stones, vomiting, diarrhea due its antispasmodic, antiseptic, carminative and antiulcer properties (Sayed-Ahmad et al. 2017).

Gulfraz et al. (2008) reported that trans-anthole was major components of fennel oil (70.1%), followed by fenchone (6.9%) and methyl chavicol (4.8%). It is concluded that *F. vulgare* seed extracts and oil are rich in trans-anethole and other compounds and are effective against *Colletotrichum albicans, Eschericia coli* and *Pseudomonas putida* and other similar organisms. Therefore *F. vulgare* seed extracts and oil are valuable not only for increasing shelf life of foodstuffs but it could be a future target for replacing synthetic antibacterial agents. Similarly, Tunisian wild fennel essential oils exhibited a free radical scavenging activities inrelationship with its phenolic contents, its displayed the sensitivity of the tested strains especially against Gram-positive (*Micrococcus luteus* and *Staphylococcus aureus*) (Khammassi et al. 2018). In additon, studies show that white bread formulated with 5–7% of fennel seed powder can make it healthier by increasing TPC (total phenolic contents) value, antioxidant activity and consumer acceptability (Sayed-Ahmad et al. 2017). Rahimi and Ardekani (2013) have studied various pharmacological activities of fennel mentioned in traditional Iranian medicine (TIM) and modern phytotherapy treatments. They reported that aquous extract of *F. vulgare* fruit had clearly a protective effect against ethanol-induced gastric mucosal lesions in rats: the use of essential oil emulsion eliminated colic in 65% of infants compared to 23.7% in the control group. Bronchodilatory activity of *F. vulgare* reflects their usefulness in asthma. Besides, the beneficial effects of *F. vulgare* on vision may be due to its aldose reductase inhibitory and oculohypotensive activities. Eliminating obstructions leads to easier removal of waste materials from liver, and implies to hepatoprotective properties of *F. vulgare*.

According to monographs, a 95% ethanolic extract of ripe fruits of *F. vulgare* to mice reduced the perception of pain as measured in the hot-plate test, and decreased yeast-induced pyrexia. An essential oil from the fruits inhibited the growth of *Alternaria species, Aspergillus flavus, A. nidulans, A. niger, Cladosporium herbarum, Cunninghamella echinulata, Helminthosporium saccharii, Microsporum gypseum, Mucor mucedo, Penicillium digitatum, Rhizopus nigricans, Trichophyton roseum* and *T. rubrum* in vitro. In another study, an essential oil was not active against *Aspergillus* species in vitro but a methanol extract of the fruits inhibited the growth of *Helicobacter pylori* (the bacterium associated with gastritis and peptic ulcer disease) in vitro. Its essential oil reduced intestinal spasms in mouse intestine, and was 26% as active as papaverine. Intravenous administration of a 50% ethanol extract of the fruits (dose not specified) reduced blood pressure in dogs. An aqueous extract of the fruits, 10% in the diet, reduced blood pressure in rats (Anonymous 2007; Borotová et al. 2021; Dahmani et al. 2022). In clinical studies with fennel, it has been determined that it can be used as an insect repellent, and it reduces pain in primary dysmenorrhea, so its essential oil can be a safe and effective drug for primary dysmenorrhea, but its doses need to be adjusted. It was found that standard extracts prepared with fennel significantly reduced the complaint of colic in breastfed infants. (Küçükboyacı 2011).

There are positive developments in fennel production all over the world, which is due to its varied uses. Although seeds come to the forefront of world trade, the trade as vegetables has found a place for itself mostly in the European continent. It is predicted that there will be a significant increase in cultivation areas of fennel, since it can be widely used as vegetables and spices, in cosmetics and different industries (medicine, pharmacist, food, etc.).

12.4 Cumin (*Cuminum cyminum* L.)

Cuminum cyminum L. (Photo: Özel A)

Cuminum cyminum L. is an annual herbaceous species of the Apiaceae (Umbelliferae) family. It is native to the Eastern Mediterranean Region (Boughendjioua 2019). Cumin, temperate climate plant, is grown in countries such as China, India, Türkiye, Iran, Syria, Mexico and Egypt. In Türkiye, it is cultivated in arid and semi-arid regions such as Konya, Ankara, Sakarya, Eskişehir, Niğde, Afyon, Yozgat and Şanlıurfa (Özel and Demirbilek 2000; Dubey et al. 2017). Cumin is generally grown in fallow areas and dry conditions in the Central Anatolian Region in Türkiye. Cumin has the potential to be grown as an alternative to plants such as barley, wheat, and lentils in dry agricultural areas due to its short vegetation period, not forming a big habitus and good evaluation of the precipitation falling in early spring.

12.4.1 Taxonomic Characteristics

Cumin belongs to the Apiaceae family, tribe Ammineae, and subtribe Carinae, and has $2n = 14$ chromosomes (Allaq et al. 2020). It is native from East Mediterranean to South Asia and allogamy with hermaphrodite flowers (Srinivasan 2018). Synonyms are *Ligusticum cuminum* (L.) Crantz (1767) and *Cuminum odorum* Salisb. (1796).

12.4.2 Crude Drug Used

Cumin has been used as a spice and condiment plant and in folk medicine since ancient times (Kırıcı 2015). Its fruits, frequently called seeds, its essential oil and tea obtained from the seeds are used in folk medicine as stomachic, carminative, digestive, stimulant, diaphoretic, milk-increasing and against toothache. To date, it is also used in pharmaceutical, food, perfumery-cosmetics and beverage industry today (Baytop 1984; Akgül 1993; Başer and Kırımer 2014). The residues of fixed and essential oil extraction, i.e.: the remaining pulp, is used as animal feed. Cumin essential oil is used in the preparation of oral antiseptic materials, in the sterilization of surgical threads, in some veterinary and agricultural drugs, in perfumery, paint and plastic industry (Kan 1990; Başer 2014).

12.4.3 Major Chemical Constituents and Bioactive Compounds

Due to its unique aroma, the mature seeds of cumin and the fixed oil, essential oils and extraction products extracted from the seeds are evaluated for different purposes (Merah et al. 2020). Cumin seeds contain essential oil (1–5%), fixed oil (10–29%), protein (15–25%), −soluble sugars (8–13%), minerals (5–11%), flavonoids, resin and gum (Baytop 1984; Akgül 1993; Akmal and Itrat 2019; Merah et al. 2020). Cumin fixed oil, fatty acid main components are petroselinic acid (47.4–51.6%), linoleic acid (30.5–32.9%), oleic acid (11.2–12.2%) and palmitic acid (3.9–4.3%) (Shahnaz et al. 2004; Merah et al. 2020). The chemical content of cumin seed an vary depending on the genotype (Acimovic et al. 2016; Khan et al. 2017; Mortazavian et al. 2018; Merah et al. 2020), the ecological conditions of the region where it is grown (Wanner et al. 2010; Hashemian et al. 2013; Aliniana et al. 2015; Dubey et al. 2017), the cultivation technique applied (Ahmadian et al. 2011; Kahrizi et al. 2011; Nejad 2011; Nezami et al. 2011; Erden et al. 2013; Aliniana et al. 2015; Abdel-Kader et al. 2016) and the processing technique (Beis et al. 2000; Başer and Kırımer 2014; Saha et al. 2016) (Table 12.3).

The quantity of cumin essential oil and its essential oil components varied greatly according to the regions where it was grown (Table 12.3). Although, cumin aldehyde has been mostly determined as the main component, in some studies, ρ-cymene (Ravi et al. 2013), β-pinene (Haşimi et al. 2014; Figueredo et al. 2020), p-mentha-1,4-dien-7-al (Başer and Kırımer 2014) and γ-terpinene-7-al (Petretto et al. 2018; Pardavella et al. 2021) have been reported as major constituents. This change was due to the differences in the ecological conditions of the region, cultivated ecotypes and the cultivation techniques applied. It has been also reported that the fineness of grinding the seed, the amount loaded into the distillation unit and the distillation time also affected the essential oil yield (Beis et al. 2000). The content of p-Mentha-1,4-diene-7-al (γ-terpinene-7-al) which is the main component in freshly ground seeds was found to be easily oxidized to cumin aldehyde and γ-terpinene, under the influence of heat treatment (Başer and Kırımer 2014).

12.4.4 Morphological Description

Cumin has a taproot that goes as deep as 30 cm and has thin lateral roots. Plant height varies between 15–50 cm and in Türkiye it is 20–35 cm (Koşar et al. 2017; Koşar et al. 2019). The stem is thin, slightly angular and hairless, branching upwards from the base. The number of branches varies between 15.6–5.5 numbers/plant (Erden et al. 2013). The leaves are bare, fine thread-like compound pinnate and 2–3 knotty. The leaves are petiolate in the lower part of the plant and sessile in the upper part (Fig. 12.5a). The main stem and lateral branches end by a compound umbellate flower cluster (Fig. 12.5b). Flowering starts from the main stem and continues laterally to the branches. Its flowers are in the structure of five, and there are 5 sepals, two of which are long and pointed. Each flower has five petals and five stamens. Petals are egg or inverted egg-shaped, white or light pink in color and unequal in size. The ovary is slightly hairy and has 2 divisions. As a result of fertilization, cylindrical, pointed ends and a schizocarp fruit is formed from the union of two seeds. Seeds are 5–6 mm long and 2 mm wide, yellowish-brown, longitudinal ribs

Table 12.3 Variability of the cumin essential oil content and some main components according to their growing regions

Esential oil content (%)	Main chemical composition	Location	References
1.4–2.8	Cumin aldehyde (27.60%), γ-terpinene (17,25%), p-mentha-l.3-dien-7-al (15.18%), β-pinene (10.22%), p-mentha-l,4-dien-7-al (9.48%)	Eskishehir, Turkiye	Beis et al. (2000)
1.9–2.4	Cumin aldehyde (19.9–23.6%), p-mentha-1,3-dien-7-al (11.4–17.5%), p-mentha-1,4-dien-7-al (13.9–16.9), γ-terpinene (10.3–13.6%), p-cymene (7.7–11.6%)	Konya, Turkiye	Kan et al. (2007)
2.59–3.08	p-mentha-1,4-dien-7-al (23.69%), cuminaldehyde (20.58%), γ-terpinene (15.71%), β-pinene (12.22%), p-cymene (7.69%), p-mentha-1,3-dien-7-al (6.95%)	Diyarbakır, Turkiye	Kizil et al. (2008)
1.22	Cumin aldehyde (39.48%), γ-terpinene (15.21%), O-cymene (11.82%), β-pinene (11.13%), 2-caren-10-al (7.93%), trans-carveol (4.49%), myrtenal (3.5%)	Swassi, Tunisian	Hajlaoui et al. (2010)
–	Cumin aldehyde (22.4–41.5%), γ-terpinene (6.5–31.1%), β-pinene (10.7–15.7%), p-cymene (10.1–20.2%), p-Mentha-1,3-dien-7-al (5.5–10.6%)	Egypt, Europe, India, Iran	Wanner et al. (2010)
2.2–2.8	Cumin aldehyde (41.86–45.75%), p-cymene (10.1–20.219.62–22.46%), γ-terpinene (14.60–16.25%), β-pinene (12.44–16.74%), p-Mentha-1,3-dien-7-al (1.85–2.19%)	Sistan, Iran	Ahmadian et al. (2011)
2.63–4.08	Cumin aldehyde (23.22–30.57%), β-pinene (19.21–24.34%), γ-terpinene (10.00–13.84%), p-Mentha-1,3-dien-7-al (7.74–8.88%), p-Mentha-1,4-dien-7-al (6.24–21.74%), p-cymene (5.48–8.97%),	Şanlıurfa, Turkiye	Erden et al. (2013)
1.4–2.2	Cumin aldehyde (17.5%–22.3%), Safranal (16.8%–29.0%), γ-terpinene (14.1%–19.6%), γ-terpinene-7-al (13.5%–25.5%), β-pinene (6.8%–10.4%), p-cymene (4.1%–8.8%)	Khorasan, Iran	Hashemian et al. (2013)
	ρ-cymene (23–39%), β-pinene (22–27%), γ-terpinene (11–27%), Cumin aldehyde (8–17%), β-Myrcene (1.3–1.75%), p-mentha-1,4-dien–7-al (1.0–5.5%)	Different regions of India	Ravi et al. (2013)
1.2–3.2	p-mentha-1,4-dien-7-al(α-terpinen-7-al) (25–41%), Cumin aldehyde (19–27%), p-mentha-1,3-dien-7-al (α-terpinen-7-al) (4–12%),γ-terpinene (7–16%), p-cymene (5–9%), β-pinene (3–9%)	Turkiye	Başer and Kırımer (2014)

(continued)

Table 12.3 (continued)

Esential oil content (%)	Main chemical composition	Location	References
2.46	β-pinen (% 15.77), α- terpinen (% 15.52), 1-fenil-1-butanol (% 15.13), Cumin aldehide (% 12.74), Terpineolen (% 8.42)	Diyarbakır, Turkiye	Haşimi et al. (2014)
3.0	Cumin aldehyde (49.4%), p-cymene (17.4%), α-terpinen-7-al (6.8%), β-pinene (6.3%), γ-terpinene (6.1%), p-cymen-7-ol (4.6%)	Gujarat, India	Rana (2014)
2.29–4.83	Cumin aldehyde (0.93–32.62%), p-cymene (1.39–19.66%), p-Mentha-1,3-dien-7-al (3.18–22.72%), γ-terpinene (1.08–14.92%), β-pinene (1.45–5.43%)	Assiut, Egypt	Abdel-Kader et al. (2016)
2.0–4.0	Cumin aldehyde (19.5–36.1%), β-pinene (15.6–23.7%), γ-terpinene (11.8–20.2%), γ-terpinene-7-al (2.4–30.2%), p-cymene (4.9–13.7%)	Four different commercial samples	Acimovic et al. (2016)
0.72–1.71	Cumin aldehyde (37.31–52.56%), Carenal (24.53–25.78%), Cumic alcohol (13.26–19.31%), γ-terpinene (1.85–4.43%), β-pinene (12.18–15.47%),	India	Saha et al. (2016)
4.5	Cumin aldehyde (36.67%), Caren-10-al (21.34%), β-pinene (18.76%), γ-terpinene (16.86%), terpinen-4-ol (2.44%)	Maharashtra, India	Patil et al. (2016)
–	Cumin aldehyde (29.02%), α-terpinene (20.7%), γ-terpinene (12.94%), γ-terpinene 3 L (8.9%), p-cymene (8.55%)	Tabriz, Iran	Valizadeh et al. (2016)
2.12–4.45	Cumin aldehyde (25.84–39.90%), γ-terpinene (13.18–33.79%), β-pinene (12.18–15.47%), Cumic alcohol (10.33–14.40%)	Rajasthan, Gujarat, India	Dubey et al. (2017)
1.66–3.66	Cumin aldehyde (31.65–40.88%), γ-terpinene (0–9.74%), Santolina triene (0–12.52%), p-Menthatriene (0–24.63%), Myrtenal (1.48–17.86%), cis-Ocimene (0–10.26%)	Jodhpur, India	Khan et al. (2017)
1.20–1.59	Cumin aldehyde (53.32–57.48%), γ-terpinene (13.13–17.00%), m-cymene (6.94–16.94%), β-Pinene (6.59–7.43%)	Tehran, Iran	Mortazavian et al. (2018)
2.9–3.7	γ-terpinen-7-al (226.9–550.6 mg/mL), α-terpinen-7-al (60.8–214.6 mg/mL), Cumin aldehyde (73.8–191.5 mg/mL), β-pinene (20.8–86.4 mg/mL), p-cymene	Three different geographical areas of Morocco	Petretto et al. (2018)

(continued)

Table 12.3 (continued)

Esential oil content (%)	Main chemical composition	Location	References
	(6.2–24.7 mg/mL), γ-terpinene (80.3–169.0 mg/mL),		
3.66	Cumin aldehyde (50.5%), p-cymene (11.8%), γ-terpinene (10.0%), β-pinene (9.5%),	Algeria, Northwest Africa	Boughendjioua (2019)
1.28	β-pinene (36.46%), γ-terpinene (36.29%), p-cymene (10.43%), Terpinene-7-al-γ (3.48%)	Saudi Arabia	Figueredo et al. (2020)
1.6–2.9	Cumin aldehyde (36.19–49.5%), 1,4-p-menthadien-7-al (9.82–17.47%), β-Pinene (8.21–12.61%), p-Cymene (7.77–13.77%), γ-terpinene (6.44–13.14%), 1,3-p-Menthadien-7-al (4.40–8.88%)	Lebanon, France, Algeria, Syria	Merah et al. (2020)
–	γ-terpinen-7-al (34.9%), Cumin aldehyde (26.5%), α-terpinen-7-al (12.8%), γ-terpinene (11.1%)	Athens, Greece	Pardavella et al. (2021)

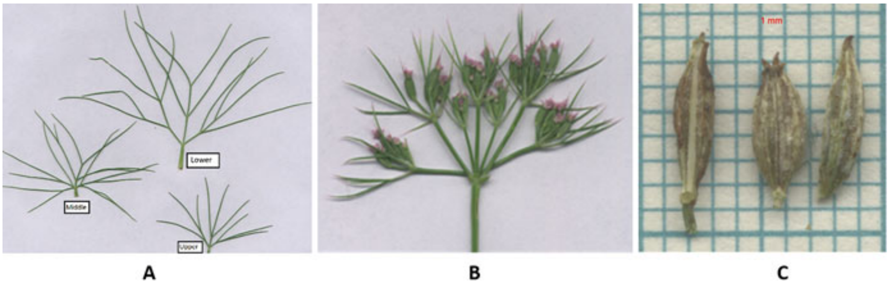

Fig. 12.5 Cumin leaves (**a**), umbels (flowers) (**b**) and seeds (fruit) (**c**). (Photo: Özel A)

(5 per seed) and flattened ovate in cross-section (Fig. 12.5c). 1000 seed weight varies between 2.0–2.9 g (Rizvi et al. 2015; Koşar et al. 2017; Tuncay and Yeşil 2019).

12.4.5 Geographical Distribition

Cumin has been known since antiquity. Its cultivation is currently most important in China, India, Morocco, Cyprus, Egypt, Türkiye, Iran and southern Russia. In other parts of the world, cultivation is only occasional; in South-East Asia, only in mountainous areas (e.g. in Indonesia) (Jansen 2022).

12.4.6 Ecological Requirements and Cultivation

Cumin is a long day plant that can withstand temperatures down to −18 °C. The optimum germination temperature is around 20 °C. The plant continues its development between 9–26 °C. For a satisfactory yield, 300–400 mm of precipitation is sufficient. However, cumin is not resistant to long-term drought and high temperatures. It is necessary to irrigate in periods when precipitation is insufficient (Özel and Demirbilek 2000). Some soil-borne fungal diseases can become epidemics with irrigation. *Alternaria burnsii* and *Fusarium oxysporum* f.sp. *cumini* pathogens are the main risk factors for cumin cultivation in Türkiye (Özer and Bayraktar 2015). Before planting, seed spraying (coating) must be done to prevent against diseases and pests. Cumin is not very selective in terms of soil requirements, it grows well in sandy-clay soils rich in organic matter and plant nutrients. It can be grown in no deep profile soils and between pH 4.5–8.3.

The germination ability of cumin seeds decreases in a short time and disappears completely after the second year. Therefore, it must be used from the new crop as a reproduction material. Seed sowing can be done in autumn or spring according to climatic conditions. Weeds can be a big problem in autumn planting. Sowing can be done by spreading or grain seeder. In sowing, the row spacing is 15–20 cm, the seed quantity is 10–15 kg ha^{-1}, and the sowing depth does not exceed 3 cm (Erden et al. 2013). According to Kizil et al. (2008), lower row distances produced higher seed yields as compared to wider row distances in cumin cultivation. Depending on the planting time and climatic conditions, the harvested can be implemented in late May or early June. Grain shedding is quite high in cumin production. Therefore, the harvesting time must be well determined. It should be done when the plants begin to turn yellow and the fruits on the main stem turn brown. Harvesting can be done by picking, a prairie mower or a scythe and should take place early in the morning to reduce harvest losses. After harvest, the plants are left to dry and then threshed.

The cultivation techniques, genotype and climatic conditions significantly affect the yield and chemical composition of the cumin seed. In some studies, the water stress and fertilization (Ahmadian et al. 2011; Abdel-Kader et al. 2016; Mortazavian et al. 2018), location, plant density and nitrogen fertilization (Kahrizi et al. 2011; Nejad 2011), genotype (Nezami et al. 2011) and harvest time (Kan et al. 2007) were reported those had significant effects on yield, essential oil content and components. For these reasons, cultivation techniques should be determined according to ecological conditions and genotypes.

In general, cumin production is labor intensive. Therefore, cumin production has generally concentrated in countries where labor was cheap. In these countries, it is of great importance in providing emloyment for family workforce, in dry agricultural areas, and increasing the incomes obtained from the unit area (Özel and Demirbilek 2000). Cumin is produced both for seeds and biochemicals derived from seeds. Its seeds are mostly used as spice. Its essential oil and extracts are used in food supplements and drug development due to their pathogenic activities. This usage efficiency may vary depending on the chemical content of the seed and therefore it may vary depending on the genotype, the ecological conditions of the growing region and the cultivation technique applied. For this reason, it is important to determine the cultivation techniques according to the suitable regions where cumin cultivation will be carried out.

12.4.7 Traditional Used and Common Knowledge

Cuminum cyminum L. (Kreuzkümmel (Al.), Semence de cumin (Fr.), Cumin seed (In.)) is also known as Avcar, Persian cumin, Kemmon and Zira. It is used as stomachic, gas-digesting, stimulant, diuretic and diaphoretic among the people (Baytop 1984; Ceylan et al. 2003). Cumin is included in the mixture of spices used especially in pastrami and sausage making. Apart from its use as a spice, it is used as a digestive aid, antispasmodic, urinary and bile enhancer, expectorant, relieving cold and upper respiratory tract infections (Baydar 2021). Cumin powder is good for skin wellness if water is applied to the face, as well as to heal inflamed wounds and to have a calming effect when boiled and drunk (Kan 1990).

In the southern provinces of Türkiye, in folk medicine, cumin is boiled and drunk to treat colds, along with fennel and anise against pain and indigestion. Cumin is boiled and drunk to relieve the pain caused by indigestion, especially in pregnant women, and the mint-cumin mixture is also good for nausea. To relieve the baby's gas pain, cumin is boiled and drunk warmly. Another recipe is to put some cumin in a spoon to relieve the baby's gas and relieve pain, breast milk is milked on cumin, and is given to child to drink so that the residue remains at the bottom. In addition to these, künlük, black sesame, black cumin, and cumin are burned in the house against the evil eye (Özgen 2007). In addition, cumin is used to make the ointment prepared for postpartum women to make their bodies healthier. The mixture contains thyme, basil, cumin, cinnamon, cloves and clay. All these spices are mixed with molasses, and left for 24 hours. Then this mixture is applied to the whole body of the puerperant who has passed 40 days after birth, left for half an hour and washed. The ointment applied to the body makes the woman sweat, so all the ailments in the woman are removed from the body, this ointment takes away the aches and pains in the whole body of the puerperal woman and almost renews her (Avcı 2018).

Cumin is used in the form of whole, powder or essential oil in food, beverage and liquor production as a flavoring and also for medical purposes. Its seeds, which have a dominant aromatic odor and a sharp burning taste, are preferred as flavoring in curries, soups, pickles, cheese, sauces, meat, bread, prepared foods and cakes. It is used as an alternative natural antimicrobial additive in the treatment of digestive disorders, diarrhea, epilepsy, toothache and wounds in traditional medicine, which has been accepted as not posing a risk to human health in recent years (Demir 2022).

12.4.8 Modern Medicine Based on Its Traditional Medicine Uses

Phenolic compounds are a rich source of antioxidants, thus acting as radical scavengers. These components exert an antioxidant defense mechanism on plant cells and organelles through low molecular polyphenols and flavonoids to maintain the effect of biotic/abiotic stress, free radicals and toxic oxygen intermediates in plants (Dubey et al. 2017). The quality and quantity of the extracts obtained from ground cumin seeds varied depending on the cumin origin, the solvent used and the extraction technique (Table 12.4). Rizvi et al. (2015) reported the following rates of dry matter dissolved in different solvents as follows: in petroleum ether at 2.86% (sterols), in chloroform at 4.20% (sterols, tannins, proteins, amino acids and

Table 12.4 Variability of the cumin seed's total polyphenol content, total flavonoid content, and antioxidative capacity according to their growing regions

Total polyphenol content	Total flavonoid content	Antioxidative capacity	Location	References
20.16 mg GAE/g (essential oil)	–	27.50% (mg/mL, DPPH scavenging), 8.3 μM trolox/100 g dry sample	Akşehir, Turkiye	Malayoğlu et al. (2011)
19.24–25.17 mg GAE/g (dry weight)	–	34.25–39.25% (mg/mL, DPPH scavenging)	Syria	Juhaimi and Ghafoor (2013)
11.93–14.40 mg/g galic acid (seed), 3.93–5.52 mg/g galic acid (leaf)	1.35–1.78%	–	Isfahan, Nishabur, Yazd, Khour, Iran	Aliniana et al. (2015)
30.1–47.5 mg GAE/g (post distilled cumin seeds waste)	–	0.02–0.04 TE/g (in post distilled cumin seeds waste)	Four different commercial samples	Acimovic et al. (2016)
9.3–10.2 μg GAE/mg (seed)	–	0.046–0.064 FRAP (μmol trolox/g), 0.24–0.28 DPPH (μmol trolox/g) Seed)	India	Saha et al. (2016)
41.50–58.61 mg GAE/g (seed)	27.14–36.03 mg QE/g (seed)	29.21–29.97 mg BHT/g (seed)	Rajasthan, Gujarat, India	Dubey et al. (2017)
16.91–27.49 mg GAE/g		36.88–54.92% (DPPH radical scavenging), 26.08–44.59% (ABTS radical scavenging)	Korea	Shamsiev et al. (2021)
91.6 mg GAE/ g (dry matter)	66.04 mg QE/100 g (dry matter)	22.17–68.51% (DPPH radical scavenging)	Aleppo, Syria	Bouhenni et al. (2021)

alkaloids), in ethanol at 4.43% (sterols, tannins, flavonoids, proteins, amino acids, glycosides, phenolic compounds, carbohydrates and alkaloids) and in water at 2.50% (flavonoids, proteins, amino acids, glycosides, and carbohydrates). According to Shamsiev et al. (2021), the cumin seeds ethanol extract contained myricetin, rutin, ferulic acid, catechin, p-coumaric acid, quercetin, caffeic acid and kaempferol as phenolic compounds, and the myricetin and rutin were the dominant compounds. The amount of phenolic compounds was found to increase with limited irrigation under arid conditions (Aliniana et al. 2015).

Cumin seeds have antimicrobial, anti-inflammatory, antiseptic, analgesic, antidiabetic, hypolipidemic and antihypertensive properties due to their content of essential oils (Mahmood et al. 2019; Asaad et al. 2020). Therefore, they have the potential to be used in the preparation of medicinal drugs (Sheikh et al. 2010; Belal et al. 2017; Agarwal et al. 2019).

Chen et al. (2014) reported that the antioxidant activities of cumin seed content were ordered as distillation residue = cumin oleoresin > cumin essential oil > condensed distillate Cumin oil could be used as an effective antioxidant source, and one of the active antioxidant components in essential oil was the γ-terpinene. Cuminaldehyde, the main component of cumin essential oil was of low antioxidant capacity (Malayoğlu et al. 2011). Cumin seeds methanolic extracts contained flavonoids, tannins, terpenoids, anthocyanins and cardiac glycosides, of which caffeic acid, isoquercetin, vanillic acid, myricetin 3-0, rutinoside, syringaresinol, citrusine, rosmarinic acid and p-coumaric acid have been identified (Bouhenni et al. 2021). They reported that its antioxidant activity was higher than measured from hydrodistillation (Saha et al. 2016). Also, Einafshar et al. (2012) reported that the addition of cumin methanolic extract to sunflower oil significantly improved its oxidative stability, the essential oil showed no antioxidant activity, and the methanolic extract had the potential to be used as a natural antioxidant in bulk oil and emulsion systems.

The cumin essential oil and extracts have antibacterial effects. Therefore, they have a significant potential to control human and foodborne pathogens. The antimicrobial properties of cumin seeds are due to the α-pinene, α-terpineol, apigenin and flavonoids it contains. These compounds generally exerted their antimicrobial effects by forming pores in the cell membrane of gram-positive bacteria and destroying the outer membrane of gram-negative bacteria (Valizadeh et al. 2016). The antibacterial effect of cumin essential oil against gram-positive bacteria in foods exceeded the values of gram-negative bacteria (Farag et al. 1989; Özcan and Erkmen 2001; Wanner et al. 2010; Hashemian et al. 2013; Mahmoudi 2013; Haşimi et al. 2014; Patil et al. 2016; Valizadeh et al. 2016; Belal et al. 2017; Petretto et al. 2018; Ahari et al. 2020).

Cumin essential oil is also effective on some bacteria that cause disease in humans. It has been found to inhibit the proliferation of oral bacteria and therefore exhibits strong antimicrobial activity against the microbial flora of the teeth (Abbaszadegan et al. 2016; Amalia et al. 2019; Ghazi et al. 2019). Saee et al. (2016) reported that cumin extract and essential oil were effective against bacterial isolates that cause urinary tract infections, the essential oil is more effective on gram-negative bacteria, and cumin extract has good effect against both gram-positive and gram-negative bacteria. Some studies reported that the therapeutic potential of different cumin genotypes was been different, and that methanol and hexane extracts were being exhibited variable antibacterial activity on both gram-positive and negative bacterial strains (Amal et al. 2009; Hajlaoui et al. 2010; Agarwal et al. 2019). Sheikh et al. (2010), investigating the antibacterial activity of cumin seed extracts, reported that ethanol, methanol and acetone extracts were being inhibited the growth of all bacteria studied, while methanol extract was relatively more effective.

Cumin essential oils and extracts have antifungal activities. The degree of effectiveness of this activity varies depending on the origin of the cumin, the species of the fungus and the strains tested (Farag et al. 1989; Özcan and Erkmen 2001; Petretto et al. 2018; Agarwal et al. 2019; Dolatabadi et al. 2019; Hartini et al. 2019). The antifungal effect of cumin essential oil is attributed to the chemical composition of the tested oils. It was determined that cumin essential oil is more effective on some types of fungi (Wanner et al. 2010; Valizadeh et al. 2016). Wanner et al. (2010) reports that cumin essential oil had a significant inhibitory effect on *Candida albicans* isolates: essential oils rich in cumin aldehyde outperformed pure cumin aldehyde, and this may be due to the additive or synergistic effect of other components present in cumin oil. Cumin essential oil may have the potential to be used as a fungicide, as it inhibited the growth of *Verticillium dahliae* Kleb. and *Fusarium oxysporum* Schl. mycelium and fungi (Üstüner et al. 2018).

Cumin extracts had a high effect on bacteria causing typhoid fever (Belal et al. 2017) and showed anti-inflammatory properties: they were effective in all parameters that affect blood sugar, blood pressure and hypolipidemic properties (total cholesterol, triglycerides, LDL, HDL (Ceylan et al. 2003; Devkar et al. 2018; Pishdad et al. 2018; Agarwal et al. 2019; Akmal and Itrat 2019; Haque and Ansari 2019). Alkubaisy et al. (2019) reported that cumin seed water extract had anti-ulcer effect and can safely protect the gastric mucosa against ethanol-induced damage. Amal et al. (2009) and Prakash and Gupta (2014) found that cumin seeds extract exhibited antitumor activity, Haghparast et al. (2009) showed that cumin essential oil reduced morphine, intake in morphine-dependent mice. According to Kim et al. (2016) cumin extract could be developed as a therapeutic strategy in the treatment of Parkinson's neurodegeneration. Also, Keyhani et al. (2017) reported that cumin essential oil and methanolic extract showed strong scolicidal activity without significant toxicity and could be used as a natural scolicidal agent in hydatid cyst surgery. Haddad et al. (2018) found that cumin essential oil did not show any signs of toxicity at acute doses up to 1000 mg/kg and was safe for short-term (28 days) use, at doses up to 25 mg/kg. The LD50 values for cumin essential oil and fixed oil were found to be 0.52–0.780 ml/kg and 1.039 ml/kg respectiely (Sayyah et al. 2002; Özbek et al. 2004).

In addition, there are reports according to which cumin seeds and pulp can be used as a feed supplements, causing an increase in HDL cholesterol level and a decrease in triglyceride ratio (Berrama et al. 2017; Ramadevi et al. 2018). The use of cumin essential oil in the control of plant bacterial diseases is due to its antibacterial effect (Iacobellis et al. 2005): as an herbicide it inhibits seed germination, root and shoot growth (Üstüner et al. 2018). It can be used against also root-knot nematodes (*Meloidogyne incognita* ve *M. javanica*) (Pardavella et al. 2021) and *Tetranychus cinnabarinus* (Boisd.) and *Aphis gossypii* Glov., as an insecticide in greenhouses (Tunç and Şahinkaya 1998).

12.5 Conclusions

Anise, fennel and cumin plants have an important place in gastronomy and folk medicine as spices, in Anatolia for thousands of years. These species have been cultivated in Türkiye for many years, and they are both exported and domestically consumed. These plants are generally grown in fallow areas and dry conditions, in the Central Anatolian Region of Türkiye. They have the potential to be grown in dry agricultural areas due to their short vegetation period, since they do not form a big plant and utilize the precipitation of early springs. In addition, they are capable of adaptation to the changing environmental conditions caused by the climate change. In Türkey, research is going on to develop high yielding and quality varieties of anise, fennel and cumin. By elaborating and applying appropriate agricultural techniques, the production of high value-added and quality and standardized products can be realized. Ultimately, it seems possible to preserve the established high-ranking place of these species also in traditional agriculture.

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Chapter 13
Traditional Uses of Turkish Asteraceae Species

Bahar Gürdal

Abstract Turkey boasts one of the richest temperate zone floras, with over 11,000 species of vascular plants, one-third of which are endemic to the country. The largest family of Turkish flora is Asteraceae and its endemism is about 37%. Traditional knowledge of medicinal plants is common and it is transferred inter-generationally in Turkey. This unique knowledge is documented by ethnobotanical studies. Asteraceae is one of the most commonly used plant families also in Turkish traditional medicine. The most frequently used genera are *Achillea* L., *Centaurea* L., *Gundelia* L., *Helichrysum* Mill., and *Matricaria* L. Studies on biological activities endorse their traditional uses. The diversity of established traditional uses of further representatives of the Asteraceae family underpins their importance in the search for new drugs.

Keywords Medicinal plants · Traditional medicine · Asteraceae · Compositae · Turkey · *Achillea* · *Centaurea* · *Gundelia* · *Helichrysum* · *Matricaria*

Abbreviations

ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
CaOx	Calcium oxalate
CAT	Catalase
EG/AC	Ethylene glycol/ammonium chloride
GPx	Peroxidase
GSH	Glutathione
HSV-1	Herpes simplex virus Type-1
MDA	Malondialdehyde

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PI-3 Para-influenza-3
SOD Superoxide dismutase

13.1 Introduction

Turkey has one of the richest temperate zone floras, with approximately 10,000 species of vascular plants, one-third of which are endemic to the country (Byfield et al. 2010; Şekercioğlu et al. 2011). Asteraceae is the largest plant family in Turkey, as it is the largest family in the world. There is one volume (vol. 5) of "Flora of Turkey and the East Aegean Islands" that includes only one plant family, which is Asteraceae (Davis 1975). Between 1965 and 2000, these Floras were published. New taxa and records are constantly being added to the Turkish flora. Fifteen percent of the taxa added the Turkey's flora are from the Asteraceae family (Özhatay et al. 2019). The family with the most endemic species is also Asteraceae. The diversity of Asteraceae species also influences the prevalence of its use as a traditional folk medicine. Numerous ethnobotanical studies are carried out in all regions of Turkey. Apart from the medicinal uses of plants, their use as food, spice, tea and other uses are also recorded (Yeşilada et al. 1993, 1999; Fujita et al. 1995; Honda et al. 1996; Sezik et al. 2001; Kocyiğit and Ozhatay 2006; Kültür 2007; Bulut and Tuzlaci 2013; Gürdal and Kültür 2013; Özdemir and Alpınar 2015; Özdemir and Kültür 2017; Yeşil et al. 2019; Çelik and Yeşil 2020; Emre et al. 2021; Yeşil and İnal 2021; Gürdal and Öztürk 2022).

The Asteraceae family has large morphological and geographical diversity. It is found all over the world except for Antarctica. In addition to this, it is the largest plant family. There is ca. 33,000 accepted species, ca. 1900 genera, and 43 tribes (Funk et al. 2009; The Plant List (2013) Version 1.1; Panda et al. 2019). The Asteraceae plants have been used in traditional medicine and also as foods since ancient times all over the world. The species is capable of producing a diverse range of secondary metabolites such as monoterpenes, diterpenes, triterpenes, sesquiterpenes and sesquiterpene lactones, polyacetylenes, flavonoids, phenolic acids, benzofurans, coumarins and pyrrolizidine alkaloids (Calabria et al. 2009).

13.2 Medicinal Plant Representatives in the Family Asteraceae, in Turkey

The oldest comprehensive source in Anatolia about medicinal plants is De Materia Medica, written by Pedanius Dioscorides (first century A.D.). He was born and lived in Anazarbos (presently Adana province in Turkey). Over 600 plants and also animals, minerals are described in this book. The most frequently mentioned uses are dermatological, gastrointestinal, and gynecological. Dioscorides' "De Materia

Medica" is widely acknowledged to have impacted and guided the development of Mediterranean and European herbal medicine (Yesilada 2005; Staub et al. 2016).

Anatolia has hosted many different civilizations. Cultural variety and a diverse flora are the key indicators of Anatolia's rich traditional medicine. The number of ethnobotanical studies in Turkey is steadily increasing, and today, there are over 2500 publications (Alpınar and Yazıcıoğlu 2019). There are general ethnobotanical studies covering geographical regions and detailed district/city-based ethnobotanical studies. The number of plant species utilized as traditional folk medicine in Turkey has lately been estimated to be approximately 1500. Unani medicine is still practiced in the country's southern and southeast regions. In different studies, ethnobotanical knowledge in Turkey has been evaluated (Yeşilada 2002; Kendir and Güvenç 2010; Ozturk et al. 2012; Ertuğ 2014). The most commonly used plant families are Lamiaceae, Rosaceae, and Asteraceae in Turkey. About 13% of species that are used in folk medicine are from the Asteraceae. Most used Asteraceae taxa are ***Achillea*** sp., ***Centaurea*** sp., ***Gundelia*** *tournefortii* L., ***Helichrysum*** sp., and ***Matricaria*** *chamomilla* L.

Asteraceae have a wide variety of secondary metabolites that act as storage compounds or chemical defense mechanisms. The family is characterized by the presence of inulin-type fructans, acetylenic fatty acid derivatives converted into cyclic compounds, and sesquiterpene lactones. The major storage carbohydrates of Asteraceae are inulins, which are synthesized as a homologous series of -2-1-linked polymers and kept in solution in the vacuole. Sesquiterpene lactones are bitter and poisonous and are found in latex, glandular hair subcuticular cavities, and extruded glandular hairs. Other chemical constituents of the Asteraceae family include triterpenes, steroids, essential oils, carotenoids, flavonoids, benzopyrans and benzofurans, lignans and other phenolics, labdanes and kauranes, coumarins, prenylated coumarins, thymol derivatives, diterpenoids, alkaloids, cyanogenetic glycosides, inositol esters, isobutyl amides, and fixed oils. Asteraceae terpenoid essential oils are complex mixes found in secretory glandular hairs and resin ducts; constituents include acetylenes, phenylpropanols, and chromenes, thymol derivatives, monoterpenoids, sesquiterpenes (common), and furanosesquiterpenes. Flavonoids are distinguished by quercetagetin-based yellow flavonols. The major anthocyanin is cyanidin. The diverse chemistry of the family leads to their extensive usage as medicinal plants (Jeffrey et al. 2007).

13.2.1 Genus Achillea *L.*

13.2.1.1 Taxonomic Characteristics

Perennial pilose herbs and subshrubs. Leaves alternate, rarely to 4-pinnatipartite, sometimes vermiform. Capitula usually in dense corymbs, rarely solitary, pedunculate or subsessile, heterogamous, radiate. Involucre oblong-cylindrical, hemispherical or depressed. Phyllaries pluriseriate, with ± scarious margins. Receptacle flat, hemispherical or conical. Ray flowers female, fertile; white or yellow. Disc florets hermaphrodite, fertile; 5-toothed, white or yellow. Achenes glabrous, obovoid, dorsiventrally flattened (Davis 1975; Kadereit and Jeffrey 2007). In Turkey, there are 52 species and 33 taxa are endemic (Güner et al. 2012).

13.2.1.2 Major Chemical Constituents and Bioactive Compounds

Achillea taxa are rich sources of flavones, other flavonoids, guaianolides, lignans, non-saturated carboxylic acids, phenolic glycosides, phthalate derivatives, piperidine amides, polyacetylenes, proazulenes, sesquiterpene lactone-diol, sesquiterpene lactones, sesquiterpenes, sesquiterpenoids, spirodepressolide, tannins, and triterpene alkamides (Mohammadhosseini et al. 2017). Baser (2016) reported essential oil composition of 31 *Achillea* taxa from Turkey. Aerial parts are used for essential oil and yield ranges between <0.01% and 1.2%. Main compounds are camphor and 1,8-cineole in 19 *Achillea* species. The most often seen compounds are also cis and trans-sabinene hydrate, borneol, α-thujone, β-thujone, linalool, α-terpineol, ascaridol, isoascaridol, *cis*-piperitol, p-cymene, borneol, α-thujone, β-pinene, germacrene D, and β-caryophyllene (Baser 2016; Mohammadhosseini et al. 2017). The most commonly used species in traditional folk medicine are *Achillea biebersteinii* Afan., *A. lycaonica* Boiss. & Heldr., *A. millefolium* L., *A. schischkinii* Sosn., *A. setacea* Waldst. & Kit., *A. vermicularis* Trin., and *A. wilhemsii* C. Koch. The chemical compositions of these species are given in Table 13.1.

13.2.1.3 Traditional Uses, Parts Used, and Common Knowledge

In traditional medicine, *Achillea* species are cited mainly for gastro-intestinal disorders and animal bite. Aerial parts of *A. biebersteinii* are used for stomache, ulcer, diarrhea, dyspepsy, cold, dyspnea, urinary tract infection, while capitulum is used as digestive, appetizer, diuretic, and for diabetes, hemorrhoids, rheumatism. Infusion made with the capitulum of *A. lycaonica* is used as digestive. Used parts of *A. millefolium* are capitulum, leaves, and aerial parts. It is used for nausea, stomache, diarrhea, dyspepsy, ulcer, cold, diabetes, hemorrhoids, anaemia, kidney stones, rheumatism, and as diuretic. Capitulum of *A. schischkinii* is used for dyspepsy and diabetes. *A. setacea* is used for diarrhea, dyspepsy, and stomache. Aerial parts of *A. vermicularis* is used for dyspepsy, stomache, and dyspnea. Aerial parts of *A. wilhemsii* is used for stomache, diarrhea, dyspepsy, ulcer, cold, dyspnea, hemorrhoids, arteriosclerosis, and as cholesterol lowering, diuretic. Leaves of some species are also used as hemostatics externally, and for wound (Tuzlacı 2016).

Table 13.1 Chemical composition of the most commonly used *Achillea* species in Turkish traditional medicine

Species	Part of the plant	Chemical composition	References
A. biebersteinii	Capitulum	Ascaridole (43.22%), iso-ascaridole (37.87%)	Jaffal and Abbas (2019)
	Essential oil	1,8-cineole (20.36%), cyclohexanone (8.39%), 2-cyclohexen-1-one (5.38%), (+) spathulenol (4.19%)	Sevindik et al. (2018)
	Essential oil	1,8-cineole (32.5%), piperitone (14.4%), camphor (13.7%)	Gülsoy Toplan et al. (2022)
	Essential oil	p-cymene (18.6%), 1,8-cineole (16.5%), camphor (11.7%), hexadecanoic acid (11.2%), β-eudesmol (10.1%)	Turkmenoglu et al. (2015)
A. lycaonica	Essential oil	1,8-cineole (12.3%), decanoic acid (4.6%), α-pinene (4.3%)	Gülsoy Toplan et al. (2022)
	Essential oil	Nonacosane (10.6%), heptacosane (9.2%), pentacosane (6.1%), spathulenol (4.6%)	Turkmenoglu et al. (2015)
	Essential oil	L-camphor (43.19%), artemisia alcohol (21.18%), camphor (16.48%)	Azaz et al. (2008)
	Essential oil	Trans-sabinene hydrate (9.3%), terpinen-4-ol (9.0%), caryophyllene oxide (7.2%)	Baser et al. (2001)
	Aerial parts	Chlorogenic acid, caffeic acid, dicaffeoylquinic acid, and salicylic acid, rutin, luteolin, quercetin, naringenin, apigenin, and 8-hydroxy-salvigenin	Taşkın et al. (2018)
A. millefolium	Essential oil	α-bisabolol (11.7%), caryophyllene oxide (7.7%), muurola-4,10(14)-dien-1-ol (6.8%)	Turkmenoglu et al. (2015)
	Aerial parts	Linoleic acid, palmitic acid, caffeoylquinic and dicaffeoylquinic acids, luteolin O-acetylhexoside, apigenin O-acetylhexoside, quercetin, kaempferol	Dias et al. (2013)
A. schischkinii	Essential oil	Caryophyllene oxide (17.5%), spathulenol (9.1%), p-cymene (8.5%), (E)-nerolidol (6.2%)	Turkmenoglu et al. (2015)
A. setacea	Essential oil	α-bisabolon oxide A (27%), hexadecanoic acid (16.4%), α-bisabolol oxide B (5.7%)	Turkmenoglu et al. (2015)
	Aerial parts	Palmitic acid (33.45%), myristic acid (13.36%), arachidic acid (11.15%), sinapic acid, Caffeic acid, 4-hydroxy benzoic acid, ferulic acid	Rezaei et al. (2017)
A. wilhemsii	Essential oil	Camphor (41.3%), caryophylladienol II (6.4%), borneol (6.2%), camphene (6.1%)	Turkmenoglu et al. (2015)
	Essential oil	Camphor (39.62%), artemisia alcohol (17.92%), 2,5,5-trimethyl-3,6-heptadien-2-ol (16.10%)	Azaz et al. (2008)
A. vermicularis	Essential oil	15-hexadecanolide (19.6%), camphor (6.7%), heptacosane (6.3%), chrysanthenyl isovalerate I (4.8%)	Turkmenoglu et al. (2015)
	Aerial parts	Palmitic acid (38.86%), myristic acid (18.62%), lauric acid (11.7%), p-coumaric acid, Syringic acid, ferulic acid	Rezaei et al. (2017)
	Aerial parts	Chlorogenic acid, caffeic acid, rutin, dicaffeoylquinic acid, naringenin, quercetagetin 3,6-dimethyl ether, and 8-hydroxy-salvigenin	Taşkın et al. (2019)

13.2.1.4 Modern Medicine Based on Its Traditional Medicine Uses

The essential oil of *A. wilhemsii* showed inhibitory activity on methicillin-susceptible and methicillin-resistant *Staphylococcus aureus* strains (Alfatemi et al. 2015). It is rich in monoterpenes, phenolic and flavonoid compounds, which have antimicrobial activity. The essential oils of *A. wilhemsii* and *A. lycaonica* showed antimicrobial effects on *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, and *Candida albicans* (Azaz et al. 2008). Antimicrobial activity of *A. millefolium* essential oil against *Streptococcus pneumoniae*, *Clostridium perfringens*, *Candida albicans*, *Mycobacterium smegmatis*, *Acinetobacter lwoffii*, and *Candida krusei* was demonstrated (Candan et al. 2003). *A. setacea* and *A. teretifolia* showed inhibitory effects on *Clostridium perfringens*, *Acinetobacter lwoffii*, and *Candida albicans* (Ünlü et al. 2002). *A. vermicularis*, *A. teretifolia*, and *A. biebersteinii* were tested for insecticidal activity (Polatoglu et al. 2013). Essential oils of these species afford considerable insecticidal activity. *In vivo* hepatoprotective activity of *A. biebersteinii* was studied and biochemical parameters were evaluated (Al-Said et al. 2016). As a result, the essential oil of *A. biebersteinii* significantly indicates a hepatoprotective effect against CCl4-induced liver damage. Significant antinociceptive and anti-inflammatory activities were demonstrated by the ethanol extracts of *A. wilhelmsii*, *A. setacea*, and *A. vermicularis*. *A. phrygia* was shown to only have strong antinociceptive action (Küpeli et al. 2007). A hydroalcoholic extract of *A. millefolium* was demonstrated to effectively protect acute gastric lesions and chronic gastric ulcers *in vivo* (Potrich et al. 2010). Methanolic extract of *A. schischkinii* strongly inhibited acetylcholinesterase (AChE), butyrylcholinesterase (BChE), α-glycosidase (α-Gly), and glutathione S-transferase (GST) enzymes (Türkan et al. 2020). Antioxidant activity has been demonstrated in some species such as *A. biebersteinii*, *A. millefolium*, *A. wilhemsii*, *A. teretifolia*, *A. setacea*, *A. schischkinii*, and *A. vermicularis* (Candan et al. 2003; Turkoglu et al. 2010; Polatoglu et al. 2013; Alfatemi et al. 2015; Al-Said et al. 2016; Rezaei et al. 2017). The *in vitro* estrogenic activity of *A. millefolium* was reported by Innocenti et al. (2007). Methanol extract and the methanol/water fraction exhibited estrogenic activity, and active pure compounds were determined as apigenin and luteolin and their glucosidic forms.

13.2.2 *Genus* Centaurea *L.*

13.2.2.1 Taxonomic Characteristics

Annual, biennial or perennial herbs or small shrubs with spiny branches. Leaves alternate, sometimes all basal; often pinnatifid or pinnatipartite, sometimes decurrent. Capitula heterogamous, disciform or radiant. Involucral ovoid, subglobose or hemispherical; bracts pluriseriate, imbricate, scarious, with a variable appendage, entire, ciliate, spiny, or unarmed, membranous. Receptacle with smooth bristles. Flowers blue, pink, purple, or yellow, rarely whitish. Sterile florets radiant and showy. Achenes glabrous or sparsely pilose, oblong, ±compressed, apex rounded or truncate. Pappus several series; bristles scabrous, barbellate, pinnulate or plumose (Davis 1975; Kadereit and Jeffrey 2007). *Centaurea* is a large genus with 177 species and 125 taxa are endemic in Turkey (Güner et al. 2012). The genus *Centaurea* primarily originated in East Anatolia and the Transcaucasus, with secondary origin centers in the Mediterranean region and the Balkan Peninsula (Ayad and Akkal 2019).

13.2.2.2 Major Chemical Constituents and Bioactive Compounds

The presence of sesquiterpene lactones of the guaianolide and germacranolide types is characteristic of *Centaurea* species. Triterpenes, carotenoids, sterols, polyacetylenes, flavonoids, and organic acids are also found (Al Easa and Rizk 1992). The presence of sesquiterpene skeletons (caryophyllene, eudesmol, and germacrene); hydracarbons (tricosane, pentacosane, and heptacosane); fatty acids (hexadecanoic acid, tetradecanoic acid, and dodecanoic acid) and monoterpenes (aspinene, terpinene, and carvacrol) characterize the essential oil composition of *Centaurea* species (Ayad and Akkal 2019). The chemical composition of the most commonly used *Centaurea* species is given in Table 13.2.

13.2.2.3 Traditional Uses, Parts Used, and Common Knowledge

The most commonly used species in traditional medicine are *Centaurea calcitrapa* L., *C. iberica* Trevir. ex Spreng., *C. jacea* L., and *C. solstitialis* L. (Fig. 13.1). Aerial parts, capitulum, and leaves of *Centaurea* species are used. Different traditional uses of *Centaurea* species have also been recorded: Aerial parts of *C. solstitialis* subsp. *solstitialis* are used for malaria, diarrhea, cold (Tuzlacı and Emre Bulut 2007; Emre Bulut and Tuzlacı 2009; Tuzlacı and Doğan 2010; Tuzlacı and Şenkardeş 2011; Tuzlacı 2016). *C. iberica* is used as an antipyretic, for digestion, healing wounds, and diabetes (Cakilcioglu and Turkoglu 2010; Mumcu and Korkmaz 2018; Tuzlacı 2016). *C. calcitrapa* is used as an antipyretic; *C. jacea* is used as an apettizer, antipyretic, and emmenagogue (Baytop 1999).

13.2.2.4 Modern Medicine Based on Its Traditional Medicine Uses

Three sesquiterpene lactones were isolated as centaurepensin, chlorojanerin, and 13-acetyl solstitialin A from the aerial parts of *Centaurea solstitialis* subsp. *solstitialis*. Their antimicrobial and antiviral activities were investigated (Özçelik et al. 2009). Only 13-acetyl solstitialin A displayed remarkable activity against *Enterococcus faecalis* and *Herpes simplex* type-1. *Centaurea calcitrapa* shows antimicrobial activity against *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus agalactiae*, *Salmonella typhimurium*, *Enterococcus faecium*,

Table 13.2 Chemical composition of the most commonly used *Centaurea* species in Turkish traditional medicine

Species	Part of the plant	Chemical composition	References
C. calcitrapa	Aerial parts	Cnicin, apigenin, eupatorin, circiliol, eupatilin, jaceosidin	Kitouni et al. (2015)
	Aerial parts	p-hydroxybenzoic, protocatechuic, gallic, gentisic acid, centaureidin, jaceidin, kaempferide, nepetin, kaempferol, apigenin, luteolin, chrysoeriol, chlorogenic acid	Dimkić et al. (2020)
	Essential oils	b-caryophyllene (5.3%), 6,10,14-trimethyl-2-pentadecanone (4.7%), (Z)-b-farnesene (4.2%), heptanal (4.2%)	Dob et al. (2009)
	Essential oils	9,12-octadecadienoic acid (15.8%), hexadecanoic acid (10.2%), tricosane (8%), heptacosane (7.8%)	Senatore et al. (2006)
C. iberica	Whole plant	3-methyl-2-benzyl-4-quinazolone, methyl-2-[(methylamino)carbonyl]	Khan et al. (2011)
	Essential oils	Benzoate hexadecanoic acid (27.9%), cyclosativene (13%), dodecanoic acid (12.1%)	Baykan Erel et al. (2013)
	Essential oils	Germacrene D (%20.3%), caryophyllene oxide (10.7%), β-caryophyllene (10.5%)	Kılıç (2013)
C. jacea	Aerial parts	Cirsiliol, apigenin, hispidulin, eupatorin, isokaempferide, axillarin, centaureidin, 6-methoxykaempferol 3-methyl ether, trachelogenin, cnicin, 4′-acetylcnicin, 1-β-isobutanoyl-2-angeloyl-glucose	Forgo et al. (2012)
	Essential oils	Epi–bicyclosesquiphellandrene (18.7%), aromadendrene (12.5%), hexadecanoic acid (8.8%), ß–elemene (8%)	Politeo et al. 2019
C. solstitialis	Aerial parts	Centaurepensin, chlorojanerin, 13-acetyl solstitialin A	Özçelik et al. (2009)
	Aerial parts	Chlorojanerin, 13-acetyl solstitialin A, solstitialin A	Gürbüz and Yesilada (2007)
	Flowering parts	Caffeic acid, epicatechin, 2,5-dihydroxybenzoic acid, 4-hydroxybenzoic acid, 3,4-dihydroxybenzoic acid, cinnamic acid	Alper et al. (2021)
	Capitulum	Chlorojanerin, 13-acetyl solstitialin A, solstitialin A	Yesilada et al. (2004)
	Essential oils	B-eudesmol (15.5%), bicyclogermacrene (14.2%), spathulenol (11.3%)	Kılıç (2013)

Klebsiella pneumoniae, *Acinetobacter baumanni*, *Enterobacter cloacae*, and *Pseudomonas aeruginosa*, while *C. solstitialis* shows antibacterial activity against *Streptococcus agalactiae* and *Staphylococcus aureus* (Toribio et al. 2004; Moghannem et al. 2016). The wound healing activity of *C. iberica* was compared with Madecassol® *in vivo*. Methanol extract showed remarkable wound healing activity. It was also demonstrated that it has remarkable dose-dependent anti-inflammatory

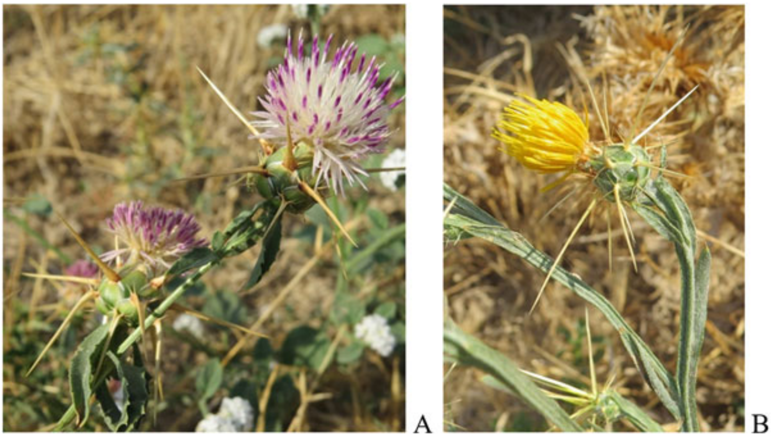

Fig. 13.1 *Centaurea iberica* (**a**) and *Centaurea solstitialis* (**b**). (Photos: Gürdal B)

activity *in vivo* (Koca et al. 2009). The guaianolide type sesquiterpene lactones were identified from the chloroformic extract of *C. solstitialis* ssp. *solstitialis* aerial parts and their anti-ulcerogenic effects were investigated *in vivo*. Chlorojanerin, 13-acetyl solstitialin A and solstitialin A were shown to have anti-ulcerogenic effect (Yesilada et al. 2004; Gürbüz and Yesilada 2007). The *in vitro* antidiabetic activity of *C. calcitrapa* was investigated. Methanolic extract of aerial parts demonstrated significant α-glucosidase inhibition as well as antioxidant (DPPH scavenging) activity (Kaskoos 2013). The essential oils of *C. lycopifolia*, *C. balsamita*, and *C. iberica* were investigated for enzyme inhibitory activity (Ertas et al. 2014). All of them showed a moderate inhibitory effect against butyrylcholinesterase and acetylcholinesterase enzymes. Three compounds were isolated from the whole plant of *C. iberica* and investigated for anti-platelet activity (Khan et al. 2011). All the isolated compounds (*3-Methyl-2-benzyl-4-quinazolone, Methyl-2-[(methylamino)carbonyl]benzoate*, and a new dimeric lignan glucoside) showed significant inhibition of platelet aggregation.

13.2.3 Genus Helichrysum *Mill.*

13.2.3.1 Taxonomic Characteristics

Lanate, tomentose or glandular perennial or annual herbs or suffruticose. Leaves alternate, simple, with entire margins, often tomentose. Capitula solitary or many in corymbs, globose to obpyramidal. Involucral bracts pluriseriate, papery, white, straw-coloured, yellow, orange or red. Receptacle flat, epaleate. Florets yellow, all hermaphrodite or marginal ones female. Anthers with flat appendages. Style branches truncate, with hairs apically. Achenes cylindrical, glabrous or glandular.

Pappus bristles yellowish, barbellate or scabrous (Davis 1975; Kadereit and Jeffrey 2007). The genus is represented by 24 species in Turkey and 17 taxa are endemic (Güner et al. 2012).

13.2.3.2 Major Chemical Constituents and Bioactive Compounds

Secondary metabolites from the *Helichrysum* species have been reported in six structural types as flavonoids and chalcones, phenolic acids, terpenes and essential oils, pyrones, benzofurans and phloroglucinols (Akaberi et al. 2019). Caffeic acid conjugates as chlorogenic acid, dicaffeoylquinic acids, and flavonoids as apigenin, naringenin, apigenin-7-*O*-glucoside, and naringenin-*O*-hexosides are identified from *H. arenarium* (L.) Moench subsp. *arenarium* inflorescences (Gradinaru et al. 2014). The major compounds of essential oil were identified as guaiol (8.9%), nerol (7.0%) and β-caryophyllene (6.0%) in *H. italicum* subsp. *serotinum* (Boiss.) P.Fourn., and as α-pinene (28.3%), epi-α-bisabolol (21.9%) and β-caryophyllene (5.5%) in *H. stoechas* subsp. *stoechas* (Tsoukatou et al. 1999), and β-caryophyllene, α-humulene, α –pinene, limonene in *H. stoechas* subsp. *barrelieri* (Teno) Nyman (Roussis et al. 2002); α-cubebene (10.5%), β-caryophyllene (9.4%), caryophyllene oxide (8.2%), azulene-octahydro (7.5%) in *H. graveolens* (Bagci et al. 2013). Essential oils of different parts such flowers, leaves, and stems were analyzed for *H. armenium* (Oji and Shafaghat 2012). Major compounds were limonene (21.2%), α-cadinol (18.2%), borneol (11.9%) in flower; limonene (29.2%), α- pinene (14.4%), caryophyllene oxide (6.5%) in leaf; limonene (23.6%), α-pinene (13.4%), spathulenol (6.4%) in stem. Essential oils of three subspecies of *H. plicatum* were identified from Turkey by Öztürk et al. (2014). Major compounds were hexadecanoic acid (21.3%), T-cadinol (7.9%) in subsp. *plicatum*; hexadecanoic acid (28.0%), myristic acid (27.8%), dodecanoic acid (9.6%) in subsp. *polyphillum* (Ledeb) P.H.Davis & Kupicha; myristic acid (37.9%), hexadecanoic acid (15.4%), dodecanoic acid (10.4%) in subsp. *isauricum* Parolly. The flavonoid contents of 16 *Helichrysum* taxa from Turkey were determined as chlorogenic acid, caffeic acid, ferulic acid, p-coumaric acid, p-hydroxybenzoic acid, syringic acid, apigenin, apigenin-7-glucoside, epicatechin, eriodictyol, hesperidin, luteolin, naringenin, quercetin, and resveratrol (Albayrak et al. 2010b). Apigenin, luteolin, kaempferol, quercetin, naringenin, and galangin 3-methyl ether were among the flavonoids found in *H. armenium* subsp. *armenium* and subsp. *araxinum* (Kirp.) Takht. from eastern Anatolia (Çubukçu and Yüksel 1982).

13.2.3.3 Traditional Use, Parts Used, and Common Knowledge

Some species are more cited in traditional medicine, such as *Helichrysum arenarium* (L.) Moench, *H. armenium* DC., *H. graveolens* (M. Bieb.) Sweet, *H. orientale* (L.) Gaertn., *H. plicatum* DC., *H. sanguineum* (L.) Kostel., and *H. stoechas* (L.) Moench. It has been determined that *Helichrysum* taxa are among the most used plants for kidney diseases in Turkey (Kültür et al. 2021). Their capitulum and aerial parts are commonly used for kidney problems such as kidney stones, nephralgia, and kidney gravels. Uses of *Helichrysum* taxa are given in Table 13.3.

Table 13.3 Uses of some *Helichrysum* taxa in Turkish traditional medicine

Species	Used part	Uses	Reference
H. arenarium subsp. aucheri	Aerial parts	Hepatitis, nephralgia, kidney stones, gastrointestinal diseases, diuretic, hypercholesterolemia, diabetes	Demirci and Özhatay (2012), Sargın et al. (2013), Mükemre et al. (2015), and Mumcu and Korkmaz (2018)
H. arenarium subsp. *rubicundum*	Herb	Diuretic, nephralgia, kidney stones	Altundag and Ozturk (2011)
H. arenarium	Capitulum	Kidney stones, kidney gravel	Özdemir and Alpınar (2015)
H. armenium subsp. *armenium*	Aerial parts	Diabetes disease, hypercholesterolemia, kidney stones, earache, hematinic	Demirci and Özhatay (2012), Mükemre et al. (2015), and Bulut et al. (2016)
H. chionophilum	Capitulum, aerial parts	Nephralgia, kidney gravels, diuretic	Sargin (2015)
H. graveolens	Aerial parts	Kidney problems	Ezer and Arisan (2006)
H. orientale	Capitulum, aerial parts	Sore throat, dyspnea, cough, cold, nephritis, icterus, dysuria, kidney stone	Ertuğ (2004) and Gürdal and Kültür (2013)
H. pallasii	Capitulum, aerial parts	Kidney stones	Altundag and Ozturk (2011), Sargın et al. (2013), and Mükemre et al. (2015)
H. plicatum	Capitulum, aerial parts	Diabetes, hepatits, kidney stones, kidney gravels, diuretic, nephralgia, diarrhea, stomach ache	Polat et al. (2013), Sargin (2015), Özdemir and Alpınar (2015), and Polat (2019)
H. plicatum subsp. *plicatum*	Capitulum, aerial parts	Diabetes, hypercholesterolemia, kidney stones, cholagogue, nephralgia, cough, diarrhoea, diuretic, stomachic, antideppessant, earache	Yeşil and Akalın (2009), Cakilcioglu and Turkoglu et al. (2010), Altundag and Ozturk (2011), Demirci and Özhatay (2012), Kılıç and Bağcı (2013), and Mükemre et al. (2015)
H. plicatum subsp. *polyphyllum*	Capitulum	Diarrhoea, intestinal disease	Altundag and Ozturk (2011)
H. plicatum subsp. *pseudoplicatum*	Aerial parts	Diabetes, kidney stones, hypercholesterolemia	Mükemre et al. (2015)
H. sanguineum	Capitulum	Cough, kidney stone	Akaydın et al. (2013)
H. stoechas	Capitulum, aerial parts	Nephralgia, kidney stone, kidney gravels, diuretic	Ertuğ (2004) and Sargin (2015)

13.2.3.4 Modern Medicine Based on Its Traditional Medicine Uses

An antioxidant effect has been reported on methanolic extract of *Helichrysum* species (*H. arenarium* subsp. *aucheri* (Boiss.) P.H. Davis & Kupicha, *H. arenarium* subsp. *erzincanicum* Davis & Kupicha, *H. arenarium* subsp. *rubicundum* (C. Koch.) Davis & Kupicha, *H. armenium* subsp. *armenium*, *H. armenium* subsp. *araxinum* (Kirp.) Takht., *H. plicatum* subsp. *plicatum*, *H. plicatum* subsp. *pseudoplicatum* (Nab.) Davis & Kupicha, *H. plicatum* subsp. *polyphyllum* (Ledeb.) P.H. Davis & Kupicha, *H. artvinense* P.H. Davis & Kupicha, *H. chionophilum* Boiss. & Balansa, *H. compactum* Boiss., *H. goulandriorum* Georgiadou, *H. graveolens* (M. Bieb.) Sweet, *H. heywoodianum* P.H. Davis, *H. kitianum* Yildiz, *H. noeanum* Boiss., *H. orientale* (L.) Gaertn., *H. pallasii* (Spreng.) Ledeb., *H. peshmenianum* S. Erik, *H. stoechas* subsp. *barellieri* (Ten.) Nyman) from Turkey (Albayrak et al. 2010a, b). Different studies have reported that *Helichrysum* species exhibit antimicrobial activity against Gram-positive bacteria, Gram-negative bacteria, and yeasts. Methanolic extract of *H. arenarium* subsp. *arenarium* showed antimicrobial activity against methicillin-resistant *Staphylococcus aureus*, penicillin-resistant *Streptococcus pneumoniae* and ampicillin-resistant *Moraxella catarrhalis* clinical isolates (Gradinaru et al. 2014). From eastern Anatolia, *H. arenarium* subsp. *erzincanicum* Davis & Kupicha, *H. arenarium* subsp. *rubicundum* (C. Koch.) Davis & Kupicha, *H. armenium* subsp. *araxinum* (Kirp.) Takht., and *H. plicatum* subsp. *pseudoplicatum* (Nab.) Davis & Kupicha have shown antibacterial activity against *Aeromonas hydrophila*, *Bacillus brevis*, *B. cereus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Albayrak et al. 2010a). The methanolic extracts of 16 *Helichrysum* species from Turkey showed antimicrobial activity against *Aeromonas hydrophila*, *Bacillus brevis*, *Bacillus cereus*, *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Morganella morganii*, *Mycobacterium smegmatis*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Yersinia enterocolitica*, *Candida albicans,* and *Saccharomyces cerevisiae* (Albayrak et al. 2010b). The essential oil of *H. armenium* showed a moderate effect on Gram-positive and Gram-negative bacteria, and it had a considerable fungicidal effect on *Saccharomyces cerevisiae* and *Candida albicans* (Oji and Shafaghat 2012). *Helichrysum arenarium* and *H. armenium* ethanolic extracts have shown significant antiviral activity against HSV-1 and PI-3 (Kutluk et al. 2018). The antibacterial activity of eight Anatolian *Helichrysum* species was investigated, and *H. pallasii*, *H. armenium*, *H. plicatum*, and *H. graveolens* were found to have a broad spectrum of activity against Gram-positive and Gram-negative bacteria. Moreover, all species showed activity against the enteric-type of bacteria, *Salmonella enteritis* and *Shigella sonnei* (Aslan et al. 2007a). *Helichrysum graveolens* displayed remarkable wound healing activity *in vivo* (Süntar et al. 2013). It contributes to the wound healing process by acting in the inflammation and proliferation phases. The major active compound was isolated as apigenin, and it is related to activity. Anti-inflammatory and antioxidant activities of *H. graveolens* were also reported (Süntar et al. 2013). The antidiabetic effect of *H. graveolens* has been demonstrated in rats, and it has antioxidant activity as well (Aslan et al. 2007b). The most cited genus is *Helichrysum* for kidney diseases in Turkey (Kültür et al. 2021). In the literature, there are several studies on the effect of *Helichrysum* species on kidney diseases. The curative effect of *H. graveolens* and *H. stoechas* subsp. *barellieri* on sodium oxalate-induced kidney stones was reported (Onaran et al. 2016). Their infusions have been studied in accordance with traditional use. The increase in the urine citrate levels and the decrease in the uric acid and oxalate levels of urine in extract groups were found to be significant and promising. *Helichrysum graveolens* and *H. stoechas* subsp. *barellieri* extracts (infusions, 3%) were shown to have a significant inhibitory effect on stone formation by Orhan et al. (2015). Bayir et al. (2011) investigated the effects of *H. plicatum* subsp. *plicatum* as a preventative agent in urolithiasis. The results showed that *Helichrysum* flowers suppressed renal calcium accumulation and urinary CaOx levels in a rat model of EG/AC-induced urolithiasis.

13.2.4 Genus **Matricaria** *L.*

13.2.4.1 Taxonomic Characteristics

Annual herbaceous. Stems erect or ascending. Leaves alternate, 2-3-pinnatisect. Capitula solitary or in corymbs, pedunculate, radiate and heterogamous or discoid and homogamous. Involucre hemispherical to cup-shaped. Phyllaries in 2–3 seriate, with scarious margins. Receptacle conical, hollow, and naked. Ray florets white, sometimes reduced. Disc florets hermaphrodite, yellow. Achenes ± terete, with 3–10 ribs; pappus absent or coronate (Davis 1975; Kadereit and Jeffrey 2007). Three species (*Matricaria aurea* Sch.Bip., *M. chamomilla* L. (Syn.: *Chamomilla recutita* L.), and *M. matricarioides* (Less.) Porter ex Britton) grow naturally in Turkey (Güner et al. 2012).

13.2.4.2 Major Chemical Constituents and Bioactive Compounds

More than 120 chemical compounds have been found as secondary metabolites in chamomile flowers. Different compounds are responsible for different effects. For instance, α-bisabolol and cyclic ethers have antimicrobial, umbelliferone has fungistatic, and chamazulene and α- bisabolol have antiseptic effects (Singh et al. 2011). Mericli (1990) investigated the chamazulene content of Turkish *Matricaria chamomilla* varieties (var. *chamomilla* and var. *recutita*) essential oils. Chamazulene was not found in most varieties; only samples from Sinop and Fethiye identified chamazulene. On the other hand, they contain a lot of bisabolol derivatives, en-in-dicycloether compounds, and coumarin derivatives with known spasmolytic effects. In another study, the essential oil of *M. chamomilla* from Ankara (Turkey) was determined (Rezaeih et al. 2015). Bisabolol oxide A, bisabolol oxide B, bisabolone oxide, en-yn-dicycloether, and a small amount of chamazulene were identified.

Chamazulene is responsible for the blue color of the essential oil. It is composed of matricin during distillation.

13.2.4.3 Traditional Uses, Parts Used, and Common Knowledge

The most widely used species in traditional medicine, generally in gastro-intestinal disorders, is *Matricaria chamomilla* L. (Fig. 13.2). It is also traditionally used to treat stomach-aches, coughs, colds, bronchitis, kidney stones, sore throats, skin lesions, and insomnia, as well as being a carminative, anti-inflammatory, antipruritic, laxative, digestive, antispasmodic, and purgative (Tuzlacı and Eryaşar-Aymaz 2001; Everest and Öztürk 2005; Kültür 2007; Fakir et al. 2009; Gürdal and Kültür 2013). Its used part is the capitulum.

13.2.4.4 Modern Medicine Based on Its Traditional Medicine Uses

Antihyperglycemic and antioxidative effects of *Matricaria chamomilla* extracts were studied *in vivo*. As a result, it decreased postprandial hyperglycemia and oxidative stress while also boosting the antioxidant system (Cemek et al. 2008). *M. chamomilla* extract was investigated for effects on lipid peroxidation (GSH and MDA levels), antioxidant enzyme systems (SOD, GPx, and CAT activities), and several liver enzymes (AST and ALT) *in vivo* (Aksoy and Bayşu Sözbilir 2012). As a result, ALT and AST increased, MDA levels decreased, and GSH, SOD, and GPx activities increased. CAT activity levels decreased. According to their findings, it may help to reduce oxidative stress and support the antioxidant system depending on the dose. In studies, the essential oil and extracts of *M. chamomilla* have shown antimicrobial effects on *Listeria monocytogenes*, *Staphylococcus aureus*, *Shigella sonnei*, *Aspergillus flavus*, *Candida albicans*, *Bacillus cereus*, and *Pseudomonas aeruginosa* (Fabri et al. 2011; Roby et al. 2013; Stanojevic et al. 2016). The antiulcerogenic

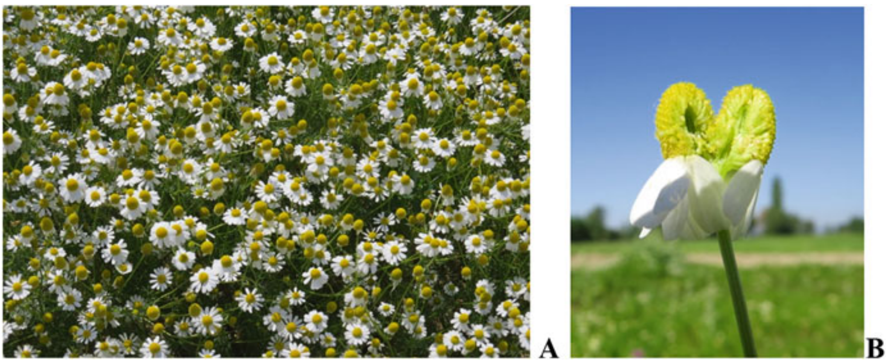

Fig. 13.2 General view of *Matricaria chamomilla* (**a**) and one of the diagnostical characteristics is the conical and hollow receptacle (**b**). (Photos: Gürdal B)

and antioxidant activities of *M. chamomilla* hydroalcoholic extract were examined in rats (Cemek et al. 2010). The results showed that the extract had a gastroprotective effect, but it was not dose-dependent. It also has antioxidative effects and the ability to decrease lipid peroxidation. This supports the traditional use.

13.2.5 Genus Gundelia *L.*

13.2.5.1 Taxonomic Characteristics

Robust perennial herb with milky latex; leaves alternate, coarsely lobulate pinnatisect, strongly spiny-dentate. Capitula few-flowered, homogamous and discoid; aggregated into 5–7-capitulate syncalathia. Phyllaries several seriate, spiny-margined. Flowers greenish, yellow, white, maroon or red, tube short; anthers ecaudate. Styles slender. Pollen with broad columellae, caveate. Achenes oblong, glabrous. Pappus coronate, with ± a denticulate-fimbriate margin (Davis 1975; Kadereit and Jeffrey 2007). There are 13 taxa in Turkey and 10 of them are endemic (Güner et al. 2012). *Gundelia tournefortii* L. is a medicinal plant and occurs in the Asian-temperate zones of Western Asia, such as Azerbaijan, Cyprus, Egypt, Iran, Israel, Turkey, and Turkmenistan (Haghi et al. 2011).

13.2.5.2 Major Chemical Constituents and Bioactive Compounds

Neochlorogenic acid, cryptochlorogenic acid, chlorogenic acid, and caffeic acid have been identified from the leaves and seeds of *G. tournefortii* (Haghi et al. 2011). Caffeoylquinic acid compounds are abundant in the leaf. Stigmasterol, β-sitosterol, α-amyrin, lupeol, olean-12-en-3-yl acetate, thunbergol, hop-22(29)-en-3.β.-ol, palmitic acid, linoleic acid, and (9Z)-9,17-octadecadienal were detected from different extracts of aerial parts (Abu-Lafi et al. 2019). The seed oil contains stigmasterol, β- sitosterol, Δ5-avenasterol, oleic acid, and linoleic acid (Khanzadeh et al. 2012). In Turkey, there are two varieties of G. *tournefortii*, which are var. *tournefortii* L. and var. *armata* Freyn & Sint. Bagci et al. (2010) compared the essential oils of these two varieties from eastern Anatolia. The major compounds are thymol, γ-terpinene in var. *tournefortii* and germacrene D, and β-caryophyllene in var. *armata*.

13.2.5.3 Traditional Uses, Parts Used, and Common Knowledge

Gundelia tournefortii is widely used in Turkish traditional medicine. The plant parts used are: roots, fruits, and latex. Ethnobotanical uses are for stomach disorders, peptic ulcer, diarrhea, cold, diabetes, eczema, kidney stone, mumps and as digestive, sedative, aphrodisiac, appetizing (Sarper et al. 2009; Cakilcioglu and Turkoglu

2010; Tuzlacı and Şenkardeş 2011; Tuzlacı 2016; Bulut et al. 2019). In Eastern Anatolia, after the aerial part of the plant has dried, the tip of the root is cut off and the flowing latex is collected. It gives Gundeliae gummi and it is traditionally used as a gum. It is called "Kenger gum" in Turkish and it is used for strengthening gingiva, oral hygiene, and appetite-stimulation (Baytop 1999).

13.2.5.4 Modern Medicine Based on Its Traditional Medicine Uses

Aerial parts and seed extracts of *G. tournefortii* were evaluated for antioxidant effects (Çoruh et al. 2007). When compared to α-tocopherol, seed extracts show a significant antioxidant ability. The seed extracts were also found to have higher phenolic content than the aerial parts. The aerial part of *G. tournefortii* has been studied for anticancer activity on the human colon carcinoma HCT-116 cell line; consequently, methanol and hexane extracts exhibited anticancer capacities (Abu-Lafi et al. 2019). Topcuoglu et al. (2015) demonstrated that a "Kenger gum" extract has moderate antiproliferative effects against the 3T3 fibroblast cell line. Antibiotic resistance-modifying activity of *G. tournefortii* has been investigated (Aburjai et al. 2001; Darwish and Aburjai 2010). It showed that aerial part extract of G. *tournefortii* enhanced the activity of some antibiotics against multidrug-resistant *Escherichia coli* and resistant strains of *Pseudomonas aeruginosa*. A study conducted with 20 healthy volunteers showed that chewing "Kenger gum" resulted in a statistically significant reduction in salivary mutans streptococci and the extract of "Kenger gum" showed an antibacterial effect against *Streptococcus mutans* (Topcuoglu et al. 2015). While not all traditional uses have been proven, there are studies to support some uses, as discussed above.

13.3 Conclusions

Asteraceae is the plant family with the largest number of species. The chemical content of its species is varied including monoterpenes, diterpenes, triterpenes, sesquiterpenes and sesquiterpene lactones, polyacetylenes, flavonoids, phenolic acids, benzofurans, coumarins, and pyrrolizidine alkaloids. The diverse content of secondary metabolites of Asteraceae species provides the foundation for their widespread usage as medicinal plants.

In ethnobotanical studies in Turkey, Asteraceae taxa are used very commonly. It has been established that species are mostly used for gastro-intestinal disorders, urological complaints, diabetes, wounds, inflammation, oral diseases, and animal bites. Supporting traditional use with studies on the chemical content and biological activity of Asteraceae species is a further important step in new drug discovery.

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Chapter 14
Anti-aging Effect of Turkish Medicinal Plants on Skin: Focus on Recent Studies

F. Sezer Senol Deniz, Nurten Abaci Kaplan, and Ilkay Erdogan Orhan

Abstract Medicinal and aromatic plants (MAPs) have always been used by humans as food and healing. Plants have afforded lead molecules not only for the pharmaceutical industry, but also for the cosmetics sector, as consumer trends are driving demand for more natural, effective and safer premium quality cosmetic products to be used in personal care, as well as beauty. Therefore, a shift from basic to more advanced products is observed in product profiles in green theme market for natural cosmetics. Although there is no legal category called "cosmeceuticals", the term has found application to designate the products at the borderline between cosmetics and pharmaceuticals. Thus, it should be emphasized that cosmeceuticals containing either natural or synthetic agents with drug-like benefits are quite popular now, all over the world. Since Turkish flora is very rich considering number of plant taxa over 12.000, it constitutes a great biodiversity as a natural source for this kind of research. Taking this potential into consideration a lot of plant species from Türkiye have been tested for their potential to be applied in cosmetics particularly towards the enzymes elastase, collagenase, and tyrosinase. Despite of a huge number of cosmetics-related studies on an enormous number of plant species throughout the world, the efficacy of Turkish MAPS in cosmetic research is presented in this chapter. Several findings are cited from the Authors' cosmetic-relevant research.

Keywords Medicinal and aromatic plants · Utilization · Cosmetics · Enzyme inhibition · Plant extract · Natural molecules · Elastase · Collagenase · Tyrosinase

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14.1 Introduction

Plants have been favorably used by mankind since ancient times for their healing properties in addition to their use as food. On the other hand, MAPS have also served humans as cosmetic ingredients. With the advancement of chemistry, chemical compositions of plants have begun to be clarified more in detail. At this point, it should be emphasized that plants have a very important role as a raw material source in both cosmetic and pharmaceutical industry, which is one of the three largest industries in the world. Due to the current green trends in the world, cosmetics of herbal or natural origin increasingly attract the attention of consumers. Since the 1980s, domestic cosmetic brands have emerged in Turkey and modern production facilities have begun to be opened. According to statistics; in the world's export and import of cosmetic products, beauty/make-up products and preparations for skin care take the first place. The Turkish cosmetics and personal care product industry produces at world standards in terms of quality, and most of the companies have ISO 9000 Quality System Certificates and ISO 14001 certificates. In the cosmetics sector, Turkey currently exports to more than 190 countries: main countries for export are Iraq, Iran, France, Saudi Arabia, Germany, and England. After the 2000s, Turkey's cosmetics exports started to target the Middle East and North African countries.

There have been an immense number of studies describing positive effects of plants on the skin through their extracts, pure compounds, fixed or essential oils (Milam and Rieder 2016; Ahmed et al. 2020; Ferreira et al. 2021; Dini and Laneri 2021). Doubtlessly, skin aging is an inevitable procedure as part of natural aging in our lives. In fact, what we mean by the concept of skin anti-aging is that the skin undergoes aging process in a healthy way without getting too wrinkled and dry. Of course, throughout our lives, we encounter many intrinsic and extrinsic factors that cause rapid aging of the skin such as UV light, malnutrition, oxidative stress, extreme make-up, smoking etc. In fact, food plants as well as MAPs contain bioactive secondary metabolites that can help improving skin conditions and, therefore, healthy eating and regular sleep may contribute to well-looking skin. Not only for keeping skin healthy, but also for several dermatological diseases, thus, nutricosmetics have been also developed besides cosmeceuticals (Dini and Laneri 2021). Cosmetic products can be classified as cleansers, moisturizers and softeners, nourishers, wrinkle removers, stain removers, tanning agents, sunscreens, and baby cosmetics according to their intended use. When these types of products are examined, it is observed that most of them contain herbal extracts.

Plant-based ingredients from terrestrial plants along with algae species can show their cosmetic effects through various mechanisms of action such as inhibition of inflammation, photoprotection, antibacterial activity along with inhibition of skin-related enzymes (Lin et al. 2017; Hwang et al. 2018). As an example: plant polyphenols have been reported to possess strong photoprotection (Nichols and Katiyar 2010; Lee et al. 2016a, b; Choi et al. 2019; Orqueda et al. 2021; Khare et al. 2021), while antioxidant plant extracts and molecules have been often offered for novel cosmetic formulations (Kalyana Sundaram et al. 2018; Jing et al. 2018; Chaiyana et al. 2021; Tseng et al. 2022).

Wrinkling is a big problem particularly among women, which decrease quality of life and well-feeling. Consequently, many anti-wrinkle cosmetics with active natural ingredients are being launched in the market (Pham et al. 2017; Lorz et al. 2019; de Lima Cherubim et al. 2020; Liu et al. 2020). The dermis layer of the skin contains two vital proteins, *e.g.* elastin and collagen. As people age and more free radicals accumulate, more enzymes are active that break down these structures. Increased elastase and collagenase activity also bring wrinkles and reduced skin resilience. Therefore, the hunt for efficient raw materials for inhibitors towards these enzymes in cosmetic products has become more critical (Banglao et al. 2020).

When a general projection is made to the world cosmetic and medical industry, it is seen that tyrosinase (TYR) inhibitors are gaining on importance and their market share is on increase. Accordingly, although many TYR inhibitory compounds of natural or synthetic origin have been discovered, only few compounds can be used for skin whitening/spot lightening purposes due to toxicity problems (Cho et al. 2020). In addition, TYR inhibitors such as hydroquinone, corticosteroids, tretinoin, 4-butylresorcinol, and α-kojic acid, which are widely used in skin-whitening cosmetics, have been proven to possess various side effects (Lee et al. 2016a, b). In consistency, a great popularity is also observed for skin-lightening cosmetics especially among female consumers, which turns direction of the research to skin-lightening/depigmentating formulations with natural ingredients (Leyden et al. 2011; Boo 2019; Rattanawiwatpong et al. 2020; Bavarsad et al. 2021). In hyperpigmentation process, the rate-limiting enzyme in melanin synthesis is called tyrosinase (TYR), and excessive amounts of TYR cause age spots, hyperpigmentation, and wrinkles due to an overabundance of melanin synthesis (Younis et al. 2022). TYR inhibitors are mostly preferred in cosmetic formulations as active compounds used for skin-lightening since they decrease melanin formation (Qian et al. 2020). Since flora of Turkey hosts over 12.000 plant taxa with approximately 30% of endemism, a great potential for pharmaceutical and cosmetic industries. In this endeavor to find out the mentioned potential of Turkish MAPs, since last ten years, Authors have been performing cosmetic-related research mostly through inhibition assays against enzymes, TYR, elastase, and collagenase on plant extracts and metabolites to develop novel formulations. In this chapter, thus, we will focus on recent outcomes of our studies on inhibition against TYR, collagenase, and elastase.

14.2 Cosmetics-Related Enzyme Inhibition Screening Studies on MAPS

Based on the large number of MAPS growing in Türkiye, in the first part of our research, we formerly screened 92 ethanol extracts prepared from various parts of 53 plant taxa and also ethanol extract of a commercial propolis sample from Türkiye for their elastase, collagenase, and TYR inhibitory potentials as well as their antioxidant activity assays with different mechanisms of action (Senol Deniz et al. 2021). The selected plant taxa in the mentioned comprehensive screening are tabulated in Table 14.1, which were the extracts from pedicels and leaves of *Cotinus coggygria* Scop., the pericarpium of *Garcinia* x *mangostana* L., and the aerial parts of *Lamium purpureum* subsp. *purpureum* L., the shell of *Pistacia vera* L., the flowers of *Punica granatum* L. The seeds of *Vitis vinifera* L., and the commercial propolis extract had higher than 50% inhibition levels against at least two of these enzymes (*i.e.*, elastase, collagenase, and TYR) at 666 μg/mL of final concentration. Consequently, these extracts for selected for further studies.

Enzyme inhibition results of initial screening of the selected plants are summarized in Table 14.2.

Cotinus coggygria (Fig. 14.1) is known as "boyacı sumağı" in Turkish. In the Anatolian folk medicine the leaves of this species have been used against diarrhea, hemorrhage as well as for its wound healing and antipyretic properties (Baytop 1999; Kultur and Bitis 2007; Aksoy et al. 2016). In the follow-up to this research, the active plant extracts were subjected to activity-guided fractionation to identify the active compounds, started with the ethanolic extracts of *C. coggygria* pedicels. Subsequent chromatographic studies on ethanol extract prepared from *C. coggygria* pedicels led to the isolation of astragalin, hyperoside, isoquercetin, and methyl gallate as active constituents of the pedicel extract (Fig. 14.2), while *in silico* studies were also performed to clarify the molecular interactions between the enzymes and the compounds (Senol Deniz et al. 2020).

It is seen that the plant species found to be inhibiting these enzymes generally overlap with their uses in folk medicine and have records for their use on skin. For instance; ethnopharmacognosic records indicated that *C. coggyria* has been used in the treatment of skin diseases in Russia. This species has also been reported to have wound healing properties and to increase skin elasticity (Savikin et al. 2009; Matic et al. 2016). As seen in our literature survey, the plant is rich in flavonoids and the fact that quercetin-3-O-glucoside (isocercitrin) and quercetin-3-O-galactoside (hyperoside) are the flavonoid derivatives we isolated from this species by activity-guided fractionation process. In accordance with our findings, catechin and piceatannol, the flavonoid derivatives previously also obtained from the roots of *Callistemon lanceolatus* (Sm.) Sweet, were isolated and showed twofold higher elastase inhibition than that of the reference, *i.e.* oleanolic acid (Kim et al. 2009). Finally, our findings on *C. coggygria* extracts led us to apply for a national patent to Turkish Patent Institute in 2019 with invention titled "Cosmetic Formulation with Smoke Tree Extract".

Polygonum L. (Polygonaceae) species, known as "madımak" in Turkish, were used to heal wounds and treat kidney stones and excessive menstrual bleeding (Gurdal and Kultur 2013; Sagiroglu et al. 2017). Especially root extracts of different species of the genus *Polygonum*, known as "madımak" in Turkish, are registered in the International Nomenclature of the Cosmetic Ingredients (INCI) list and used as raw materials in cosmetic products. We investigated the inhibition capacity of the

Table 14.1 Plant species and their families screened against elastase, collagenase, and TYR

Species name	Family
Aesculus hippocastanum L.	Sapindaceae
Aloe vera (L.) *Burm. f.*	Xanthorrhoeaceae
Arbutus unedo L.	Ericaceae
Calendula arvensis M.Bieb.	Asteraceae
Camellia sinensis (L.) Kuntze	Theaceae
Cassia L. *sp.*	Fabaceae
Cinnamomum cassia (L.) J. Presl	Lauraceae
Citrus aurantium L.	Rutaceae
Citrus deliciosa Ten.	
Citrus limon (L.) Osbeck cv. Interdonato	
Citrus limon cv. Kara limon	
Citrus limon cv. Kıbrıs	
Citrus maxima (Burm.) Merr.	
Citrus paradisi Macfad. var. Henderson	
Citrus paradisi var. Red blush	
Citrus paradisi var. Star ruby	
Citrus reticulata Blanco -Lee	
Citrus reticulata-Nova	
Citrus reticulata × *Citrus paradisi*	
Citrus sinensis Osbeck. cv. Navelina	
Citrus sinensis cv. Shamouti	
Citrus sinensis cv. Valencia late	
Citrus sinensis cv. Washington navel	
Citrus japonica Thunb.	
Cotinus coggygria Scop.	Anacardiaceae
Crataegus monogyna Jacq.	Rosaceae
Crataegus szovitsii Pojark.	
Cupressus sempervirens L.	Cupressaceae
Ficus carica L.	Moraceae
Garcinia mangostana L.	Clusiaceae
Hedera helix L.	Araliaceae
Laurus nobilis L.	Lauraceae
Lamium purpureum L.	Lamiaceae
Lamium purpureum var. purpureum L.	
Maclura pomifera (Raf.) C. K. Schneider	Moraceae
Malus Mill. sp.	Rosaceae
Olea europaea L.	Oleaceae
Origanum onites L.	Lamiaceae
Passiflora incarnata L.	Passifloraceae
Persea americana Mill.	Lauraceae
Pistacia vera L.	Anacardiaceae
Portulaca oleracea L.	Portulacaceae

(continued)

Table 14.1 (continued)

Species name	Family
Primula vulgaris subsp. vulgaris Huds.	Primulaceae
Punica granatum L.	Lythraceae
Rosa canina L.	Rosaceae
Rosa L. sp.	
Rosmarinus officinalis L.	Lamiaceae
Salix alba L.	Salicaceae
Salvia fruticosa Mill.	Lamiaceae
Tripleurospermum oreades Boiss. Rech. var. oreades	Asteraceae
Verbascum insulare Boiss. & Heldr.	Scrophulariaceae
Veronica thymoides P. H. Davis subsp. pseudocinerea M. A. Fischer	Plantaginaceae
Vitis vinifera L.	Vitaceae

extracts prepared from areal parts and roots of four *Polygonum* species (*P. aviculare* L., *P. cognatum* Meisn., *P. patulum* M. Bieb., and *P. setosum* Raf.), grown in Turkey, against elastase, collagenase, and TYR (Fig. 14.3).

The inhibition values of the root extracts prepared from *P. aviculare* and *P. patulum* were higher than 50% against elastase and collagenase (Dogru 2021). *P. cognatum* root extract (74.46 ± 3.53%) was the most potent extract for collagenase inhibition, while *P. setosum* root extract (62.92 ± 0.98%) was the most potent for elastase inhibition at 333 μg/mL final concentration. The ethanolic extracts from the aerial parts of the plants were ineffective against TYR, while the root extracts had moderate inhibition. LC-Q-ToF/MS analysis of the extracts revealed that catechin, isoquercetin, and hyperoside were the major compounds. Our literature survey and findings through activity-guided experiments on *C. coggygria* reconfirmed the fact that these compounds might be responsible for its enzyme inhibitory activity (Fig. 14.4).

In another part of the cosmetic-related study, TYR inhibition and antioxidant activities of a total of 36 ethanolic extracts belonging to 21 species of *Geranium* L. (Geraniaceae) genus collected from different localities were investigated (Table 14.3). *Geranium* species are commonly known as "turnagagası" in Turkey and several of them have been recorded to be used against wounds, pain, and infectious diseases in folk medicine around the world (Tetik et al. 2013; Rahman et al. 2016; He et al. 2022).

The extracts showed modest inhibition against TYR the extract prepared from the aerial parts of *G. glaberrimum* Boiss. & Heldr. (Fig. 14.5) was found to be most active (31.41% ± 1.11) at 133 μg/mL concentration, among all *Geranium* species screened.

The ethanolic extract of *G. glaberrimum* was subjected to preparative-LC fractionation, afterwards the phytochemical profile of the active fraction was analyzed with HPLC-PDA and LC-MS/MS. Ellagic acid, gallic acid, quinic acid, 3,4-dihydroxybenzoic acid, 4-*O*-methyl gallate, geraniin, corilagin and quercetin were detected in the extract. Subsequently, the extract was separated into 6 fractions,

Table 14.2 Inhibitory effect of the plant extracts against elastase, collagenase, and TYR

Plant	Part	TYR inhibition (Inhibition % ± S.D.[a])		Elastase inhibition (Inhibition % ± S.D.)		Collagenase inhibition (Inhibition % ± S.D.)	
		133 µg/mL[b]	666 µg/mL	133 µg/mL	666 µg/mL	133 µg/mL	666 µg/mL
Cotinus coggygria	Pedisel (fruiting)	–[c]	61.97 ± 1.80[d]	§	3.01 ± 1.18[d]	§	55.30 ± 4.68[d]
	Folia	17.19 ± 4.35[d]	64.43 ± 2.80[d]	2.09 ± 0.71[d]	51.76 ± 2.33*	–	–
Pistacia vera	Pericarpium	§	6.75 ± 1.92[d]	§	64.33 ± 1.83[d]	§	50.33 ± 4.68*
Hedera helix	Folia	14.95 ± 0.23[d]	47.35 ± 3.41[d]	–	32.53 ± 4.52[d]	–	–
Calendula arvensis	Herba	11.05 ± 3.92[d]	51.66 ± 0.57[d]	–	8.40 ± 1.30[d]	–	–
Tripleurospermum oreades	Herba	35.30 ± 0.12[d]	57.01 ± 0.53[d]	4.45 ± 1.36[d]	23.36 ± 2.45[d]	–	–
Garciniai mangostana	Pericarpium	9.13 ± 0.51[d]	52.55 ± 0.40[d]	–	36.50 ± 3.43[d]	–	52.99 ± 2.63***
Cupressus sempervirens	Folia	11.63 ± 0.94[d]	33.39 ± 1.24[d]	–	26.09 ± 1.28[d]	–	–
Arbutus unedo	Folia	1.85 ± 0.80[d]	32.21 ± 2.41[d]	–	3.49 ± 0.15[d]	–	14.05 ± 1.34[d]
	Fructus (unriped)	§	11.82 ± 1.54[d]	§	2.29 ± 0.74[d]	§	10.41 ± 1.83[d]
Cassia sp.	Folia	–	30.09 ± 5.63[d]	12.74 ± 2.17[d]	54.37 ± 2.83***	4.64 ± 1.28[d]	–
Aesculus hippocastanum	Flos	§	40.59 ± 0.33[d]	§	48.75 ± 1.64	§	–
	Folia	–	15.55 ± 3.06[d]	11.86 ± 2.45[d]	64.67 ± 2.32[d]	–	–
	Pericarpium	§	12.81 ± 1.95[d]	§	4.11 ± 0.78[d]	§	8.35 ± 0.06[d]
	Semen	§	18.01 ± 0.86[d]	§	3.53 ± 0.61[d]	§	42.05 ± 0.87

(continued)

Table 14.2 (continued)

Plant	Part	TYR inhibition (Inhibition % ± S.D.[a])		Elastase inhibition (Inhibition % ± S.D.)		Collagenase inhibition (Inhibition % ± S.D.)	
		133 μg/mL[b]	666 μg/mL	133 μg/mL	666 μg/mL	133 μg/mL	666 μg/mL
Lamium purpureum	Herba	21.01 ± 0.12[d]	57.67 ± 1.15[d]	–	25.54 ± 2.63[d]	–	–
Lamium purpureum ssp. purpureum	Herba	29.57 ± 1.64[d]	60.34 ± 1.31[d]	4.62 ± 0.56[d]	49.27 ± 2.70	–	–
Origanum onites	Herba	15.31 ± 1.03[d]	25.55 ± 2.40[d]	–	28.00 ± 1.65[d]	–	–
Rosmarinus officinalis	Herba (BATEM)	5.70 ± 1.70[d]	29.36 ± 3.12[d]	–	24.80 ± 1.58[d]	–	20.09 ± 1.09[d]
	Herba (Cyprus)	13.10 ± 1.96[d]	35.13 ± 4.27[d]	–	29.48 ± 1.46[d]	–	17.75 ± 2.41[d]
Salvia fruticosa	Herba	24.86 ± 1.68[d]	–	2.65 ± 0.70[d]	18.76 ± 2.13[d]	–	–
Cinnamomum cassia	Cortex	23.34 ± 0.58[d]	60.82 ± 3.87[d]	–	11.10 ± 1.38[d]	–	–
Laurus nobilis	Folia	3.51 ± 1.17[d]	28.47 ± 3.31[d]	–	16.78 ± 1.75[d]	–	–
	Gemmae	§	33.04 ± 4.84[d]	§	–	§	24.27 ± 0.47[d]
Persea americana	Folia	3.39 ± 0.94[d]	34.09 ± 0.31[d]	–	12.01 ± 0.78[d]	–	–
	Fructus	§	31.30 ± 4.27[d]	§	–	§	–
Persea americana	Pericarpium	§	33.73 ± 0.62[d]	§	–	§	15.80 ± 3.44[d]
	Semen	§	27.61 ± 1.98[d]	§	56.68 ± 1.74[d]	§	10.81 ± 1.60[d]
Aloe vera	Folia	5.66 ± 1.22[d]	40.89 ± 1.66[d]	17.37 ± 1.67[d]	37.58 ± 1.49[d]	–	–
Ficus carica	Folia	7.31 ± 1.88[d]	40.70 ± 0.62[d]	–	23.53 ± 3.31[d]	–	–
Maclura pomifera	Folia	48.43 ± 1.06[d]	67.40 ± 3.05[d]	–	30.69 ± 2.98[d]	26.98 ± 4.68[d]	10.12 ± 3.65[d]
	Fructus	§	54.31 ± 3.29[d]	§	–	§	–
Olea europaea	Cortex	2.70 ± 0.11[d]	21.50 ± 1.54[d]	–	–	18.49 ± 1.60[d]	16.90 ± 0.64[d]
	Folia (Denizli)	2.77 ± 0.65[d]	7.29 ± 0.31[d]	–	15.70 ± 3.08[d]	–	–
	Folia (Cyprus)	3.24 ± 1.26[d]	22.24 ± 3.86[d]	–	–	–	–

Passiflora incarnata	Herba	10.22 ± 1.74^{d}	46.33 ± 1.80^{d}	–	27.48 ± 2.18^{d}	–	9.11 ± 2.10^{d}
	Flos	§	3.58 ± 0.31^{d}	§	4.50 ± 0.95^{d}	§	$37.98 \pm 2.61^{**}$
	Fructus	§	–	§	–	§	–
Portulaca oleracea	Herba	6.81 ± 0.23^{d}	38.30 ± 2.01^{d}	–	13.42 ± 2.65^{d}	7.53 ± 3.49^{d}	–
Primula vulgaris ssp. vulgaris	Herba	12.29 ± 1.41^{d}	44.08 ± 0.38^{d}	2.74 ± 0.84^{d}	34.80 ± 1.62^{d}	–	–
Punica granatum	Flos	§	47.45 ± 0.27^{d}	§	–	§	64.88 ± 2.07^{d}
	Pericarpium	§	22.63 ± 2.74^{d}	§	–	§	–
	Semen	§	20.44 ± 2.20^{d}	§	–	§	27.01 ± 1.23^{d}
Crataegus monogyna ssp. monogyna	Flos	§	53.25 ± 1.66^{d}	§	–	§	–
	Folia	3.15 ± 1.35^{d}	33.39 ± 3.24^{d}	–	34.30 ± 1.21^{d}	–	–
	Fructus	§	30.82 ± 1.52^{d}	§	–	§	–
Crataegus szovitsii	Flos	§	44.74 ± 0.66^{d}	§	–	§	–
	Folia	6.56 ± 1.70^{d}	19.56 ± 1.04^{d}	–	17.64 ± 1.07^{d}	–	–
Malus sp.	Pericarpium (red)	§	22.48 ± 0.90^{d}	§	–	§	–
	Pericarpium (green)	§	19.34 ± 2.72^{d}	§	–	§	–
Rosa canina	Stipites	9.63 ± 0.47^{d}	51.01 ± 0.57^{d}	–	27.60 ± 0.58^{d}	–	6.94 ± 0.64^{d}
	Fructus	§	3.28 ± 0.93^{d}	§	–	§	–
Rosa sp.	Fructus (Bursa)	§	24.99 ± 1.77^{d}	§	–	§	8.02 ± 1.59^{d}
	Fructus (Tunceli)	§	11.84 ± 0.96^{d}	§	–	§	–

[a]Standard deviation (n: 3), [b]Final concentration, [c]No inhibition, § Denenmedi, [d]**** ($p < 0.0001$), * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fig. 14.1 *Cotinus coggygria*. (Photos by FS Senol Deniz, Gazi University, Türkiye)

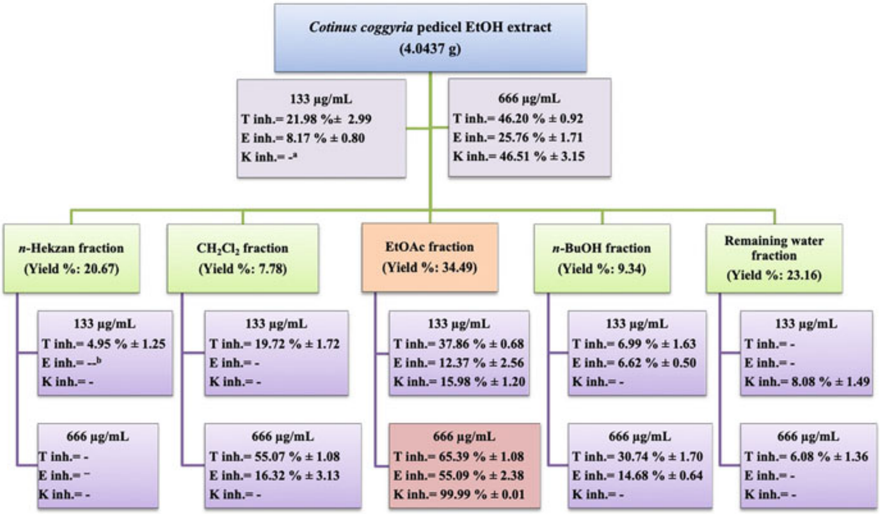
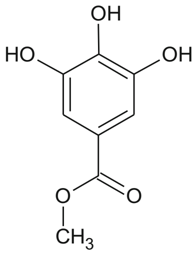
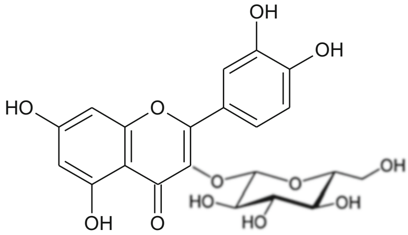


Fig. 14.2 Fractionation of the ethanolic extract from *C. coggygria* pedicels by liquid-liquid extraction and enzyme inhibition results (*T* TYR, *E* Elastase, *K* Collagenase, *a* No inhibition, *b* Absorbance not readable)

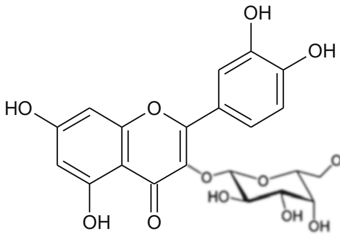
Fig. 14.3 *Polygonum cognatum* (left) and *P. setosum* (right). (Photos by Osman Tugay, Selçuk University, Türkiye)



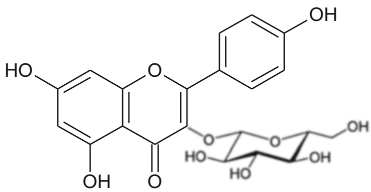
Methyl gallate



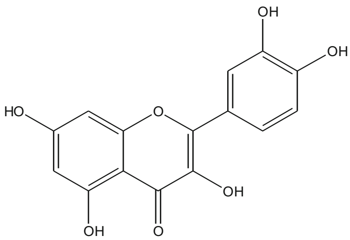
Isoquercetin



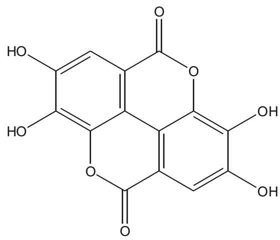
Hyperoside



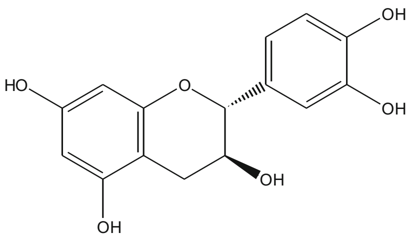
Astragalin



Quercetin



Ellagic acid



Catechin

Fig. 14.4 Chemical structures of the compounds found to be effective against elastase, collagenase, and TYR enzymes in our experiments

Table 14.3 *Geranium* species screened against TYR and their collection sites

Species	Collection site
Geranium asphodeloides Burnm.	Kastamonu province, Ilgaz Mountain, National Park
Geranium collinum Steph. ex Willd.	Ardahan province, Haskoy vicinity
Geranium dissectum L. (1)	Kutahya province
Geranium dissectum L. (2)	Antalya province, Akseki
Geranium glaberrimum Boiss. & Heldr.	Antalya province, Akseki
Geranium gracile Ledeb. ex Nordm.	Gumushane province, Zigana
Geranium gymnocaulon DC.	Artvin province, Papat
Geranium ibericum Cav. (1)	Gumushane province, Artabel village
Geranium ibericum Cav. (2)	Rize province, Ovit mountain pass
Geranium ibericum Cav. (3)	Rize province, Anzer village
Geranium lasiopus Boiss. & Heldr.	Antalya province, Akseki
Geranium lazicum (Woronow) Aedo	Rize province, Camlihemsin
Geranium lucidum L.	Antalya province, Akseki, Sadiklar village
Geranium macrostylum Boiss.	Antalya province, Elmali
Geranium molle L. (1)	Antalya province, Akseki, Gundogmus
Geranium molle L. (2)	Antalya province, Akseki-Beysehir
Geranium platypetalum Fisch. & Mey (1)	Sivas province, Serefiye
Geranium platypetalum Fisch. & Mey (2)	Sivas province, Ekinozu
Geranium platypetalum Fisch. & Mey (3)	Rize province, Ovit mountain
Geranium ponticum (P.H. Davis & J. Roberts) Aedo (1)	Gumushane province, Zigana
Geranium ponticum (P.H. Davis & J. Roberts) Aedo (2)	Rize province, Anzer
Geranium purpureum Vill. (1)	Manisa province, soma
Geranium purpureum Vill. (2)	Antalya province, Akseki
Geranium pyrenaicum Burm. (1)	Afyon province, Koroglu pass
Geranium pyrenaicum Burm. (2)	Isparta province, Aksu,
Geranium pyrenaicum Burm. (3)	Manisa province, Karakuzu mountain
Geranium pyrenaicum Burm. (4)	Kutahya province, Gediz
Geranium robertianum L.	Antalya province, Akseki
Geranium sanguineum L.	Gumushane province, Zigana
Geranium subcaulescens L'Herit. ex DC. (1)	Konya province, Kuruova, Suludere
Geranium subcaulescens L'Herit. ex DC. (2)	Isparta province, Aksu
Geranium subcaulescens L'Herit. ex DC. (3)	Denizli province, Babadag
Geranium sylvaticum L.	Rize province, Anzer
Geranium tuberosum L. (1)	Usak province, Banaz-Afyon
Geranium tuberosum L. (2)	Antalya province, Akseki-Beysehir
Geranium tuberosum L. (3)	Antalya province, Elmali

their tyrosinase inhibitory effect as well as phytochemical content was established. As 3 major compounds found in the active fraction (GG-2), 2 of them were identified as geraniin and corilagin (ellagitannin derivatives), while the 3rd one was

Fig. 14.5 *Geranium glaberrimum* Boiss. & Heldr. (Photo by Ahmet Kahraman, Uşak University, Türkiye)

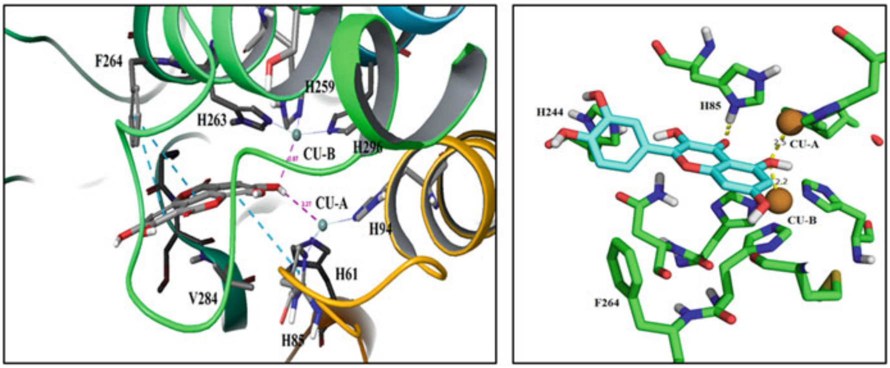


Fig. 14.6 Enzyme-ligand interactions for ellagic acid (left) and quercetin (right) in the active gorge of TYR

commented to be, most probably, castalagin as a tannin derivative. One of two major compounds found in the 6th fraction was verified as quercetin and the other major one was indicated as a flavonoid derivative based on its mass data. Ellagic acid was found to be present in highest ratio in the main extract by HPLC-PDA, while gallic acid was also detected. Tyrosinase inhibitory effect of geraniin, corilagin, ellagic acid, gallic acid, and quercetin was also tested and quercetin was found to possess the highest inhibition. Quercetin (74.77 ± 0.26%) and ellagic acid (52.50 ± 3.07%) had the highest TYR inhibitory activity among the compounds detected in the active fraction with LC-MS/MS at 333 μg/mL concentration.

In silico studies with these two compounds revealed that they also interact with the enzyme's active site (Celikler Ozer et al. 2021). On the other hand, TYR inhibitory effect of geraniin, corilagin, ellagic acid, and quercetin was also examined *in silico* using molecular docking experiments, while the enzyme-ligand interactions were established at molecular level (Fig. 14.6). The suitability of skin-whitening effects of these four compounds was investigated by PASS and Swiss Target Prediction virtual screening programs.

Finally, a skin-bleaching cream formulation based on *G. glaberrimum* ethanol extract was prepared, which we applied for another patent to Turkish Patent Institute in 2019 with invention titled "Skin-Bleaching Herbal Cosmetic Formulation".

14.3 Examples of Cosmetics-Related Studies on Turkish MAPs

MAPs growing in flora of Türkiye have been investigated for their potential use in cosmetics by several researchers. A literature survey has shown the existence of many relevant publications, nevertheless, we will herein present some selected representative examples of the effective plant species.

14.3.1 Asphodeline sp.

Asphodeline is a genus of Xanthorrhoeaceae family that comprises 20 species, 12 of which are endemic to Türkiye, where the genus is mainly distributed in the Mediterranean and Central Anatolia regions of the country. The genus is locally known as "çiriş, çiriş otu, and eşekzıpkını" in Türkiye. Along from being used as a food in meals and salads, various components of the plant are also utilized in folk medicine for various purposes such as reducing gastrointestinal spasms, curing skin ailments, improving digestion, and treating hemorrhoids and rheumatism (Ilhan et al. 2016; Sargin et al. 2015). Methanol extracts prepared from the roots of eight *Asphodeline* species collected from various parts of Turkey, including *A. anatolica* Tuzlaci, *A. baytopiae* Tuzlaci, *A. brevicaulis* (Bertol.) J. Gay ex Baker, *A. cilicica* Tuzlaci, *A. globifera* J. Gay ex Bake, *A. peshmeniana* Tuzlaci, *A. rigidifolia* (Boiss. & Heldr.) Baker, and *A. sertachiae* Tuzlaci, were connected with skin aging in a research by Zengin et al. (2016). The impact on skin imperfections that appear concurrently was studied. *In vitro* TYR inhibition screening revealed that the extracts inhibited the enzyme modestly (18.57 ± 0.64% and 33.84 ± 1.92%). The methanolic root extract of *A. sertachiae* Tuzlaci displayed the strongest inhibition at 33.84 ± 1.9%. The researchers concluded that total phenol and flavonoid amounts, as well as their anti-TYR activity, were not in right proportion and that the anti-TYR activity was in conjunction with phenolic substances present in the plant along with other undetectable phytochemicals. Spectrophotometric analysis of stem, seed, leaf, and root extracts prepared with different polarity solvents (*i.e.* acetone, methanol, and water) *A. brevicaulis* subsp. *brevicaulis* var. *brevicaulis*, *A. baytopiae*, and *A. cilicica* on hyaluronidase, collagenase, and elastase *in vitro* was also performed. The methanolic extract made from the roots was shown to exert the strongest hyaluronidase, collagenase, and elastase inhibitory activity. At 100 μg/mL concentration, *A. cilicica* root extract inhibited collagenase and elastase by 39.90 ± 1.15% and 53.78 ± 1.33%, respectively. In the same study, epigallocatechin gallate, employed as a control, inhibited the enzyme by 48.62 ± 1.14% and 84.31 ± 1.24%, respectively, at the same concentration. *A. cilicica* root extract with methanol at 100 μg/mL concentration exhibited 49.49 ± 1.17% inhibition against hyaluronidase, whereas tannic acid at the same concentration presented 87.33 ± 0.94% inhibition. As a result, it was established that extracts made with *Asphodeline* species strongly inhibited collagenase, elastase, and hyaluronidase activity. High phenolic and anthraquinone content of *A. cilicica* was hypothesized to contribute to anti-collagenase, anti-elastase, and anti-hyaluronidase properties (Ilhan et al. 2016).

14.3.2 Cichorium intybus L.

Cichorium intybus L., a member of Asteraceae, is a small, fragrant, perennial herb with blue or white blossoms that is known in Türkiye as "hindiba, ham sütlüvan, acı ot, and keklik otu" It is found practically all over the country. According to ethnopharmacological records, the aerial parts of the plant are used in Turkish folk medicine to cure obesity and the decoction made from the herb is used internally to treat dermatitis and hemorrhoids (Erbay and Sarı 2018; Sargin 2021). *In vivo* wound healing activity of methanol extract of *C. intybus* roots collected from Konya province (Türkiye) was investigated (Suntar et al. 2012). *C. intybus* roots were found to have substantial wound healing activity. ß-sitosterol was isolated from the root methanolic extract, while the enzyme inhibitory activities of this substance, at 100 μg/mL concentration, were determined. The compound inhibited collagenase similarly to epigallocatechin gallate (49.14 ± 0.58%), at a concentration of 100 μg/mL that was used as the reference. The authors arrived at the conclusion that ß-sitosterol is at least one of the active components responsible for inhibiting collagenase.

14.3.3 Daphne oleoides Schreb

Wound-healing activity of methanolic (85%) extracts of aerial parts of *Daphne oleoides* Schreber ssp. *oleoides* growing in Türkiye was investigated *in vivo* on male Sprague-Dawley mice and were found to be extremely effictive (Suntar et al. 2014). The ethyl acetate fraction of the methanolic extract was used to isolate 3 distinct substances, *i.e.* quercetin-3-O-glucoside, triumbellin, and rutarensin. The effects of isolated pure chemicals on collagenase, elastase, and hyaluronidase enzyme activity, which is crucial in wound healing and anti-aging, were studied. Only quercetin-3-O-glucoside, a flavonoid glucoside, demonstrated a considerable inhibition against three of the enzymes. At 100 μg/mL concentration, inhibition rates of these compounds were found to be 57.1 ± 0.92, 39.08 ± 1.36, and 63.02 ± 0.51 against collagenase, elastase, and hyaluronidase, respectively. At the same concentration, quercetin-3-O-glucoside outperformed the reference, *e.g.* epigallocatechin gallate, in terms of anti-collagenase activity. Similarly, it inhibited hyaluronidase at the same dose as tannic acid, which was employed as the reference in this experiment.

14.3.4 Epilobium angustifolium L.

The genus *Epilobium* L., known as "yakı otu, ezberyakısı, and anayakısı" in Türkiye, is a member of Onagraceae family. Various kinds of are *Epilobium* are consumed as salad, while *E. angustifolium* L. has been reported as utilized in folk medicine, due to its wound-healing properties. In a recent study conducted in Turkey (Karakaya et al. 2020), hyperoside, kaempferol, quercetin-3-O-α-L-arabinopyranoside, quercetin-3-O-α-L-rhamnopyranoside, and kaempferol-3-O-α-L-rhamnopyranoside were isolated from *E. angustifolium*. Inhibition on collagenase, elastase, and hyaluronidase by these isolated substances was evaluated. At 100 μg/mL concentration, hyperoside inhibited collagenase, elastase, and hyaluronidase by 30.07% ± 1.55, 19.87 ± 0.92%, and 39.66 ± 0.89%, respectively. The authors concluded that hyperoside present in *E. angustifolium* may be responsible for wound healing and indirectly also for the anti-aging activities of the plant.

14.3.5 Pinus pinaster Aiton

Pinus pinaster Aiton, as a member of Pinaceae family, is cultured successfully in Türkiye. It is known as "sahil çamı". A couple of studies have been carried out on the inhibitory activity of essential oils obtained from various parts of *P. pinaster* of Turkish origin against collagenase, elastase, and hyaluronidase Data by Tumen et al. (2018) are presented in Table 14.4. The authors concluded that α-terpineol and β-caryophyllene were the responsible for inhibition of the mentioned three enzymes.

14.3.6 Hypericum sp.

The genus *Hypericum* L. (Clusiaceae) is represented by 94 taxa in Turkish flora and is known as "sari kantaron, kantaron, binbir delik out, tentürdiyot otu, koyunkıran, kuzukıran, lüfer otu" by local people. Several *Hypericum* species have been tested for their inhibitory capacity against collagenase, elastase, hyaluronidase, and TYR, whose outcomes are listed in Table 14.5 (Boran 2018; Ersoy et al. 2019). The

Table 14.4 Inhibitory activity of the essential oil from *P. pinaster* of Turkish origin against collagenase, elastase, and hyaluronidase at 100 μg/mL

	Enzyme inhibition (Inhibition% ± S.D.)[a]		
Plant part	Collagenase	Elastase	Hyaluronidase
Cone essential oil	20.94 ± 1.51	20.07 ± 1.16	30.91 ± 0.86
Needle essential oil	17.11 ± 1.29	20.84 ± 1.30	14.67 ± 1.49
Wood essential oil	24.10 ± 1.52	17.43 ± 1.67	21.34 ± 1.38

[a]Standard deviation (n: 3)

secondary metabolites found to cause the enzyme inhibition were determined as chlorogenic acid, rutin, and quercitrin.

14.3.7 Helichrysum graveolens (Bieb.) Sweet

In Türkiye, the genus *Helichrysum* (Asteraceae) is locally known as "altın otu and yayla çiçeği". Recently, apigenin was identified in a study on the wound healing effect of flower methanolic extracts from *H. graveolens* (Bieb.) Sweet (Suntar et al. 2013). It was assessed for its ability to inhibit collagenase, elastase, and hyaluronidase, which are responsible for both anti-aging and wound healing activities and were found to inhibit collagenase, elastase, and hyaluronidase by 29.15 ± 0.87%, 19.43 ± 1.19%, and 30.29 ± 0.39%, at 100 g/mL concentrations, respectively. As a conclusion of the study, it was connorws that the component responsible for the anti-aging activity of methanol extract of *H. graveolens* might be apigenin.

14.4 Conclusions

Herbal extracts are preferred to synthetic cosmetic ingredients, since they are contained by plants in the form of mixtures, and as such they often have a synergistic effect, whereby their toxicity is relatively low. Since it is not possible for cosmetic products to be 100% natural, this situation is, in fact, used as a marketing strategy today. The active ingredient in a product, which is defined as "natural cosmetics", must be natural. In order for an effective anti-aging cosmetic product to provide a moisturizing effect, it must contain water and oil or similar substances to spread on the skin. Occasionally, they also contain components that can facilitate water transfer into the skin. This underpins the value our preliminary lab-scale results to evaluate use of Turkish MAPS in cosmetic sector. The prototype cosmetic products thus developed are more advantageous than the few similar products of local companies, as they allocate little or no budget to R&D studies in the field of skin care products and dermo-cosmetics. Proven effectiveness and innovative approaches in form can provide a scientific basis to the Turkish cosmetics industry, which is relatively

Table 14.5 Inhibitory activity of *Hypericum* species of Turkish origin against collagenase, elastase, and hyaluronidase

Plant species	Concent-ration (μg/mL)	Enzyme Inhibition (Inhibition% ± S.D.)[a] or IC_{50} values (μg/mL)				References
		Collagenase	Elastase	Hyaluronidase	TYR	
H. calycinum L.	200	51.24 ± 1.33%	IC_{50}: 55.77 ± 1.32	22.17 ± 0.02%	54.30 ± 0.49%	Ersoy et al. (2019)
H. confertum L.	200	63.01 ± 0.24%	IC_{50}: 61.6 7 ± 0.76	36.55 ± 0.11%	40.92 ± 0.21%	
H. perforatum L.	200	61.53 ± 0.40%	IC_{50}: 64.76 ± 0.55	37.30 ± 1.49%	48.22 ± 0.38%	
H. origanifolium Willd.	200	13.5 ± 0.35%	IC_{50}: 22.0 ± 0.14	8.1 ± 0.61%	Not tested	Boran (2018)
References[b–d]	100	43.47 ± 1.82%[b]	IC_{50}: 70.47 ± 0.89[b]	30.49 ± 0.08%[c]	95.05 ± 0.37%[d]	Ersoy et al. (2019)

[a]Standard deviation (n:3), [b]Epigallocatechin gallate, [c]Tannic acid, [d]α-Kojic acid

weaker in competition with imported cosmetics. It is planned that we continue the exploratory work on new, active, plant-based substances, obtained from MAPs growing in Turkey.

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