

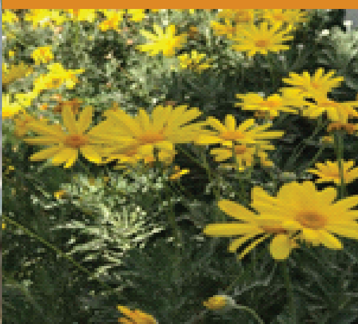
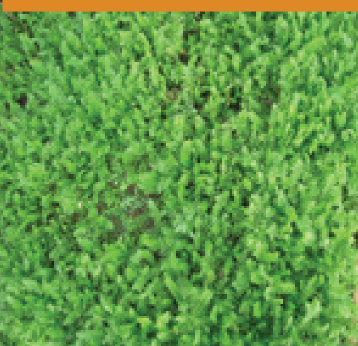
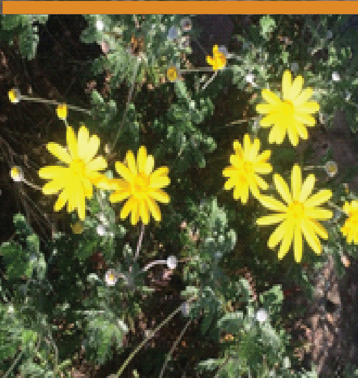


MEDICINAL AND AROMATIC PLANTS:

Economics Production Agricultural Ultilization and Other Aspects

EDITOR
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İKSAD
Publishing House

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Publishing House

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Researches Publications®
(The Licence Number of Publicator: 2014/31220)
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USA: +1 631 685 0 853
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It is responsibility of the author to abide by the publishing ethics rules.

ISBN: 978-625-8007-73-2
Cover Design: İbrahim KAYA
November / 2021
Ankara / Turkey
Size = 16 x 24 cm

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PREFACE

Turkey has an important potential in terms of natural and cultivated medicinal and aromatic plants with its rich plant diversity, wide surface area and different climates. In our country, medicinal and aromatic plants are mostly collected from nature and consumed, and plants are cultivated at a certain rate. It is very difficult or even impossible to obtain a standard quality in plants collected from nature. In order to be able to be met the increasing consumer demand and obtained a standard product, the cultivation and variety development of medicinal and aromatic plants are gaining speed day by day.

In recent years, the demand for synthetic products has decreased and continues to decrease. The interest and need for natural herbal products and many other products consisting of these products, such as food, medicine, herbal tea and cosmetics, is increasing day by day.

The fact that some plant species have become more consumed due to the epidemic we are experiencing has made the importance of medicinal and aromatic plants indisputably felt.

Medicinal and aromatic plants, which have a wide range of uses because they constitute the important raw material of pharmaceutical, food, beverage, cosmetics and many other industries, are discussed in this book from different aspects. Studies have been tried to deal with a wide range of uses of some families and plant species, from economy to production, from soil conditions to fertilization, from cultivation techniques to yield and yield parameters, from microbiological, antioxidant and antimicrobial properties to use in meat and dairy products, from morphological, physiological and biochemical properties to essential oil processing.

With the present book, it is aimed to contribute to science by creating a resource in the field of medicinal and aromatic plants, and it has been presented to the service of you, our esteemed readers.

I would like to thank our esteemed authors who contributed to the preparation of this work, Assoc. Prof. Dr. Seyithan SEYDOŞOĞLU for their help and support during the preparation of the book, and İKSAD Publishing House staff who contributed to its publication.

Assoc. Prof. Dr. Sıdıka EKREN
Editor
19th November 2021
IZMIR

CHAPTER 1

MEDICINAL AND AROMATIC PLANTS PRODUCTION, MARKETING AND FOREIGN TRADE

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1. Introduction

Since the days of humanity, people have collected plants and used them to meet their various needs. Medicinal and aromatic plants (MAPs) have been used for various purposes in many fields from medicine to cosmetics for thousands of years. And presently, it is still used as medicine for curing diseases, as food supplements, as substances in cosmetics and as insecticides etc. In recent years, with the increasing awareness of sustainable development, environmental protection and healthy life, the production and trade of medicinal and aromatic plants has also increased. As a trend in the current pandemic context (COVID-19), attention has also been drawn towards the antiviral potential of plant-based preparations and their effectiveness in supporting the human immune system against infections (Cadar et al, 2021). Thus medicinal plant based industry is a promising sector and source of enormous economic growth potential (Roosta et al., 2017).

Globally it is not possible to ascertain the exact number of species used as medicinal and aromatic plant material. Only the number of plant species used for medicinal purposes can be estimated. An enumeration of the WHO from the late 1970s listed 21,000 medicinal species. Today it is estimated that there are 422,000 plant species in the world and 50,000 of them are medicinal and aromatic plants. China alone has 4,941 of 26,092 native species (Schippmann et al, 2002).

The same is also true for MAPs international trade. It is difficult to assess how many MAPs are commercially traded. The bulk of MAPs is exported from developing countries while major markets are in the developed countries. According to ITC figures in the 2011-2020 period, MAPs' exports increased by 5% and reached 68.5 million dollars. Asian and European countries dominate the MAPs export market. On the other hand, about 46.8% of the worldwide MAPs imports are allocated to European countries. This increase is also due to the fact that alternative treatment methods with MAPs have recently attracted more attention especially in developed countries.

As an important MAPs exporter, Turkey has great plant diversity and endemic plants due to its geographical location. In Turkey the exact number of plants used medicinally is not known. But it is estimated to be around 500. It is stated that approximately 200 medicinal and aromatic plants have export potential (Faydaoglu and Surucuoglu, 2011, KUDAKA, 2013). Turkey is one of the important exporting countries in MAPs. However, despite the high export potential of medicinal and aromatic plants in Turkey, the desired level has not been reached yet.

It is known that medicinal and aromatic plants have been widely used in Turkey for thousands of years. Consumers show more interest in herbal methods, and the demand for medicinal and aromatic plants is increasing due to the fact that health-related issues have been on the agenda lately, they are safer than synthetic drugs and they are less costly. As a result of the expanding interest in medicinal and aromatic plants, new income generating opportunities are opening up for rural populations. With many of the MAPs gathered from the wild, the collection and sale of MAPs is providing a complementary source of cash for many extremely poor rural households. However, despite the fact that the products collected can have very high value in the final products, the collectors typically receive only a small share of the final value, either because they are unaware of the real value, are unable to market it in the form wanted by buyers or are unable to market to these buyers (FAO, 2005). Therefore this study aims to provide an overview of the international markets for MAPs and to indicate the place and competitiveness of Turkey in the international market of MAPs. The study also provides information on the production, trade and marketing of MAPs with special reference to Turkey, and to indicate what needs to be done in order to expand the opportunities for increasing her exports.

2 The Importance of MAPS for Turkish Economy

2.1 The Production of MAPS

2.1.1 World Medicinal and Aromatic Plants Production

Medicinal and aromatic plants are supplied by cultivation or wild collection in the world. Many medicinal plants, especially the aromatic herbs, are grown in home gardens, some are cultivated as field crops, either in sole cropping or in intercropping systems and rarely as plantation crops (Schippmann et al, 2002). Therefore, there are problems in obtaining reliable data on MAPs production. However, the most reliable production data on cultivated MAPs is published by FAO. According to these data, MAPs production areas and production amounts have increased significantly in recent years. Products with an increasing trend are anise, badian, fennel, coriander, cinnamon cloves, cocoa beans, green coffee, ginger, linseed, nutmeg, mace and cardamoms, peppermint, poppy seed, spices, tea and vanilla. The product group with the highest increase is anise, badian, fennel, coriander with an increase of 91.3%. It is followed by cloves, tea, nutmeg, mace and cardamoms, linseed, cinnamon, ginger, cocoa beans and peppermint. On the other hand, the increase in spices nested, green coffee and vanilla is below 15%. In recent years the most serious decrease in production areas are seen in carobs with 68%. This was followed by poppy seed with a decrease of 56.5%, while the decrease in mate planting areas was 1.2% (Table 1, Table 2). As in the MAPS production areas, the highest increase in the production amount has been in anise, badian, fennel and coriander in recent years. This was followed by nutmeg, mace and cardamoms (89.3%), cloves (76.7%), ginger (72.5%), linseed (41.7%), tea (34.6%). Production increase in mate, cinnamon, cocoa beans, green coffee, peppermint and spices nested is below 30%. The most significant decrease in the production amount in recent years is seen in poppy seed with 72.4%. This was followed by carobs (-70.4%) and vanilla (-10.3%) (Table 3, Table 4).

2.1.1 Medicinal and Aromatic Plants Production in Turkey

Turkey is home to many endemic plants due to its geographical advantage. Some of the medicinal and aromatic plants are cultivated in Turkey, and some of them are obtained from nature as in many parts of the world. Among the medicinal and aromatic plants, cumin, anise, thyme, fenugreek, poppy, fennel, mint and coriander are cultivated in our country. Laurel, mahaleb, linden flower, sage, rosemary, licorice root and juniper bark are collected from nature. As a matter of fact, it can be said that MAP's production tends to increase over the years. While anise cultivation area was 211,542 decares in 2011, it decreased to 155,317 decares in 2020. Due to the decrease in the production area, the production amount in 2020 was 10,716 tons. Anise yield is 69 kg per decare. Cumin production areas have increased by 6% in the last ten years and reached 212,132 decares. While the amount of production increased approximately at the same rate and realized as 14,000 tons, the yield was 66 kg per decare. There has been a significant increase of 137.7% in the last ten years in the cultivation areas of thyme. The average yield of thyme, which was produced 23,866 tons in 2020, is 129 kg per decare (Table 5).

Table 1: World MAPS Area Harvested (Ha)

	Anise, badian, fennel, coriander	Carobs	Cinnamon (cannella)	Cloves	Cocoa, beans	Coffee, green	Ginger
2011	1,085,460	44,964	241,854	403,475	10,254,014	9,929,407	307,607
2012	1,042,614	42,713	247,508	568,400	10,314,015	10,314,953	368,330
2013	1,001,891	42,218	257,639	584,767	10,176,654	10,544,876	373,591
2014	1,108,230	41,590	267,954	601,153	10,533,723	10,449,598	312,885
2015	1,151,106	41,799	277,958	633,421	10,959,721	10,858,452	347,282
2016	1,343,755	41,462	282,206	655,923	10,872,315	11,011,540	393,514
2017	2,108,759	38,817	288,204	672,943	11,997,741	10,565,783	405,591
2018	2,034,824	14,421	300,796	677,691	12,251,449	10,741,484	393,762
2019	2,076,609	14,366	309,165	673,415	12,234,311	11,120,498	385,172
Change	91.3	-68.0	27.8	66.9	19.3	12.0	25.2

Source: FAOSTAT, Crops and Livestock Products, https://www.fao.org/faostat/en/#data/QCL, Accessed: 07.11.2021

Table 2: World MAPS Area Harvested (Ha)

	Linseed	Maté	Nutmeg, mace and cardamoms	Peppermint	Poppy seed	Spices nes	Tea	Vanilla
2011	2,231,132	267,984	303,765	2,331	129,006	1,189,963	3,402,185	94,003
2012	2,430,418	274,847	319,679	4,067	72,701	1,151,087	3,512,376	98,132
2013	2,237,790	266,392	335,015	3,684	94,941	1,194,196	3,615,252	95,228
2014	2,637,642	268,641	353,105	3,529	99,831	1,155,281	3,787,752	94,973
2015	2,987,214	274,251	363,593	3,274	143,304	1,236,576	3,878,291	91,530
2016	2,765,498	260,870	391,891	3,434	109,963	1,285,536	4,154,480	92,958
2017	2,922,493	261,776	415,109	3,749	100,870	1,091,366	4,688,300	100,718
2018	3,149,344	253,844	452,665	3,422	46,347	1,417,130	4,854,692	101,273
2019	3,223,531	264,699	450,728	2,779	56,094	1,368,702	5,079,387	102,435
Change	44.5	-1.2	48.4	19.2	-56.5	15.0	49.3	9.0

Source: FAOSTAT, Crops and Livestock Products, https://www.fao.org/faostat/en/#data/QCL, Accessed: 07.11.2021

Table 3: World MAPS Production (tonnes)

	Anise, badian, fennel, coriander	Carobs	Cinnamon (cannella)	Cloves	Cocoa, beans	Coffee, green	Ginger
2011	953,713	157,418	198,837	102,878	4,614,869	8,387,101	2,365,576
2012	924,026	126,405	204,029	130,774	4,613,416	8,821,944	2,464,003
2013	907,761	114,823	208,761	143,237	4,484,825	8,896,881	2,445,355
2014	1,004,382	166,449	212,939	165,618	4,744,750	8,809,418	2,301,702
2015	1,082,290	133,349	223,035	184,250	4,827,752	8,891,891	2,753,027
2016	1,165,558	135,498	231,020	190,287	4,651,282	9,405,297	3,623,585
2017	2,153,312	138,288	235,615	164,267	5,268,238	9,365,306	3,518,955
2018	2,073,365	46,141	237,895	179,886	5,573,392	10,412,185	4,080,927
2019	1,971,482	46,604	242,635	181,788	5,596,397	10,035,576	4,081,374
Change	106.7	-70.4	22.0	76.7	21.3	19.7	72.5

Source: FAOSTAT, 2021.

Table 4: World MAPS Production (Tonnes)

	Linseed	Maté	Nutmeg, mace and cardamoms	Peppermint	Poppy seed	Spices nes	Tea	Vanilla
2011	2,165,619	774,524	74,837	62,931	107,268	2,597,295	4,827,510	8,602
2012	2,027,340	821,534	92,633	106,386	49,801	2,428,909	5,025,690	8,052
2013	2,273,498	842,650	98,128	95,176	69,624	2,597,385	5,309,841	7,600
2014	2,663,662	959,247	107,017	92,692	81,020	2,600,058	5,493,989	7,081
2015	3,149,783	990,103	107,433	107,586	101,078	2,343,344	5,761,926	7,218
2016	2,910,903	1,015,327	124,671	106,674	84,229	2,652,359	5,802,728	7,780
2017	2,872,323	1,016,085	131,682	99,262	70,285	2,732,111	5,994,682	7,995
2018	2,975,473	928,240	145,568	106,408	29,442	2,642,611	6,326,897	7,738
2019	3,068,254	945,962	141,700	74,232	29,713	2,770,523	6,497,443	7,715
Change	41.7	22.1	89.3	18.0	-72.3	6.7	34.6	-10.3

Source: FAOSTAT, 2021.

In addition, there has been a 43% increase in black cumin cultivation areas in the last five years. Especially in the last production period, the increase in the coriander cultivation area draws attention. In 2020, 2,455 decares of coriander were planted and 188 tons of coriander was obtained. In addition, with an increase in the production area of approximately 41%, the production of fennel planted on 22,204 decares was 4,365 tons (

Table **6**).

Sage production has also increased over the years. In the last five years, sage production, which has been planted with an increase of 60% by 6,655 decares, has tripled with the increase in yield. Fenugreek production area has increased five times in the last ten years and reached 6,521 decares. 713 tons of production was realized. Carob production area increased by 88% and reached a production of 18,806 tons on 9,299 decares (
Table **7**).

Significant increases in wild harvesting medicinal and aromatic plants draw attention. In addition to cultivation, carob, one of wild harvesting MAPs, was collected only 23 tons in 2011 and 642 tons in 2020. Bay leaves were collected 12,329 tons in 2011 and 32,537 tons in 2019. The amount of linden collected has also increased from 3 tons to 76 tons in the last ten years (Table 8).

Since a significant part of medicinal and aromatic plants are wild harvesting, it becomes difficult to obtain reliable statistical data.

Table 5: Production Area (Da), Production (Tonnes) and Yield (Kg/Da) of Some MAPs (Harvested)

	Anise			Cumin			Thyme		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
2011	211,542	14,879	70	200,117	13,193	66	77,707	10,953	141
2012	194,430	11,023	57	226,294	13,900	61	94,283	11,598	123
2013	152,431	10,046	66	247,045	17,050	69	89,137	13,658	153
2014	140,506	9,309	66	224,421	15,570	69	92,959	11,752	126
2015	138,118	9,050	66	270,247	16,897	63	104,863	12,992	124
2016	136,552	9,491	70	268,849	18,586	69	121,127	14,724	122
2017	121,833	8,418	69	267,358	19,175	72	121,472	14,477	119
2018	124,455	8,664	70	361,761	24,195	67	139,061	15,895	114
2019	239,171	17,589	74	321,889	20,245	63	157,074	17,965	114
2020	155,317	10,716	69	212,132	13,926	66	184,711	23,866	129
Change	-26.6	-28.0	-1.4	6.0	5.6	0.0	137.7	117.9	-8.5

Table 6: Production Area (Da), Production (Tonnes) and Yield (Kg/Da) of Some MAPs (Harvested)

	Black Cumin *			Fennel *			Coriander *		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
2012	2,299	161	70	15,775	1,862	118	11	1	91
2013	3,261	352	108	13,848	1,994	144	11	1	91
2014	1,717	140	82	15,848	2,289	144	11	1	91
2015	4,681	425	91	15,512	1,461	94	150	11	73
2016	23,160	2,527	109	17,503	2,464	141	503	42	83
2017	32,560	3,094	95	16,525	2,022	122	410	29	71
2018	33,864	3,322	98	23,400	3,067	131	405	29	72
2019	37,085	3,603	97	33,859	4,655	137	155	12	77
2020	33,773	3,412	101	22,204	4,365	197	2,455	188	77
Change	1,369.0	2,019.3	44.3	40.8	134.4	66.9	22,218.2	18,700.0	-15.4

* Data have been compiled since 2012.
Source:TUIK, 2021.

Table 7: Production Area (Da), Production (Tonnes) and Yield (Kg/Da) of Some MAPs (Harvested)

	Sage*			Fenugreek			Carob		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
2011	-	-	-	1,055	141	134	4,940	13,978	48
2012	54	7	130	645	67	105	5,449	14,166	45
2013	30	4	133	1,678	195	116	5,119	14,261	48
2014	130	19	146	1,979	218	110	6,307	13,985	46
2015	536	80	149	4,825	491	114	5,244	12,851	45
2016	3,681	411	112	8,234	914	111	5,693	13,405	46
2017	4,123	557	135	14,499	1,521	105	6,735	15,016	45
2018	3,951	428	108	7,188	745	104	6,821	15,506	47
2019	5,602	1,233	220	6,040	645	107	7,652	16,256	47
2020	6,655	1,271	191	6,521	713	109	9,299	18,806	54
Change	12,224.1	18,057.1	46.9	518.1	405.7	-18.7	88.2	34.5	12.5

* Data have been compiled since 2012. Source: TUIK, 2021.

Table 8: Production of Some MAP's (Collected) (Tonnes)

	Carob	Bay Leaves	Linden
2011	23	12,329	3
2012	24	12,351	56
2013	522	15,178	29
2014	539	15,581	50
2015	614	21,634	48
2016	1,492	21,788	65
2017	669	27,678	208
2018	933	28,582	35
2019	642	32,537	76

Source: T.C. Ministry of Agriculture and Forest, Forest General Directorate, 2021.

2.2 The Marketing of MAPS

In MAPs marketing, the supply chain is often very long with as many as six or seven marketing stages involving primary collectors and producers, local contractors, regional wholesale markets, large wholesale markets and specialized suppliers. Industry buys from suppliers and wholesalers rather than direct from smallholders because of the substantial quantities and broad range of raw material that is needed. This makes product traceability nearly impossible. Currently, contract farming and buy-back arrangements provide the only practical alternatives for exporters whose customers require traceability (FAO, 2005).

In Turkey, the marketing channels of medicinal and aromatic plants vary according to the products. The domestic marketing channel of medicinal and aromatic plants is given in Figure 1. Manufacturers and collectors sell the product to local wholesalers and packaging companies. Local wholesalers generally make an agreement with the demands of certain processing companies or large wholesalers, and get the product by communicating with the people who can collect the products demanded from that region. Processing companies buy products directly from local collectors and producers, especially from large wholesalers. The processed and packaged products are given to the domestic market through herbalists, markets and neighborhood markets, or they are exported to the foreign market (Artukoğlu and Uzmay, 2003).

In a study conducted in Isparta province, 29% of the lavender producing enterprises markets their products in the distribution channel as producer-factory-firms-consumer, 22% are producer-merchant-wholesaler-retailer-consumer and 19% are producer-factory. It is stated that only 6.35% of the producers sell directly from the producer to the consumer (Bozkıran, 2015).

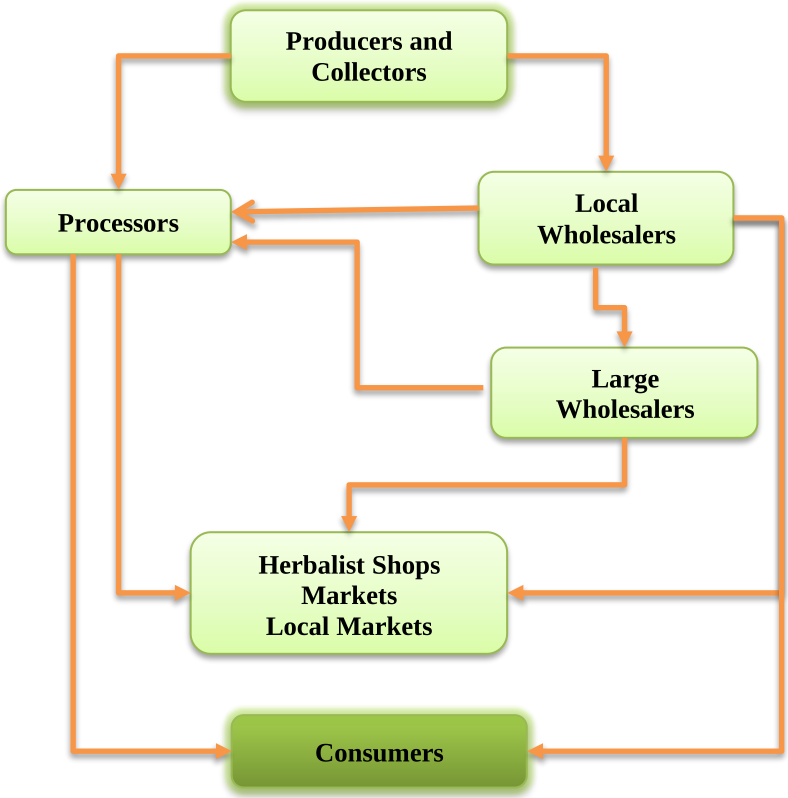

Figure 1: Marketing Channels of MAPs in Turkey
Source: Artukoğlu ve Uzmay, 2003.

2.3 Trade of MAPS

2.3.1 World Medicinal and Aromatic Plants Trade

In the last two decades, interest in the use of medicinal and aromatic plants in health care has increased in developed countries. Legal restrictions on chemicals used in food preservation have been effective in this development. The recognition of herbal products as safe and healthy products with few side effects, is also an important factor in the growth of market share. Also, this general trend has led to the development of the herbal medicine industry. Therefore market demand for medicinal and aromatic plant products will remain strong in the near future.

Moreover, the global dietary supplements market size was valued at USD 140.3 billion in 2020 and is expected to expand at a compound annual growth rate of 8.6% from 2021 to 2028 (Grand View Research, 2021). The U.S. emerged as a leading market in the North American region in 2020. On the other hand the botanicals market was valued at USD 93.6 billion in 2020, registering a rate of 6.63%, during the period, 2021-2026 (Mordor Intelligence, 2020). The growth of the market for botanical ingredients is expected to be hindered by the ongoing pandemic COVID-19, which has relentlessly hit the global trade and production business.

In the light of these developments, when the foreign trade of medicinal and aromatic plants is examined, it is seen that there is an export potential of 65.73 billion dollars. Although the export of MAP reached to 68.57 billion USD in 2020, there is a difficulty in assessing exact trade figures. This problem is that the MAPs are not gathered under the same harmonized commodity chapters. In general, medicinal and aromatic plants are included under chapters 09, 12, 13 and 33. According to world trade figures, 75.21% of world MAP trade consists of coffee, tea, mate and spice. Although medicinal plants and essential oils have low shares in world trade, they are the product groups whose trade has increased the fastest in the last decade (Table 9).

Table 9: World export of medicinal and aromatic plants by product ($1,000)

	Coffee, tea, maté and spices	Medicinal plants	Lac; gums, resins, saps and extracts	Essential oils	Total
2011	51,255,925	2,539,936	7,939,374	3,634,883	65,370,118
2012	48,641,432	2,663,893	12,736,899	3,674,944	67,717,168
2013	45,355,147	3,467,213	9,237,509	3,966,056	62,025,925
2014	49,644,156	3,559,692	8,656,524	4,450,614	66,310,986
2015	48,180,272	3,140,843	6,898,080	4,846,850	63,066,045
2016	48,476,499	3,201,753	6,734,226	4,734,472	63,146,950
2017	52,088,378	3,194,721	7,230,626	5,431,453	67,945,178
2018	49,749,048	3,215,550	8,122,695	5,955,614	67,042,907
2019	49,179,452	3,242,997	8,064,189	5,642,249	66,128,887
2020	51,828,339	3,554,136	7,901,192	5,290,510	68,574,177
Average	49,439,865	3,178,073	8,352,131	4,762,765	65,732,834
Share (%)	75.21	4.83	12.71	7.25	100.00
Change (%)	1.12	39.93	-0.48	45.55	4.90

Source: ITC, Trademap, 2021.

There are approximately 20,000 MAPs species in the world, and about 2,000 of them are traded (HABDER, 2020). When the single countries export shares are analyzed for the year 2020, Brazil ranks first with a share of 9.5% in 2020, followed by China (7.1%) and India (6.5%) for coffee, tea, maté and spices (Figure 2). Germany with a share of 5.7% and Viet Nam with a share of 5.6% follow these first three countries.

On the 2011-2020 period average, Brazil (11.5%) ranks the first. It is followed by Viet Nam (8.3%), Germany (6.3%), India (6.2%) and China (5.7%), respectively. Turkey's export share is 0.4% for the same period (Table 10).

Table 10: The 5 leading countries of MAP exports (2011-2020)

	Coffee, tea, maté and spices		Medicinal plants		Lac; gums, resins, saps and extracts		Essential oils	
	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%
Brazil	5,702,824	11.5	11,791	0,4	113,406	1,4	298,753	6.3
China	2,832,507	5.7	975,219	30.7	1,303,793	15.6	412,404	8.7
India	3,062,604	6.2	253,875	8.0	1,984,097	23.8	746,025	15.7
Germany	3,123,785	6.3	166,738	5.2	560,312	6.7	187,705	3.9
Viet Nam	4,114,703	8.3	18,762	0.6	27,623	0.3	10,483	0.2
USA	1,182,696	2.4	159,966	5.0	622,134	7.4	639,050	13.4
Canada	601,128	1.2	167,252	5.3	66,548	0.8	58,324	1.2
France	1,097,877	2.2	54,236	1.7	591,062	7.1	392,373	8.2
Turkey	181,228	0.4	19,087	0,6	13,126	0.2	35,387	0.7
World	49,439,865	100,0	3,178,073	100,0	8,352,131	100.0	4,762,765	100.0

Source: ITC, Trademap, 2021.

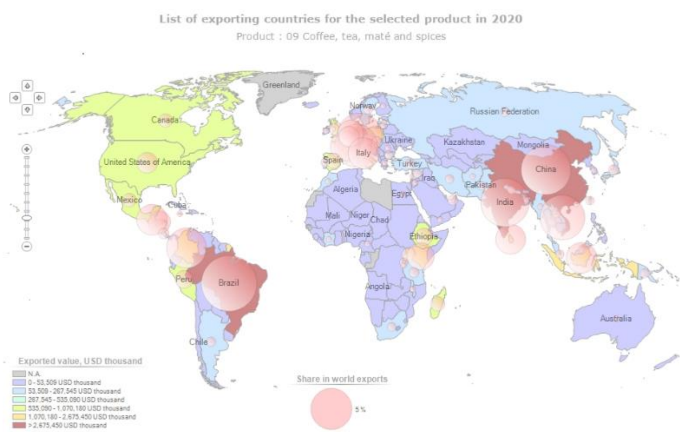

Figure 2: The Main Exporting Countries for Coffee, Tea, Maté and Spices (2020)

Source: ITC, Trademap, 2021.

In medicinal plants, China and India rank the first two places with a share of 14.8% for medicinal plants in 2020. Egypt ranks third with a share of 5.9%. Spain's share who ranks in the top five is 4.4%, while Poland's is 4.1% (Figure 3). On the average China heads the world's top countries of export. It has 30.7% on average in medicinal plants in the period 2011-2020, which is one third of the total exportation of medicinal plants. Further important exporters are India (8.0 %), Canada (5.3%), Germany (5.2%) and the USA (5.0%). Turkey, on the other hand, ranks 26th with a share of 0.6% (Table 10).

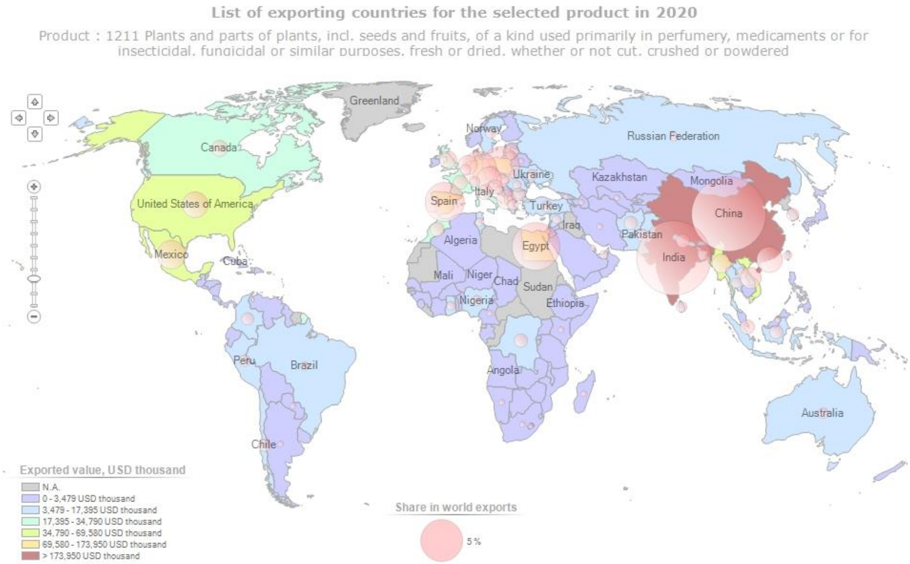

Figure 3: The Main Exporting Countries for Medicinal Plants (2020)
Source: ITC, Trademap, 2021.

A similar ordering applies to lac; gums, resins, saps and extracts. China (20.7%) is still the largest exporter in 2020. China is followed by India (9.2%) again. The third country is the USA. As of 2020, it has a share of 7.7% in lac; gums, resins, saps and extracts exports (Figure 4). However, when the average of the last decade is taken into account, it is seen that India surpassed China and ranked first with the share of 23.8%. As the period average, China's share is 15.6%. Other important exporting countries are the USA (7.4%), France (7.1%) and Germany (6.5%). Turkey's export share is 0.2% for the same period (Table 10).

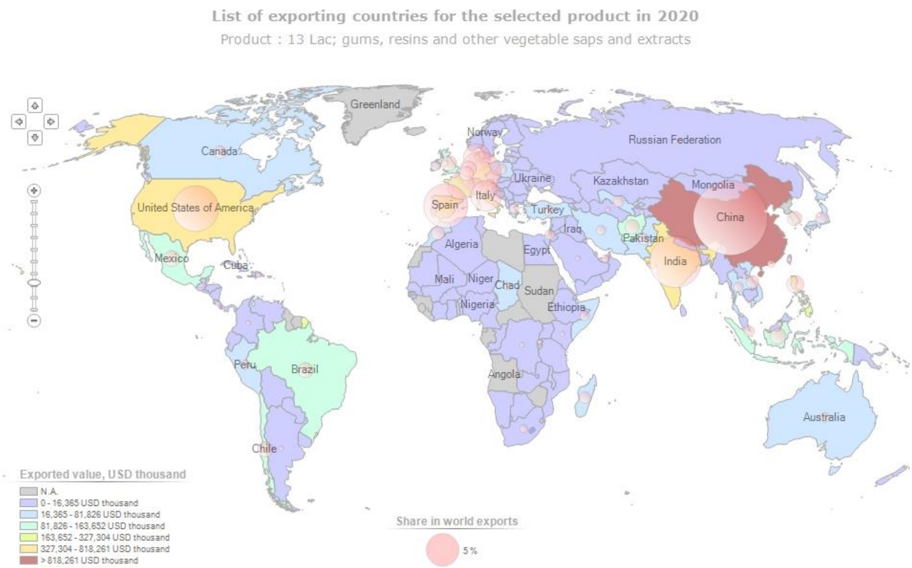

Figure 4: The Main Exporting Countries for Lac; gums, resins, saps and extracts (2020)
Source: ITC, Trademap, 2021.

It is seen that the top five countries have not changed much in essential oils exports as of 2020. In this group, India ranks the first with a share of 15.1%, while the USA ranks the second with a share of 14.5%. China is in fourth place with a share of 5.5% (

Figure 5). France has 8.6% and ranks the third. On the average (2011-2020), India heads the list of the world's top 5 countries of essential oils exports with a share of 15.7%. Further important exporters on average are the USA (13.4%), China (8.7%), France (8.2 %) and Brazil (6.3%). Turkey, on the other hand, ranks 25th with a share of 0.7% (Table 10).

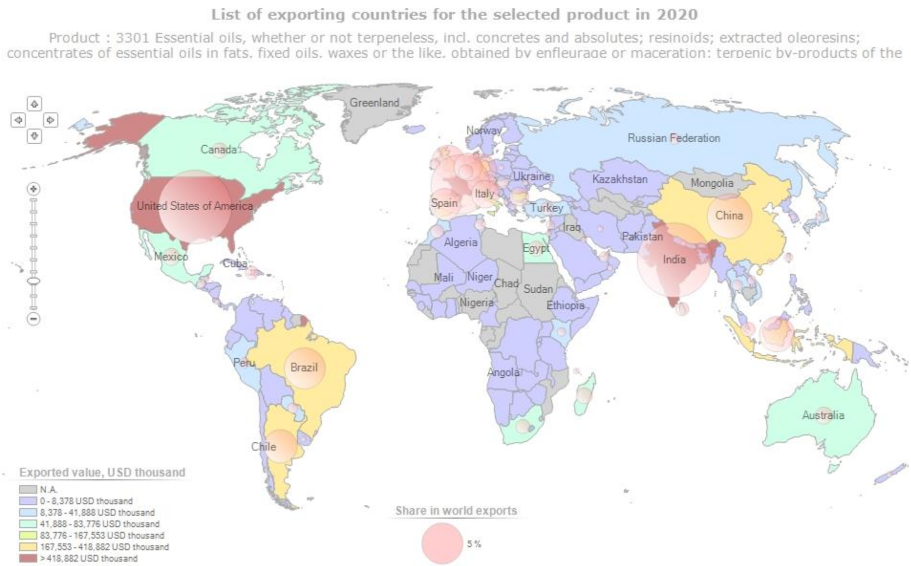

Figure 5: The Main Exporting Countries for Essential oils (2020)
Source: ITC, Trademap, 2021.

Although Turkey is one of the countries with the richest plant diversity in the Mediterranean, its share in MAPs exports is below 1%. The reason for Turkey's low export rates in global MAPs trade is that Turkey still exports unprocessed MAPs. As a matter of fact, it is seen that Asian (35.8%) and European (28.8%) countries dominate the MAPs export market. American countries, on the other hand, rank the third place in MAPs exports with a share of 27.6% (**Hata! Başvuru**

kaynağı bulunamadı.). Another main feature of MAPs imports is the dominance of European countries; about 46.8% of the worldwide MAPs imports are allocated to European countries. The countries of Asia and America are responsible for 24.8% and 24.6% respectively of the worldwide MAPs imports (Figure 6). The emergence of such differences between countries is associated with MAPs prices, plant variety and processing status, and the socio-economic status of the suppliers. Also higher prices are paid for processed, semi-processed and organic certified products from countries such as the USA, Chile, Hong Kong, Japan, Taiwan (Lange, 2006).

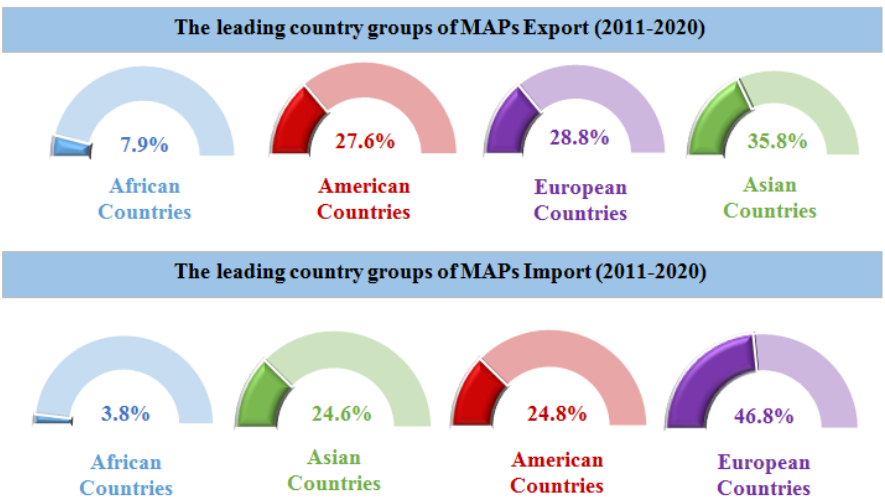

Figure 6: The leading country groups of MAP trade (2011-2020)

Import of MAP also has an important place in the world trade. As a matter of fact, when the last decade is examined, it is seen that there is an import potential of 68 billion dollars in MAPs. On MAPs imports side, coffee, tea and spices are the most imported product groups with a share of 75.65%. Lac and extracts are the second important product group. Although medicinal plants and essential oils have low shares in world MAPs import, they are the product groups whose import has increased the fastest in the last decade (Table 11).

Table 11: World import of medicinal and aromatic plants by product ($1,000)

	09 Coffee, tea, maté and spices	1211 Medicinal plants	13 Lac; gums, resins, saps and extracts	3301 Essential oils	Total
2011	50.942.282	2.537.115	7.150.412	3.765.050	64.394.859
2012	48.091.717	2.666.343	9.986.222	3.679.157	64.423.439
2013	44.252.452	3.114.990	8.258.297	3.904.264	59.530.003
2014	47.550.036	3.260.405	7.860.721	4.139.641	62.810.803
2015	48.014.383	3.078.843	6.882.051	4.427.385	62.402.662
2016	47.425.261	3.106.031	6.572.505	4.627.929	61.731.726
2017	51.359.005	3.141.439	7.191.717	5.405.416	67.097.577
2018	49.841.314	3.831.483	8.039.940	6.097.214	67.809.951
2019	49.033.270	3.299.906	8.024.182	5.987.026	66.344.384
2020	50.385.371	3.434.631	8.034.581	5.240.871	67.095.454
Average	48.689.509	3.147.119	7.800.063	4.727.395	64.364.086
Share (%)	75,65	4,89	12,12	7,34	100,00
Change (%)	-1,09	35,38	12,37	39,20	4,19

Source: ITC, Trademap, 2021.

In 2020, the USA (15.4%), Germany (8.4%) and France (6.6%) are the leading countries that import coffee, tea, mate and spices. Almost all of the countries in the top five in the coffee, tea, maté and spices group are European countries (Figure 7). On the 2011-2020 period average, the USA (16.8%) ranks the first. It is followed by Viet Nam (8.3%), Germany (6.3%), Germany (9.8%) and France (6.4%), respectively. Turkey's import share is 0.5% for the same period (Table 12).

Table 12: The 5 leading countries of MAP imports (2011-2020)

	09 Coffee, tea, maté and spices		1211 Medicinal plants		13 Lac; gums, resins, saps and extracts		3301 Essential oils	
	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%
USA	8,156,401	16.8	391,109	12.6	2,052,690	26.3	981,352	20.8
Germany	4,794,295	9.8	281,244	9.1	597,756	7.7	345,477	7.3
France	3,101,997	6.4	97,334	3.1	366,627	4.7	392,995	8.3
Netherlands	1,542,404	3.2	53,915	1.7	165,950	2.1	125,519	2.7
UK	1,675,640	3.4	76,075	2.5	228,893	2.9	292,985	6.2
Japan	2,010,015	4,1	269,113	8.7	355,784	4.6	190,762	4.0
Hong Kong, China	230,392	0,5	316,186	10.2	41,649	0.5	34,549	0.7
China	575,549	1,2	145,314	4.7	261,502	3.4	226,813	4.8
Turkey	229,654	0.5	9,877	0.3	45,321	0.6	27,057	0.6
World	48,689,509	100.0	3,102,289	100.0	7,800,063	100.0	4,727,395	100.0

Source: ITC, Trademap, 2021.

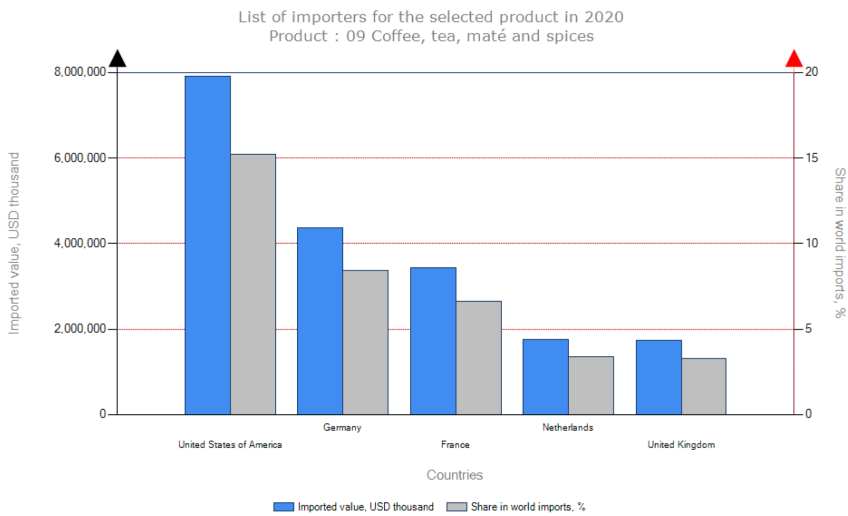

Figure 7: The Main Importing Countries for Coffee, Tea, Maté and Spices (2020)
Source: ITC, Trademap, 2021.

In 2020, Hong Kong (10.4%), the USA (7.3%), and Germany (6.3%) ranked first in the world's imports of medicinal plants. India (4.5%)

and Spain (4.4%) are the other leading countries (Figure 8). According to the average of 2011-2020 period, the five major importing countries are the USA (12.6%), Hong Kong (10.2%), Germany (9.1%), Japan (%8.7) and China (4.7%) (Table 12). Turkey's import share is 0.3% for the same period (Table 12).

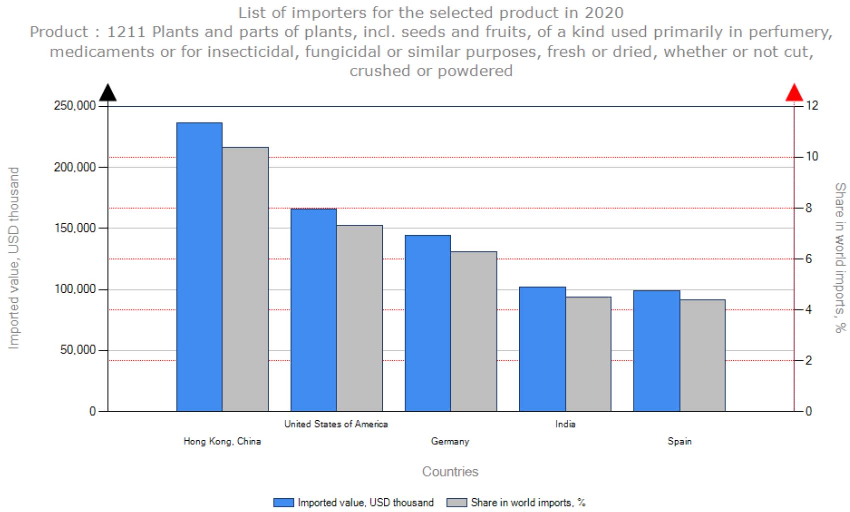

Figure 8: The Main Importing Countries for Medicinal Plants (2020)
Source: ITC, Trademap, 2021.

In extracts, the most important importing country for 2020 is the USA. The USA is followed by Germany, France, China and Japan in order. While the share of the USA in its imports is 18.4%, Germany's following it is 7.6% (Figure 9). Looking at the period average, it is seen that the USA ranks first with a share of 26%. This country is followed by Germany (7.7%), France (4.7%), Japan (4.6%) and China (3.4%), respectively. Turkey's import share is 0.5% for the same period (Table 12).

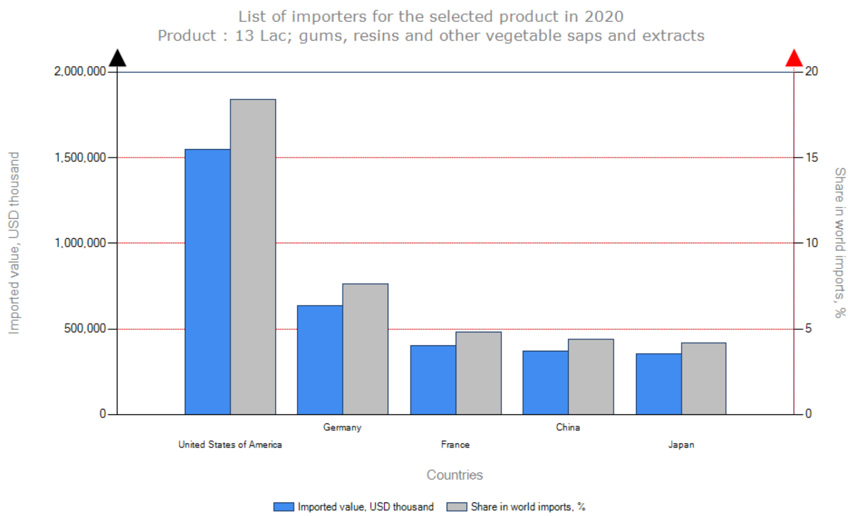

Figure 9: The Main Importing Countries for Lac; gums, resins, saps and extracts (2020)
Source: ITC, Trademap, 2021.

In the import of essential oils, the USA ranks first with a share of 18.9%. France ranks the second place with a share of 7.3%, and Germany ranks the third place with a share of 6.5% in 2020. China and UK are other major countries in essential oil imports. (Figure 10). According to the average data, a similar country distribution emerges for essential oils. The USA (20.8%) also maintains its importance in essential oils imports. Other important importers are France (8.3%), Germany (7.3%), UK (6.2%) and China (4.8%), respectively. Turkey's import share is 0.6% for the same period (Table 12).

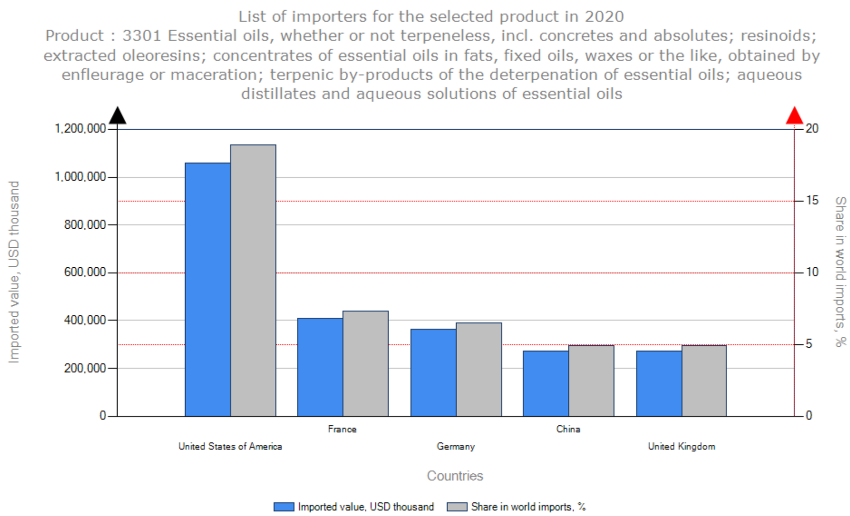

Figure 10: The Main Importing Countries for Essential oils (2020)
Source: ITC, Trademap, 2021.

Briefly, a main feature of international trade is the dominance of European and Asian countries. 68.0% of the global imports and exports of MAPs are allocated to these countries. Asian countries are responsible for 35.8% of MAPs export and 24.6% of MAPs imports. European countries’ share in MAPs import is more than one third. This situation, which was also expressed in Lange's study (2006), seems to be still valid today.

2.3.2 Medicinal and Aromatic Plants Trade in Turkey

It is known that the use of some MAPs as food and medicine in Turkey has a history of millennia. As a matter of fact, Turkey's natural wealth allows many medicinal and aromatic plant species to be collected and cultivated from nature. However, the use of these plants as a commercial commodity is quite new. Although these products are commercially new, their production areas have increased over the years. Depending on these developments, Turkey has become one of the leading countries in the trade of these plants. In Turkey, 347 species are traded and 139 species are exported (HABDER, 2020). However, medicinal and aromatic plants are generally exported as raw products, creating low added value. This results in a low income from MAPs exports. As a matter of fact, during the period under consideration, there was an increase of 129.9% in the value of MAPs exports and MAPs exports reached 350 million dollars in 2020. Turkey's export of MAPs shows a similarity with the world. Turkey's most important MAPs export item is coffee, tea and spices. The share of essential oils in Turkey's exports is also high (Table 13).

Table 13: Export of medicinal and aromatic plants in Turkey ($1,000)

	Coffee, tea, maté and spices	Medicinal plants	Lac; gums, resins, saps and extracts	Essential oils	Total
2011	110,495	12,944	6,636	22,177	152,252
2012	118,694	11,908	8,403	24,794	163,799
2013	185,149	19,983	10,607	25,149	240,888
2014	205,283	25,660	9,783	32,244	272,970
2015	168,481	15,676	9,107	33,586	226,850
2016	196,162	16,332	10,283	41,292	264,069
2017	178,338	17,577	12,003	49,187	257,105
2018	180,685	20,336	16,387	47,481	264,889
2019	211,864	24,399	19,122	40,065	295,450
2020	257,132	26,052	28,925	37,894	350,003
Average	181,228	19,087	13,126	35,387	248,828
Share (%)	72.8	7.7	5.3	14.2	100.0
Change (%)	132.7	101.3	335.9	70.9	129.9

Source: ITC, Trademap, 2021.

Turkey is exporting a wide range of spices, but is particularly strong in ginger, saffron, turmeric, thyme, bay leaves and seeds of anise, badian, fennel, coriander, cumin (Figure 11). Thyme, which has many uses, especially in the spice, medicine, cosmetics and chemical industry, has an important place in the foreign trade of medicinal and aromatic plants of our country. Turkey holds approximately 70-80% of the world's thyme export. Thyme (31.1% takes the first place in exports of MAPs. Bay leaves ranks the second with a 21.1% share in Turkish MAPs exports. Another important group product in Turkey's MAPs export is essential oils. The most important export item in terms of essential oils is rose oil. It accounts for 36.4% of MAPs exports in the period under consideration. Almost all of the rose oil produced in Turkey is exported. This is followed by volatile oils (12.3%), thyme oil (10.4%), extracted oleoresins (9.0%) and steraopten (6.4%).

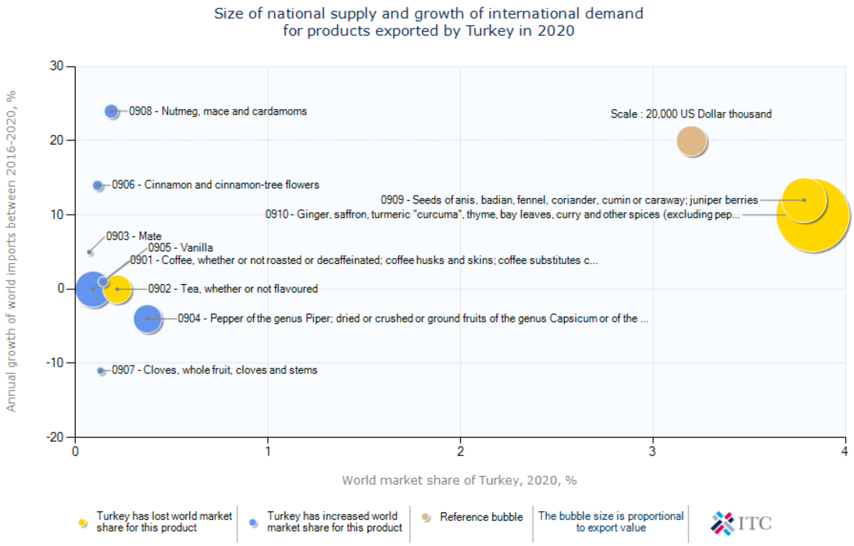

Figure 11: The share of coffee, tea, maté and spices exports (2020)
Source: ITC, Trademap, 2021.

The USA is the most important market for Turkish spices. The main markets are the USA and Germany, which absorb about 30% of total Turkish spices exports. Other important markets are Viet Nam, Belgium and Netherlands. In medicinal plants again the USA and Germany are the major countries. They have approximately 43% share in Turkish medicinal plants export. These countries are followed by UK, France and Japan. In lac and extracts exports Germany is the leading country with a share of 18.6% and followed by Italy, China, S. Korea and Malaysia. Turkey exports also significant amounts of essential oils to the world. France is the dominant country in essential oil exports; its export share is 56.7%. France is followed by UK, Germany, the USA and Switzerland (Table 14). In general, it is seen that the USA, Germany and France are main markets in the export of Turkish MAPs.

Table 14: The 5 leading countries in Turkish MAPs exports (2011-2020)

	Coffee, tea, maté and spices		Medicinal plants		Lac; gums, resins, saps and extracts		Essential oils	
	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%
USA	33,681	18.6	3,923	20.6			2,331	6.6
Germany	17,290	9.5	4,141	21.7	2,442	18.6	2,834	8.0
Viet Nam	12,896	7.1						
Belgium	8,853	4.9						
Netherlands	6,931	3.8						
UK			1,154	6.0			2,889	8.2
France			910	4.8			20,076	56.7
Japan			563	2.9				
Italy					2,023	15.4		
China					1,313	10.0		
S. Korea					1,098	8.4		
Malaysia					598	4.6		
Switzerland							1,191	3.4
Total	181,228	100,0	19,087	100,0	13,126	100.0	35,387	100.0

Source: ITC, Trademap, 2021.

The increasing trend in the world has also been observed in Turkey's foreign trade. Turkey also imports many MAPs. Data on the import value of MAPs in Turkey are presented in Table 15. It is seen that the import value of the coffee, tea and spices, which was 118 million dollars in 2011, increased approximately 2 times and reached 343,7 million dollars in 2020. The same increasing trend is observed in other product groups of MAPs. Especially the medicinal plants import has increased 3 times since 2011.

Table 15: Import of medicinal and aromatic plants in Turkey ($1,000)

	Coffee, tea, maté and spices	Medicinal plants	Lac; gums, resins, saps and extracts	Essential oils	Total
2011	118,020	4,390	36,700	19,477	178,587
2012	136,177	4,940	38,259	18,048	197,424
2013	175,646	15,336	45,702	19,519	256,203
2014	187,841	15,591	43,905	23,693	271,030
2015	199,779	6,505	39,577	26,727	272,588
2016	215,998	7,623	42,599	27,398	293,618
2017	319,580	9,965	43,861	36,394	409,800
2018	266,302	9,401	51,754	33,546	361,003
2019	333,448	12,503	50,844	32,457	429,252
2020	343,749	12,511	60,005	33,314	449,579
Average	229,654	9,877	45,321	27,057	311,908
Share (%)	73.63	3.17	14.53	8.67	100.00
Change (%)	191.26	184.99	63.50	71.04	151.74

Source: ITC, Trademap, 2021.

The coffee, tea and spices supplying countries with the highest imports are Brazil, Sri Lanka, Syria, the Netherlands, and Vietnam for 2011-2020 period. Albania, India, Turkmenistan, Morocco and Azerbaijan are the leading supplying markets for medicinal plants imported by Turkey. The reason why Albania ranks first in Turkey's imports is that Turkey re-exports the products imported from Albania. It is stated in the report prepared by USAID (2010) that there are no facilities for sterilizing sage in Albania, so that the product exported to Turkey and sterilized there before being re-exported to USA. In lac and extracts imports Germany is the leading country with a share of 19.9% and followed by France, India, China, and Italy. India and

Germany are the main essential oil supplying countries for Turkey; their import share is 30.4%. These countries are followed by France, the USA and Spain (Table 16).

Table 16: The 5 leading countries in Turkish MAP imports (2011-2020)

	Coffee, tea, maté and spices		Medicinal plants		Lac; gums, resins, saps and extracts		Essential oils	
	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%	Value (1000 $)	%
Brazil	108,830	47.4						
Sri Lanka	20,583	9.0						
Syria	12,304	5.4						
Netherlands	11,545	5.0						
Viet Nam	8,336	3.6						
Albania			2,141	21.7				
India			1,126	11.4	4,732	10.4	4,519	16.7
Turkmenistan			1,032	10.4				
Morocco			737	7.5				
Azerbaijan			553	5.6				
Germany					9,009	19.9	3,715	13.7
France					6,704	14.8	2,632	9.7
China					4,726	10.4		
Italy					3,071	6.8		
USA							2,501	9.2
Spain							2427	9.0
Total	229,654	100.0	9,877	100.0	45,321	100.0	27,057	100.0

Source: ITC, Trademap, 2021.

Turkey, which is an important exporter of MAPs, also imports some plant species. Turkey is an importer of coffee, black pepper, ginger, turmeric, ginseng, nutmeg and cinnamon since it is not possible to cultivate these in Turkey. Coffee ranks first among the most imported products. Brazil is the major supplying market for Turkey, followed by the, Colombia, Guatemala and India (ITC, 2021). Being an important source country as a producer and exporter for MAPs, Turkey shows high imports MAPs at the same time. The underlying reason for this is insufficient production in Turkey, more affordable costs of importing countries and the advanced spice processing technologies in our country (Boztaş et al, 2021). These imported products are processed and re-exported. Among the re-exported products is coffee and black pepper with a high share. In addition, it is seen that bay leaves are imported, which is one of our most important export products. The reason for importing bay leaves is that Georgian bay leaf is preferred especially in Europe. Therefore bay leaves are re-export (Boztaş et al, 2021).

Prices allow drawing conclusions on the kind of commodity, their degree of processing, and the socioeconomic situation of the collectors. The leading countries in medicinal plants import and export prices of different countries are assessed for the period 2011-2020. Comparing the average export and import prices for one tonne in selected countries, it can be concluded that consumer countries and countries with huge MAP-processing industries show higher export prices. Another striking fact is that the most important supply countries show lower prices (Figure 12). Low prices indicate that mainly raw plant material is exported, in most cases of wild-collection origin. The benefit is relative low. Consequently, only unemployed or unskilled people or people with low wages are collecting botanicals (Lange, 2006).

Figure 12: Import and export prices of medicinal plants (2020)
Source: ITC, Trademap, 2021.

3 Competitiveness of Turkey in MAPS International Market

Various types of MAPs have been produced as raw materials of both modern and traditional medicine. The large demand of MAPs results in tremendous international trade. For all exporting countries of MAPs, it is important to improve competitiveness of MAPs aimed to hit the export market and also to be able to compete with import products in domestic market (Riptanti et al, 2018). Therefore we examined the competitiveness of MAPs in international market for the leading five exporting countries. We employed the basic comparative advantage method, known as Revealed Comparative advantage (RCA), to examine the competitiveness of MAPs.

In this study, Vollrath index of Revealed Comparative Advantage Index (RCA) index is used. Vollrath (1991) proposed that RCA can be estimated under international competitiveness based on four principal areas under RCA theory which consist of; the relative trade advantage (RTA), revealed comparative advantage index (RCA), the relative export advantage (RXA), and relative import advantage (RMA). Positive values of RXA, RTA, and RCA indicate competitive advantage, while negative values indicate competitive disadvantage. Vollrath's indices can be calculated as follow:

$RXA_{ij}= (X_{ij} / X_{it}) / (X_{nj} / X_{nt})$ Equation (1)

$RMA_{ij}= (M_{ij} / M_{it}) / (M_{nj} / M_{nt})$ Equation (2)

$RTA_{ij}=RXA_{ij}-RMA_{ij}$ Equation (3)

$RCA_{ij}= \ln(RXA_{ij})-\ln(RMA_{ij})$ Equation (4)

where X_{ij} the exports of commodity j, by country i; X_{it} the exports of all commodities, excluding commodity j, by country i; X_{nj} the exports of commodity j, by the rest of the world, excluding country i; X_{nt} the exports of all commodities excluding commodity j, by all countries in the world excluding country i; M_{ij} the imports of commodity j, by country i; M_{it} the imports of all commodities, excluding commodity j, by country i; M_{nj} the imports of commodity j, by the rest of the world; M_{nt} the imports of all commodities, excluding commodity j, by all countries in the world, excluding country i; X the exports; M the imports; n the rest of the commodities; t the rest of the world.

The structure of global market of medicinal and aromatic plants is mostly competitive. In MAPs international market there are large numbers of effective competitors. In other words, none of them has more than 10 percent of the market share. Also major exporters possess nearly 35 percent of the market and other exporters can take this opportunity to enter into the business (Roosta et al, 2017). Roosta et al's results showed that Singapore, Japan, Germany, Malaysia, and the U.S. have the highest importing advantage.

When the exporting advantage of MAPs in the global market is examined, it is seen that the competition in this market is high. Table 17 shows the RCA value for coffee, tea and spices of five major exporting countries during periods of 2011-2020. The mean score of the value of RCA for Brazil, India and Vietnam was above 1 indicating a strong comparative advantage in international markets. Although Germany ranks the third in coffee, tea and spices, it has comparatively low advantage. Likewise Germany, China has a disadvantage in the international markets.

Table 17: RCA Index for Coffee, tea, maté and spices

	Brazil	China	India	Germany	Vietnam	Turkey
2011	12.12	0.39	3.64	0.84	14.38	0.30
2012	9.91	0.37	3.68	0.86	16.00	0.31
2013	9.27	0.44	3.47	0.90	12.43	0.50
2014	11.71	0.41	3.45	0.83	12.83	0.49
2015	11.04	0.38	3.77	0.74	8.44	0.45
2016	9.57	0.47	3.76	0.74	8.99	0.51
2017	7.94	0.44	3.85	0.79	7.32	0.46
2018	8.09	0.53	3.87	0.84	6.67	0.51
2019	8.35	0.55	3.86	0.78	4.85	0.44
2020	8.77	0.53	4.55	0.82	3.86	0.52
Average	9.68	0.45	3.79	0.81	9.58	0.45

Source: WITS Database, 2021.

China heads the world's top countries of medicinal plants export. However, ranking the first does not give a competitive advantage for China. Instead, India has a comparative advantage in medicinal plant market (Table 18).

Table 18: RCA Index for Medicinal plants

	China	India	Canada	Germany	USA	Turkey
2011	2.78	3.95	1.30	0.70	0.66	0.69
2012	2.83	4.66	2.48	0.68	0.57	0.54
2013	2.98	3.40	2.23	0.56	0.59	0.68
2014	2.88	4.00	2.72	0.58	0.55	0.82
2015	2.38	4.68	2.89	0.60	0.49	0.64
2016	2.42	5.02	2.50	0.57	0.54	0.67
2017	2.34	5.45	2.43	0.67	0.61	0.67
2018	2.02	5.83	--	0.75	0.68	0.82
2019	2.10	5.15	--	0.73	0.61	0.79
2020	1.78	6.23	--	0.77	0.61	0.76
Average	2.45	4.84	2.36	0.66	0.59	0.71

Source: WITS Database, 2021.

India maintains its superiority in international markets in the lac, gums, resins, saps and extract market as well. It is clearly seen that India has a competitive advantage among the other major exporting countries (Table 19).

Table 19: RCA Index for Lac; gums, resins, saps and extracts

	India	China	USA	France	Germany	Turkey
2011	18.50	1.27	1.00	0.99	1.07	0.12
2012	33.81	0.72	0.72	0.65	0.67	0.08
2013	19.97	1.14	0.86	0.99	1.02	0.14
2014	17.04	1.31	0.88	1.10	1.06	0.14
2015	10.13	1.41	0.96	1.24	1.18	0.15
2016	7.64	1.43	0.92	1.28	1.19	0.17
2017	8.14	1.45	0.88	2.86	0.86	0.18
2018	7.51	1.40	0.94	2.73	1.13	0.21
2019	6.50	1.40	0.90	2.60	1.17	0.24
2020	5.71	1.37	0.92	3.09	1.23	0.37
Average	13.50	1.29	0.90	1.75	1.06	0.18

Source: WITS Database, 2021.

India also has a comparative advantage in the essential oils international market. But in this market, besides India, Brazil, France and the USA also have the moderate advantage (Table 20).

Table 20: RCA Index for Essential oils

	India	USA	China	France	Brazil	Turkey
2011	8.69	1.59	0.59	2.52	5.16	0.82
2012	12.34	1.57	0.53	2.42	5.02	0.80
2013	10.18	1.51	0.72	2.50	4.12	0.74
2014	7.99	1.46	1.06	2.70	4.33	0.81
2015	7.32	1.35	1.18	2.43	4.65	0.75
2016	7.96	1.49	0.69	2.77	6.44	0.94
2017	8.58	1.52	0.50	2.90	6.45	0.96
2018	8.63	1.56	0.61	2.97	6.10	0.86
2019	12.13	1.55	0.45	2.67	4.41	0.72
2020	9.76	1.81	0.38	3.15	4.15	0.72
Average	9.36	1.54	0.67	2.70	5.08	0.81

Source: WITS Database, 2021.

When overall MAPs market is evaluated, it is seen that India has a strong competitive advantage. India is followed by China, Germany and the USA. Unfortunately, Turkey's competitiveness in MAPs is quite low. The product group it can compete with is the essential oils group. The average RCA index in this group is 0.81. Considering Turkey's production potential, a competitive advantage can be reached in essential oils. In a study, calculating Brülhart indices on a product basis, it was found that Turkey's IIT for MAPs was very low. Also Turkey’s foreign trade has shown differences according to IIT before and after 2012 (Kurt and İmren, 2018).

4 Conclusion

Due to their functional properties, medicinal and aromatic plants are also used in different industrial areas along with their traditional use.

The widespread use of medicinal and aromatic plants has increased with the increase of people's awareness of health, their desire to take precautions against diseases and to create their own treatments. Accordingly, their production and trade has increased both in the world and in Turkey. This has not as yet, however, resulted in substantial benefits to developing countries or particularly benefits to growers and producers.

MAPs are both wild harvested and cultivated in the world as well as in Turkey. It is seen that awareness and interest in the economic, social and environmental benefits and importance of MAPs have increased in the world in recent years. These plants are important in terms of biodiversity, as well as in the protection of wildlife. Especially in small family farming, MAPs have the potential to provide an opportunity for high income.

Turkey is at an important point in terms of surface area, climate and gene centers. Therefore, it has rich endemic plant diversity. MAPs constitute a significant part of this endemic diversity in Turkey. However, in Turkey since MAPs are exported as raw materials, its value added is low. In Turkey, MAPs cleaning, sorting, classification, processing and packaging are done only in spice and herbal tea production. Therefore, processed and standardized MAPs production is insufficient. So, every process to be made on MAPs will increase the MAPs' value added and their exports.

Although Turkey has an important place in world trade in MAPs' exports, her current exports and competitiveness in this market are low. It is not possible to produce MAPs only by collecting. In addition, MAPs, which is important and has economic value, should be cultured. Thus, Turkey's exports and competition in world trade will increase. In order for Turkey to conceive this increase, it is important to produce standardized MAPs that can meet market demands. Here, traceability in is also important. A holistic approach should be adopted for the development of the industry. Also Turkey should develop effective strategies to support improved cultivation, quality controls systems, provision of high quality planting materials, and the encouragement of investments in new technologies. Since most of these plants are wild collected, the protection of nature and sustainability is also important here. The policies and the measures to be implemented should not ignore sustainability. For cultivated and wild harvested MAPs implementing organic agriculture standards along with other international standards is a possibility to consider.

Certification of organic or other standards could strengthen long-term buyer-seller trade relationships and increase income. There may also be an opportunity to link such products to the market for genuine origin or geographical indication products. These measures will also support the quality, traceability and competitiveness of MAPs.

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CHAPTER 2

EFFECT OF SALINITY ON MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL PROPERTIES OF MEDICINAL PLANTS

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1.Introduction

Medicinal plants

Since ancient times, medicinal plants have been widely used in countries such as India, Pakistan, China, Thailand, Japan, Sri Lanka and Nepal (Imadi et al., 2016). It has been used as medicine since prehistoric times including many herbs and spices used today. Medicinal and aromatic plants are grown for different parts and their active ingredients are evaluated in various ways especially in the pharmaceutical industry. In developing some countries, antibiotics are still used for herbal treatment today as they are expensive (Mondal and Kaur, 2017).

Salinity

Salinity is the most important abiotic stress, which causes osmotic pressure leading to cell dehydration, accumulation or reduction of secondary metabolites, and affects agricultural productivity, especially in arid and semi-arid areas. Secondary metabolites include terpenoids, flavonoids, alkaloids, steroids and phenolics that function in plant defense against salt stress (Jan et al., 2021). These conditions adversely affect seed germination, seed viability, plant growth, yield, morphological and physiological properties such as photosynthesis and respiration, total carbohydrate, fatty acid and protein content, but amino acid, especially proline content increases.

Although the effects of salt stress on many plants such as wheat, corn, cotton, barley and rice have been studied intensively, there is still a lack of information on medicinal and aromatic plants (Mondal and Kaur, 2017). The growth and development of medicinal and aromatic plants are adversely influenced by salinization in soil and water, therefore it plays a significant role in the geographical distribution of medicinal plants. The negative effects of salt stress on the yield of medicinal plants are increasing day by day due to the increasing salinity of soils. Besides, while salinity causes a decrease in production, it also affects the physicochemical properties of the soil and the ecological balance of the region (Mondal and Kaur, 2017; Mohammadi et al., 2020).

Osmotic stress occurs when there is an excessive amount of soluble salt in the soil and this causes the death of plants (Mondal and Kaur, 2017).

Effects of salinity stress on medicinal plants

When the increase in the salt concentration in the soil, the germination one of the most salt sensitive growth stages, is adversely affected. Due to the salt in the environment, the osmotic potential of the plants decreases and water uptake required for the mobilization of nutrients slows down, thus affecting seed germination or salt ions become toxic to embryonic growth (Mondal and Kaur, 2017).

Increased salt stress causes a decrease in germination percentage, plumule length, radicle length and seed vigor in *Thymus kotschyanus* and *Thymus daenensis* plants (Bagheri et al., 2012). It has been observed that increasing doses of salt applications results decreases the germination rate and Kadioğlu (2021) reported that one of the best examples of this is *Salvia nemorosa* L. In *Plantago ovata* and *Caryophyllus aromaticus* germination was inhibited at high salt levels, while *Cucurbita pepo* was unaffected. NaCl application caused a serious decrease in early seedling growth by reducing root and shoot length at higher salinity levels (Bina and Bostani, 2017).

Salt stress negatively affected the growth of *Foeniculum vulgare* subsp. vulgare (Abd El-Wahab, 2006), *Majorana hortensis* (Shalan et al., 2006), *Matricaria recutita* (Baghalian et al., 2008), *Thymus vulgaris* (Najafian et al., 2009), *Salvia officinalis* (Ben Taarit et al. 2009), *Mentha pulegium* (Queslati et al., 2010) and *Chamomilla recutita* (Ghanavati and Sengul 2010).

Root growth, number of leaves and dry matter content (Moghbeli et al., 2012) decreased in *Aloe vera* plant exposed to salinity conditions and the number of tillers in *Citronella java* plant (Chauhan and Kumar, 2014).

It was observed that 6 dS/m salt application to *Melissa officinalis* caused the death of plants (Öztürk et al., 2004). The growth of *Lepidium sativum* L., *Linum usitatissimum* L., *Nigella sativa* L., *Plantago ovate* Forssk and *Trigonella foenum-graecum* L. plants decreased due to salinity (Muhammad and Hussain, 2010).

The plant is significantly affected by salinity stress during the maturation period and serious decreases in yield are detected. Salinity significantly reduced umbel number, fruit yield and 1000 seed weight in *Foeniculum vulgare* and *Cuminum cyminum* plants (Nabizadeh, 2002; Abd El-Wahab, 2006).

In *Mentha piperita*, leaf number, leaf area and leaf biomass (Ta batabaie and Nazari, 2007) and in *Satureja hortensis*, leaf area, leaf and stem fresh weight and dry weight decreased under salt stress conditions (Najafi et al., 2010). Salt stress adversely affected biomass production in *Cyanoposisa tetragonoloba* (Ullah et al., 2018), *Ocimum basilicum* (Ullah et al., 2019) and *Cymbopogon citratus* (Ullah et al., 2020). In moderately salt-tolerant *Ammi majus* plants salt stress caused significant reductions in both the fresh and dry weight of roots and shoots as well as seed yield (Ashraf et al., 2004).

Salinity conditions, dry matter production in *Thymus vulgaris* and *Thymus daenensis* species, K^+ and Ca^{2+} content in shoots and leaves decreased with salt stress. On the other hand, flavonoid and cinnamic acid values increased. Salt stress significantly reduced the yield of thyme species and improved the amount of phenolic compounds and antioxidant capacity (Bistgani et al., 2019). Arid conditions combined with salt stress reduced the germination rate of *Nigella sativa* L. seeds (Nezamivand Chegini et al., 2021).

Salinity affects photosynthesis in plants mainly due to the decrease in leaf area, chlorophyll content and stomatal conductivity. To a lesser extent, a decrease in photosystem II activity occurs (Netondo et al., 2004).

Germination, seedling growth, chlorophyll content, glutathione and alphatocopherol were adversely affected under salt conditions in *Withania somnifera* plant (Jaleel et al., 2008 b). NaCl applied to *Echinacea angustifolia* decreased stomatal conductivity, photosynthesis and transpiration rate (Sabra et al., 2012). In *Capsicum annumm L.* photosynthetic pigments decreased and water use efficiency increased with the increase in salt stress. 1 dS m^{-1} saline application increased photosynthesis, transpiration rate, stomatal conductivity, and intracellular CO_2 rate (de Melo et al., 2017).

Jaffel-Hamza et al. (2013) emphasized that salt decreases growth, seed yield and total fatty acid while increasing lipid peroxidation in *Borago officinalis* L. In *Carum copticum* plant (Davazdah Emami and Mazaheri, 2009) and *Rosmarinus officinalis* (Dehghani Bidgoli et al., 2019) EO percentages decreased significantly with increasing salinity. In another study it was observed that salt stress reduced the fresh and dry weight and leaf/stem ratio of *Rosmarinus oficinalis* L. (Piri et al., 2017).

In *Satureja hortensis*, saline conditions caused a decrease in shoot dry weight, potassium content and photosynthetic pigments, while malondialdehyde, hydrogen peroxide, proline and sodium content increased in shoots (Mohammadi et al., 2019).

Salt stress decreased the fresh and dry weight, germination rate, ascorbate content, and increased the hydrogen peroxide and proline in *Cassia angustifolia* (Agarwal and Pandey, 2004). At 160 mM salt concentration, the content of artemisinin in *Artemisia annua* (Qureshi et al., 2005) and ajmalisin in *Catharanthus roseus* were decreased under 100 mM NaCl conditions (Jaleel et al., 2008 a).

In *Trachyspermum ammi* EO yield (Ashraf and Orooj, 2006) and in Bacopa monnieri, bacoside-A content and yield decreased significantly (Bharti et al., 2013) exposed to salt stress. Significant biochemical changes (amino acids, amides, proteins, quaternary ammonium compounds (betaines) and polyamines) occur with the accumulation of osmoregulatory nitrogen-containing compounds in plants exposed to salt (Rabie and Almadini, 2005). With increasing salinity, proline content raised in *Echium amoenum* (Ramezani et al., 2011), *Chamomilla recutita* and *Origanum majorana* (Ali et al., 2007). Phenolic compounds in *Nigella sativa* (Bourgou et al., 2010), *Matricaria chamomilla* (Cik et al., 2009), *Mentha pulegium* (Queslati et al., 2010) and *Achillea fragratissima* (Abd EL-Azim and Ahmed, 2009) has increased significantly under salt conditions. *Ginko biloba* female seedlings treated with 40 mmol dm^{-3} NaCl showed higher photosynthesis rate and water use efficiency and lower transpiration compared to male seedlings (Jiang et al., 2010). Salt also disrupted the carbohydrate balance in *Foeniculum vulgare* in another study (Abd El-Wahab, 2006).

Salinity adversely affected the morphological characteristics of *Andrographis paniculate* as well as relative growth rate, moisture content and salt tolerance index. Total protein content was significantly affected at the highest salt dose (Hossain, 2016). Salt stress reduced the amount of EO in *Trachyspermum ammi*, *Foenicum vulgare* (Abd El-Wahab, 2006; Ashraf and Orooj, 2006), *Mentha suaveolens* Ehrh (Aziz et al., 2008) and *Origanum majorana* (Baatour et al., 2010). Some researchers emphasized that EO increases with salt in *Satureja hortensis* (Baher et al., 2002), *Salvia officinalis* L. (Hendawy and Khalid, 2005), *Thymus vulgaris* L. (Ezz El-Din et al., 2009). The total amount of fatty acids in *Coriandrum sativum* leaves also decreased significantly due to salt stress (Neffati and Marzouk, 2008). Salt conditions increased the total amount of free amino acids in *Catharanthus roseus* (Osman et al., 2007) and *Matricaria chamomilla* (Cik et al., 2009). This increase resulting from salt stress is due to the degradation of intact proteins (Roychoudhury et al., 2015). Against all these adverse conditions, the plant develops a tolerance mechanism (Said-Al Ahl and Omer, 2011; Kadıoğlu, 2021) and accumulates a large number of secondary metabolites (Deshmukh and Khare, 2017; Bhattacharyya et al., 2020).

2. Conclusion

Among the abiotic stress factors, especially salinity and drought, have the highest effect on medicinal plants (Heidari et al., 2008). The root under control conditions ensures the intake of water and nutrients from the soil throughout the plant's entire life. However, it differs due to changes in structure and functions as a result of exposure of roots to stress conditions. Along with salt stress, roots cannot get enough water, where high salt accumulation and osmotic pressure occur (Jan et al., 2021). Salinity affects the growth, development, yield and quality of medicinal plants by causing physiological and metabolic problems. Finally, while it has a negative effect on photosynthesis, respiration, carbohydrate, fatty acid and protein content in the plant, the amount of proline and secondary metabolites increases significantly.

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CHAPTER 3

MEDICINAL PLANTS WITH ANTIOXIDANT ACTIVITIES

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* This chapter is part of a publicly defended MSc. Thesis of Diren Kaçar.

INTRODUCTION

There is an increasing interest in using medicinal and aromatic plants as natural sources in pharmaceutical, food and cosmetic industries all over the world. Bioactive compounds of medicinal plants led them to be used in these industries as botanical drugs, dietary supplements, functional foods and food packaging, etc. Plants also have been used in ethnopharmacy for various diseases such as hypertension, cholesterol, eczema and diarrhoea for centuries and today their scientific validation was provided by identification and isolation of bioactive phytochemicals (Littleton et al., 2005). Phytochemicals are the secondary metabolites that have several subgroups possessing various bioactivities such as antioxidant, antimicrobial, antivirus, anticancer, etc., (Duffy and Power, 2001). Nowadays re-emerging connection between plants and human health especially depends on their antioxidant activities that may delay or reduce the hazardous effects of free radicals. The major causative for the generation of free radicals in food, drugs, and living systems is the oxidation process (Pourmorad et al., 2006). Free radicals and other reactive oxygen species (O2•- , H2O2 , OH•-) are released continously during the essential aerobic metabolism as metabolic by-products which are potentially producing damage on biomolecules such as membrane lipids, cellular proteins and DNA which leads to cell death and several diseases (Antolovich et al., 2002). Most common radical related diseases are atherosclerosis, arthritis, diabetes, cancer and neurodegenerative diseases (Parkinson, Alzheimer and Huntington’s disease) and also aging (Pourmorad et al., 2006). Living systems have their own cellular defense systems including some enzymatic and nonenzymatic systems which protect the functional and structural molecules that are the targets of free radicals (Prior et al., 2005). They are able to keep the system in the state of equilibrium by controlling the harmful effects of free radicals under normal physiological conditions, but in some cases the equilibrium may be disturbed by some factors that induce the formation of free radicals such as environmental pollutants, radiation, chemicals, physical stress and also some endogenous sources including some enzymes and immune system products (Serafini, 2006). Oxidative stress occurs as a result of an overproduction and accumulation of highly reactive compounds (Antolovich et al., 2002). Dietary antioxidants are the supplements that may delay or reduce the effects of oxidative stress and phenolic compounds are the phytochemicals that are widely present in the plant kingdom exhibiting several bioactivities (King and Young, 1999) and can be classified in natural antioxidants that take an important place in our diet which absorb and neutralize free radicals by donating an hydrogen atom from their hydroxyl groups (Boskou et al., 2006).

Infectious diseases are the primarily threat that account for death worldwide. In the last decades, the clinical efficacy of many synthetic antibiotics is being threated by the emergence of a serious problem which can be defined as multi- drug resistant pathogens (Eldeen et al., 2005). Multi- drug resistance in both human and plant pathogenic microorganisms has developed due to the indiscriminate usage of commercial antimicrobial drugs that have widely applied in the treatment of infectious diseases. Therefore scientists have tried to discover new antimicrobial substances from various sources including plants. It is known that, now natural products and their derivatives hold more than 50% of all the drugs in clinical usage with one quarter originating from higher plants (Eldeen et al., 2005).

Turkey has one of the greatest floras in Europe due to its various numbers of plants also including many endemics (Cetin and Yanikoglu, 2006). In this chapter scientific evaluation and ethno-botanical use of some Turkish medicinal plants are summarized. Classification of phytochemicals, common phtytochemical constituents in plants and their extraction studies are discussed. Antioxidant activity of phytochemicals and widely used measurement methods for the determination of antioxidant capacity are given.

1. MEDICINAL PLANTS

“ Let your food be your first medicine” (Hippocrates, 377 BC) was probably the first time that the link was made between nutrition and well-being which emphasizes the importance of functional foods (Carbone, 2005). In addition, the practice of medicinal plants is very well known for treating the diseases from ancient times. Even today because of the belief that medicinal plants are safe and effective most of the plant products are being used in local traditional systems of medicine (Dhawan, 2003). In developing countries, a report of WHO survey indicates that 80% of the populations rely on mostly traditional medicine for their primary health care needs (Goyal et al., 2007).

Besides, scientific validations of medicinal plants have been ensured by various phytopharmacological studies which evaluate active plant constituents. So today, plants are the important raw materials for pharmacological research and drug developing (Mendonça, 2006), and they are also being increasingly used as the complementary or alternative medicine in industrialized countries.

Medicinal plants have considerable importance in international trade and their clinical, pharmaceutical, and economic value is still growing, although this varies widely between countries. Based on current research and financial investments, medicinal plants will, seemingly, continue to play an important role as a health aid. Use of herbal medicines in Asia represents a long history with several applications against various diseases (Draipandiyan et al., 2006). The practice of traditional medicine is widespread in China, India, Japan, Pakistan, Sri Lanka and Thailand. The countries of the region such as China (30,000 species of higher plants), Indonesia (20,000), India (17,000), Myanmar (14,000), Malaysia (12,000) and Thailand (12,000) have large floras (Ics-Unido, 2006). In China about 40% of the total medicinal consumption depends on traditional medicines. In Thailand, herbal medicines make use of legumes encountered in the Caesalpiniaceae, the Fabaceae, and the Mimosaceae.

The use of medicinal plants like Eupatorium perfoliatum in Central America medicinal plants have been widely used (Hoareau et al., 1999).

However, among the estimated 250,000-400,000 plant species, only 6% have been studied for biological activity, and about 15% have been investigated phytochemically . This shows a need for phyto-pharmacological evaluation of herbal drugs (Goyal et al., 2007). A vast knowledge of how to use the plants against different illnesses may be taken on a shape in the regions where the use of plants is still of great importance. The medicinal value of plants lies in some chemical substances that produce a definite physiological action on the human body. These phytochemicals are the active constituents that exhibit some biolological activities concerning antioxidant, antimicrobial, antiinflammatory, and anticancer activities, ext. Exploration of the chemical constituents of the plants and pharmacological screening is of great importance which leads for development of novel agents (Goyal et al., 2007). The most important phytochemicals are alkaloids, flavanoids, tannins and some other phenolic compounds which are abundantly found in plants (Draipandiyan et al., 2006).

Medicinal plants were the main source of products used to maintain well-being until the nineteenth century, when the German chemist Friedrich Wöhler in 1828, attempting to prepare ammonium cyanate from silver cyanide and ammonium chloride, accidentally synthesized urea. This was the first organic synthesis in history and revealed a new area of the synthetic compounds (Mendonça, 2006). Today, herbal remedies are back into prominence because of the ineffectiveness of conventional medicines such as antibiotics. The history of modern psychopharmacology is short, and its current concepts are more "pharmaco-centric" than those of most other branches of modern medicine (Husain et al., 2007). In more recent history, the use of plants as medicines has involved the isolation of active compounds, beginning with the isolation of morphine from opium in the 19th century. Drug discovery from medicinal plants led to isolation of early drugs such as cocaine, codeine, digitoxin, and quinine, in addition to morphine, of which some are still in use (Balunas and Kinghorn, 2005). In addition some synthetic medicines have been derived from medicinal herbs are digioxin, aspirin, reserpine, ephedrine, quinine, vincristine, vinblastine, taxol, artemisinin, hypericin and silymarin (Singh, 2006).

Rediscovery of the connection between plants and health is responsible for launching a new generation of botanical therapeutics that include plant-derived pharmaceuticals, multicomponent botanical drugs, dietary supplements, and functional foods. Many of these products will soon complement conventional pharmaceuticals in the treatment, prevention and diagnosis of diseases, while at the same time adding value to agriculture (Raskin, et al., 2002). Today, many plant derived products are being consumed commercially in a rising rate.

1.1. Turkish Medicinal Plants

Turkey is very rich in medical and aromatic plants with its large floristic diversity. The estimated number for Turkish flora is 11,000 for specific, and infraspecific taxa of higer plants including 3000 endemic species. Turkey contains 347 species that have commercial values and about 30,000 tons of plants are being exported annually. In Anatolia plants have been commonly used as the source of food, remedy, animal fodder, tinder and some utensils from time immemorial. Although the ethnobotanical experience is being lost with the modernization of society, in some rural areas, people still use traditional medicine for health care (Satıl et al., 2008, Coskun et al., 2005). Some important plant species and their ethnobotanical use are shown in Table 1.

Table. 1. Ethnobotanical use of some Turkish plants (Source: Sezik et al., 2001, Tuzlacı and Erol, 1999, Tuzlacı and Aymaz, 2001)

Plant species	**Ethnobotanical use**
Hypericum perforatum, *Urtica dioica*, *Thymus longicaulis*, *Salvia tomentosa*	Mostly used for the treatment of haemorrhoid, rheumatism, stomach and kidney ailments.
Juniperus oxycedrus	Cold, stomachache
Origanum onites	Stomachache
Teucrium chamaedrys	Goiter
Pictacia terebinthus L. *ssp.*	Diabetes mellitus, decoction, as tea
Alkanna cappadocica	Wound healing, red-colored barks are roasted in butter to obtain ointment and applied on wounds

Brassica oleracea L. *var. capitata*	Ulcer; fresh leaves are ingested
Juniperus oxycedrus L. *ssp.*	Bronchitis;
Quercus libani Olivier	Hemorrhoids
Hypericum perforatum	Wound healing; stomach ache, colitis, intestinal disorders
Allium cepa L.	Abscess, gastric ulcers
Allium sativum L.	Sunstroke, hemorrhoids, as hypotensive
Urtica dioica L.	Abscess, rheumatic pain, eczema
Teucrium polium L.	Common cold, antipyretic; decoction, as tea for rheumatic pain

Today, developing phytopharmacological industry leads to the examination of some medicinal species for their biological activities in the laboratories and these studies mostly confirm therapeutical usage in ethnopharmacy of some species. Table 2 summarizes some of the Turkish species examined for their activities and phytochemical groups.

Table 2. Scientific evaluation of some Turkish medicinal plants

Scientific name	Findings of the studies	References
Arbutus unedo	A phytochemical study of the petroleum ether and ethyl acetate extracts of the entire plant of *Arbutus unedo* led to the isolation of a new sterol,	Carcache et al., 2006
Arbutus unedo	Quercitrin, isoquercitrin, hyperoside and rutin were identified in all leaf samples by means of thin-layer chromatography; the fruits contained only isoquercitrin	Males et al., 2006
Cistus genus	Flavonoids (quercetin-3-O-methyl ether) was found to be as potent against diabet	Coşkun and Özkan, 2005

Capparis sinosa	The methanolic extract of the aerial parts of *Capparis spinosa* yielded the new flavonoid quercetin 3-*O*- w690-a-L-rhamnosyl-60-b-D-glucosylx-b-D-glucoside.	Sharaf et al., 2004
Hypericum empetrifolium	Antioxidant activity and total phenol assays were performed for three hypericum species. *Hypericum empetrifolium* exhibited the highest values for both experiments.	Meral et al., 2004
Lavandula stoechas	Lavender had effective reductive potential, free radical scavenging, superoxide anion radical scavenging, and metal chelating activities at all tested concentrations.	Gülçin et al., 2004
Pistacia lentiscus	A quantitative determination of a-tocopherol in *Pistacia lentiscus, Pistacia lentiscus* var. chia, and *Pistacia terebinthus,* leaves was established by TLC- densitometry and colorimetry. The highest amount of a-tocopherol was found in *P. lentiscus* var. chia.	Kıvçak and Akay, 2005
Pistacia lentiscus	Total phenol content was determined in a comparison study	Stocker et al., 2004
Pistacia terebinthus	the most active three fractions in DPPH assay were purified from P.terebinthus to afford a new flavone 60-hydroxyhypolaetin 30-methyl ether .	Topçu et al., 2007
Pistacia terebinthus	It has a noticable antioxidant activity particularly in the protection of human LDL from oxidation . However the phytopharmacology and phytochemistry of this plant is not known.	Kıvçak and Akay, 2005
Quercus infectoria	Quercus infectoria is rich in phenolic acids, flavonoid glycosides, and phenolic volatile oils.	Surveswaran et al., 2007
Solanum nigrum	Antioxidant and total phenol content was determined in a comparison study of 133 Indian plants	Surveswaran et al., 2007

Teucrium chamaedrys	Strong inhibitory activity was shown by *T. montanum* and *T. chamaedrys* extracts.	Panovska et al., 2005
Teucrium polium	Tyrosol, caffeic acid, ferulic acid and lutein were identified.	Proestos et al., 2006
Teucrium polium	Flavanoid and total phenol contents were determined.	Djeridane et al., 2006
Urtica dioica	*Urtica dioica* had powerful antioxidant activity when compared with standard antioxidants	Gülçin et al., 2004
Urtica dioica	Flavvonoid content and total phenol content were identified with some other Greek plants	Proestos et al., 2006
Vitex agnus-castus	Dopaminergic compounds present in *Vitex agnus castus* are clinically the important compounds which improve premenstrual mastodynia and possibly also other symptoms of the premenstrual syndrome.	Wuttke et al., 2003

2. PHYTOCHEMICALS

The "phyto-" of the word phytochemicals is derived from the Greek word *phyto*, which means plant. Therefore, phytochemicals can be defined as plant chemicals. Phytochemicals are bioactive plant compounds in fruits, vegetables, grains, and other plant foods that play a role of reducing the risk of major chronic diseases. It is estimated that 5000 individual phytochemicals have been identified in fruits, vegetables, and grains, but a large percentage still remain unknown and need to be identified before we can fully understand the health benefits of phytochemicals in whole foods (Liu, 2004). There are apparent evidences that bioactive compounds will reduce the risk of many diseases, including chronic diseases such as cardiovascular disease. One example of how bioactive compounds that show how they modify disease risk is illustrated by the large difference in absolute coronary disease mortality rates at a given total cholesterol level observed in the 25-year follow-up of the Seven Countries Study (Kris-Etherton et al., 2004). Epidemiological studies have consistently shown that a high dietary intake of fruits and vegetables as well as whole grains is strongly associated with reduced risk of developing chronic diseases, such as cancer and cardiovascular disease, which are the top 2 causes of death in the United (Liu, 2004). Identifying bioactive compounds and seeking their health effects are active areas of scientific surveys. Because of the great number of bioactive compounds and the diversity of likely biological effects, numerous and diverse experimental approaches must be taken to increase our understanding of the biological activities of bioactive compounds. Recognizing the complexity of this biology, sophisticated experimental designs and analytical methodologies must be employed to advance the field. The discovery of novel health effects of bioactive compounds will provide the scientific basis for future efforts to use biotechnology to modify and fortify foods and food components as a means to improve public health (Kris-Etherton et al., 2004).

Phytochemicals can be classified as carotenoids, phenolics, alkaloids, nitrogen- containing compounds, and organosulfur compounds. The most studied of the phytochemicals are the phenolics and carotenoids (Liu, 2004). These groups have also several subgroups. For example, phenolics can be phenolic acids, stilbenes, flavonoids, coumarins, tannins. Flavonoids can again be divided into subgroups such as, flavanols, flavanes, catechins, flavanones, anthocyanidins and isoflavanoids.

2.1. Phenolic Constituents in Plants

Among the various phytochemicals as the secondary metabolites of plants, phenolic compounds are the common ones and frequently present in the plant kingdom. Phenolic constituents exhibit several bioactivities such as antimicrobial, antioxidant, antiviral, antiinflammatory. Dietary phenolics that have being researched deeply in the last decades are divided into various subgroups and the major categories of phenolic compounds are flavonoids, phenolic acids, and tannins (King and Young, 1999). Some of the other types of phenolics are coumarins, lignans, quinones, and stilbenes (Chai et al., 2004).

2.1.1. Flavonoids

Flavonoids are the most important and most studied phenolic phytochemicals that are widely distributed in plants (Chai et al., 2004). More than 6,400 flavonoid structures were determined in the performed studies (Silva et al., 2006). Generally they include particular hydroxyl groups with the constitution of ring structures. They have a basic carbon skeleton ($C_6 + C_3 + C_6$). Flavonoids are consist of several subclasses such as; flavones, flavonols, flavanones, flavanonols, chalcones, isoflavonoids, anthocyanins, biflavonoids (Chai et al., 2004). Flavonoids are basically divided into two groups; anthocyanins and anthoxanthins. Anthocyanins have some colour pigments such as red, blue, and purple. Anthoxanthins possess colorless or white to yellow molecules (flavonols, flavones, isoflavones) (King and Young, 1999).

Differences in the generic structure of the heterocycle C ring classify them as flavonols, flavones, flavanols (catechins), flavanones, anthocyanidins, and isoflavonoids. Flavonols (quercetin, kaempferol, and myricetin), flavones (luteolin and apigenin), flavanols (catechin, epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate), flavanones (naringenin), anthocyanidins, and isoflavonoids (genistein) are common flavonoids in the diet (Liu, 2004).

Flavonoids generally exist as glycosides, nevertheless some of them are found as aglycones. There is an insufficient knowledge about metabolism, extraction and absorption of dietary polyphenols in humans and recovery in the gastrointestinal surface. Furthermore, the hydrolysis of flavonoid glycosides and the reductive metabolism are performed by intestinal microorganisms (Rice-Evans et al., 1997).

2.1.2. Phenolic acids:

Phenolic acids form another large class of phenolic compounds. Phenolic acids contain two main groups; (1) *Hydroxybenzoic acids* (e.g. gallic acid, *p*-hydroxybenzoic acid, protocatechuic acids, vanillic acids), (2) *Hydroxycinnamic acids* (e.g. ferulic acid, caffeic acid, coumaric acid, chlorogenic acids, cinnamic acids).

2.1.3. Tannins

Phenolic polymers, commonly known as tannins and they are divided into two general classes: (1) *Hydrolyzable tannins* : They include a central core of polyhydric alcohol such as glucose and hydroxyl groups. They are esterified partially or wholly by gallic acid (gallotannins) or hexahydroxy-diphenic acid (ellagitannins). (2) *Condensed tannins*: They are more common and have more complex structures then the hydrolyzable tannins. They consist of oligomers and polymers of catechins. In some cases hydrolyzable and condensed tannins are present together in plants, so this kind of tannins can be defined as *complex tannins* (Chai et al., 2004).

Polyphenolic phytochemicals are ubiquitous in plants, in which they function in various protective roles. A recommended human diet contains significant quantities of polyphenolics, as they have long been assumed to be antioxidants that scavenge excessive, damaging, free radicals arising from normal metabolic processes (Stevenson et al., 2007). Structural diversity of polyphenolics are a diverse class of plant secondary metabolites. They are characterised structural by the presence of one or more six-carbon aromatic rings and two or more phenolic (i.e.., linked directly to the aromatic ring) hydroxyl groups. Strictly speaking, mono-phenols such as p-coumaric acid are not polyphenolics , but they share many of their properties and characteristics and are most usefully considered as functional polyphenolics (Stevenson et al., 2007).

3. EXTRACTION

The pharmaceutical definition of extraction may be expressed as the separation of medicinally active portion from plant or animal tissues using selective solvents through standard extraction procedures. Primarily criteria of extraction techniques is separating the soluble and insoluble components and leaving behind only insoluble cellular marc. The extraction products of plants have relatively complex mixtures covering a number of groups of plant metabolites either in liquid form or semi-solid state or after removing the solvent resulting in dried powdered extract. Obtaining the therapeutically desired portion of the plant material and the elimination of unwanted material by treatment with a selective solvent is the main purpose of a standardized extraction procedure for medicinal plants. An extract may be further processed through various techniques of fractionation to isolate individual chemical entities such as vincristine, vinblastine, hyoscyamine, hyoscine, pilocarpine, forskolin, codeine, etc., to be used as modern drugs (Ics-Unido, 2006). Extraction and characterization of several active phyto-compounds from these green factories have given birth to some high activity profile drugs (Mandal et al., 2007).

The choice of extraction method, can have an effect on the efficacy of active plant constituents (Shaalan et al., 2005). The general techniques of extraction of medicinal plants include maceration, infusion, percolation, digestion, decoction, hot continuous extraction (soxhlet), aqueous-alcoholic extraction by fermentation, counter current extraction, microwave assisted extraction, ultrasound extraction (sonication), supercritical fluid extraction (SFE), phytonic extraction (with hydro-flouro-carbon solvents), etc. For the aromatic plants, three types of hydro-distillation techniques (water distillation, steam distillation, steam and water distillation), hydrolytic maceration followed by distillation technique, expression method and enfleurage method (cold fat extraction) may be employed. Some of the latest methods of extraction for aromatic plants include head space trapping technique, solid phase micro-extraction, protoplast extraction technique, micro-distillation, thermo-micro-distillation, and molecular distillation techniques (Ics-Unido, 2006). Novel extraction methods including microwave assisted extraction, supercritical fluid extraction, pressurized solvent extraction have drawn significant research attention in the last decade (Shaalan et al., 2005). In recent years, the use of microwave for extraction of constituents from plant material has shown tremendous research interest and potential. Conventional techniques for the extraction of active constituents are time and solvent consuming, thermally unsafe and the analysis of numerous constituents in plant material is limited by the extraction step (Shaalan et al., 2005).

The extraction of essential oil components using solvent at high pressure, or supercritical fluids (SCF), has received much attention in the past several years, especially in food, pharmaceutical and cosmetic industries, because it presents an alternative for conventional processes such as organic solvent extraction and steam distillation

(Xiao et al., 2007). There is also a technique called enzyme assisted extraction. The mechanism for enzyme-assisted extraction is that cell wall degrading enzymes (i.e., glucanases and pectinases) can weaken or break down the cell wall rendering the intracellular materials more accessible for extraction (Li et al., 2006).

Many valuable natural materials have traditionally been extracted with organic solvents. However, some of the organic solvents are believed to be toxic, and the extraction conditions are often harsh. A simple method using ethanol (a food-grade solvent) instead of methanol for the extraction of phenolic compounds is the preference frequently in the literature (see Table 3) (Li et al., 2006). The traditional techniques of solvent extraction of plant materials are mostly based on the correct choice of solvents and the use of heat or/and agitation to increase the solubility of the desired compounds and improve the mass transfer. Usually the traditional technique requires longer extraction time thus running a severe risk of thermal degradation for most of the phyto-constituents (Mandal et al., 2007). Thus the basic parameters influencing the quality of an extract are: a) the plant part used as starting material, b) the solvent used for extraction, c) the manufacturing process (extraction technology) used with the type of equipment employed, and d) crude-drug: extract ratio (crude drug: extract). The use of the appropriate extraction technology, plant material (nature of the plant material, its origin, degree of processing, moisture content, particle size), manufacturing equipment (type of extraction, filling height, hydrostatic pressure, batch size), extraction method (type of extraction, time of extraction, flow velocity, temperature and pressure) and the solvent (nature of solvent, its concentration and polarity) and good manufacturing practices, will certainly produce good desired quality of extract. From laboratory scale to pilot scale, all the conditions and parameters, if properly and accurately recorded, one can employ process simulation for successful industrial scale production (Ics-Unido, 2006). In Table 3 the basic parameters such as solvent type and concentration, solid liquid ratio and extraction time that have been applied in several studies were summarized. The studies in Table 3 cover the screening of some medicinal plants for their antioxidant and antimicrobial properties. It is nearly imposible to optimize extraction parameters for each plant material in screening studies that includes great numbers of plant species. So for screening studies generally a standardized extraction procedure is applied for all samples. Table 3 indicates for commonly used parameters in extraction of screening plants. Mostly ethanol and methanol in various concentrations of water are used as solvent in these studies. But ethanol is more advisable because it is much safer than methanol which has high toxic effects. The solid-liquid ratio is another important parameter in extraction of plant materials and studies indicate that mostly 1/10-50 ratios are used in screening studies.

Table 3. Comparison of performed studies related with extraction of phytochemicals

solvent type	solid-liquid ratio (g/ml)	extr. time (min.)	references
methanol	1/3	30	Mosaddik et al., 2004
methanol	1/20	NA	Chanwitheesuk et al., 2005
1-)methanol 2-)water+cloroform	NA	180	Tepe et al., 2006
1)water 2)ethanol	1/20	1-15	Gülçin et al., 2003
1-)70% acetone 2-)methanol	1-)1/8 2-)1/5	NA	Neergheen et al., 2005
70% methanol	NA	180	Lee et al., 2003
80% ethanol	NA	120	Mantle et al., 2000
aqueous extraction	1/20	10	Vanderjagt et al., 2002
aqueous extraction	1/10	15	Ljubuncic et al., 2005
1-)water 2-)60% ethanol	1/8	30	Duffy and Power, 2001
1-)methanol 2-)water+chlaroform	NA	360	Sökmen et al., 1999
1-)methanol 2-)chlaroform	1/10	360	Matkowski et al., 2006
70% ethanol	1/50	1440	Djeridane et al., 2006
methanol	1/10	2880	Pourmorad et al., 2006
80% ethanol	1/10	NA	Boskou et al., 2006

1-) 90% ethanol			
2-)water	NA	NA	Auddy et al., 2003
water	3/200	30	Katalinic et al., 2006

4. FREE RADICALS

Oxidation process is the major occurrence that gives rise to free radical formation in food, drugs, and living systems (Pourmorad et al., 2006). Free radicals and other reactive oxygen species (ROS) are released continously during the essential aerobic metabolism as unwanted metabolic by-products (Mantle et al., 2000). Structurally unstable free radicals has been defined as a molecular entitiy which retain an unpaired electron and that's the reason of free radicals are mentioned as highly reactive (Madhavi et al., 1996).

Several facts contribute the formation of free radicals such as environmental pollutants, radiation, chemicals, toxins, deep fried and spicy foods, also physical stress leading to depletion of immune system antioxidants, modifications in gene expression and proteins (Pourmorad et al., 2006). That's why the free radicals are among the common intracellular DNA modifiers (Ramos et al., 2003).

Superoxide radical ($O_2^{-\bullet}$), hydroxyl radical ($^{\bullet}OH$) and non-free radical species such as H_2O_2 and singlet oxygen ($^1O_2$) are generated during the oxidative stress and accelerate more than one hundred disorders in humans. Most common radical related diseases are atherosclerosis, arthritis, diabetes, ischemia, central nervous system injury, cancer, AIDS, inflamentation and aging (Pourmorad et al., 2006, VanderJagt et al., 2002, Chanwitheesuk et al., 2005, Chai et al., 2002). The most reactive forms of active oxygen species are $HO^{\bullet}$ and $^1O_2$.

Comparison of the reactivity: $HO^{\bullet}$ and $^1O_2 > O_2^{\bullet -} > H_2O_2$

Primary factors that contributing prooxidant states in the initiation of chain reactions (Madhavi et al., 1996): hyperbaric oxygen tension, radiation, reagents, electron transport chain, inhibition of antioxidant defence system.

4.1. Free Radical Chain Reactions

Lipid oxidation process causes complex free radical chain reactions releasing various radicals (Maisuthisakul et al., 2007). Peroxyradicals and hydroperoxides are the initiators of this chain reaction introduced when unstable free radicals react with molecular oxygen. Free radical chain reaction termed as autoxidation is distinguished in three distinct steps: initiation, propagation and termination.

Initiation :

When an unsaturated lipid contact with oxygen this produces free radicals (Eq. 4.1)

$$RH \rightarrow R^{\bullet} + H^{\bullet} \qquad (4.1)$$

$$ROOH \rightarrow RO^{\bullet} + HO^{-} \qquad (4.2)$$

$$2ROOH \rightarrow RO^{\bullet} + ROO^{\bullet} + H_2O \qquad (4.3)$$

$R^{\bullet}$= lipid radicals

$RO^{\bullet}$= alkoxy radicals

$ROO^{\bullet}$= lipid peroxyradicals

Propagation :

Propagation reactions generate different type of radicals. Previously formed free radicals in the initiation reactions take part in the chain reactions and as a result of consuming of oxygen by lipids new free radical species occurs such as peroxy radicals ($ROO^{\cdot}$) and peroxides (ROOH).

$R^{\bullet}+O_2{}^3 \rightarrow ROO^{\bullet}$ (4.4)

$ROO^{-}+RH \rightarrow ROOH+R^{\bullet}$ (4.5)

ROOH: lipid peroxides

$R^{\bullet}$: lipid radicals

$ROO^{\bullet}$: lipid peroxy radicals

As a result of repated reactions in propagation step, accumulation of hydroperoxides occurs. Lipid peroxy radicals react with other molecules which give rise to lipid hydroperoxides (ROOH) and lipid free radicals $R^{\bullet}$. Lipid hydroperoxides can be also generated enzymatically by the action of lipoxygenase.

Termination:

In the further steps of propagation, the amount of unsaturated lipids (or fatty acids) is reduced and free radicals react with each other, resulting in stable non radical compounds (Madhavi et al., 1996).

$$R^{\bullet} + R^{\bullet} \rightarrow R\text{-}R \qquad (4.6)$$

$$R^{\bullet} + ROO^{\bullet} \rightarrow ROOR \qquad (4.7)$$

$$ROO^{\bullet} + ROO^{\bullet} \rightarrow ROOR + O_2 \qquad (4.8)$$

In the situation of imbalance between scavenging enzymes and free radical formation, destructive and lethal cellular effects occur (Mantle et al., 2000). Scavenger systems contain both endogenous defences and diatery antioxidants. Endogenous defences are enzymes such as superoxidedismutase (SOD), catalase (CA), glutathione peroxide (GPX), plus vitamin E, uric acid and serum albumins. Beside these, intaking of dietary antioxidants is quite essential for human health to cope with the degenerative effects of lipid oxidation (Antolovich et al., 2002). Enzymatic and non-enzymatic antioxidant defense mechanisms convert these life threatening free radicals and reactive oxygen species into non- reactive forms (Dasgupta and De, 2007).

5. ANTIOXIDANTS

Antioxidants have several definitions, but the common definition can be expressed as “any substance delay or inhibit oxidation of oxidizable substrate by neutralizing free radicals” (Antolovich et al., 2002). Antioxidant activity is an important parameter and it is widely used for characterize and determine the various plant materials such as fruits, vegetables, wine, teas, oils and etc. In the recent years, the strategy of implementing the diet with antioxidants especially deriving from natural sources, is becoming more and more convincing against oxidative stress damages (Vertuani et al., 2002). Some of the natural antioxidant classes are flavonoids (quercetin, catechin rutin), tannins (procyanidin, ellagic acid, tannic acid), stilbenes (resveratrol) (Pokorny, 2007).

Living organisms have their protective systems with a high regenerative ability which protect the structures and the functional molecules of the organisms against hazardous effects of both endogenous radicals and exogenous radicals generated as a result of normal metabolic processes. The intracellular mechanisms for suppressing by products of aerobic metabolism include enzymatic mechanisms such as glutathine- peroxidase- glutathione system, superoxide dismutase (SOD) and the catalase (CA) (Matthias et al.). Besides, the biological systems use different antioxidant sources such as, some large molecules (albumin, ceruloplasmin, ferritin, other proteins), and small molecules (ascorbic acid, glutathione, uric acid ,tocopherol, carotenoids, (poly)phenols) and some hormones (estrogen, angiotensin, melatonin, etc.) (Prior et al., 2005). Under normal conditions natural protective systems of organisms can cope with the radicals and keep the system in the state of equilibrium by controlling the harmful effects of them, but in some cases this equilibrium may be disturbed by exogenous factors. The increased accumulation of highly reactive compounds is called oxidative stress (Matthias et al.). Clasically oxidative stress is described as an imbalance between generation and elimination of ROS (Reactive Oxygen Species) and RNS (Reactive Nitrogen Species) thus goes with many critical diseases and aging (Emerit et al., 2004).

5.1 Antioxidative Mechanism of Action

Individual antioxidants may, in some cases, act by multiple mechanisms depending on the reaction system. Furthermore, antioxidants may respond in a different manner to different radical or oxidant sources due to their different characteristics (Prior et al., 2005). In that manner antioxidants can be classified in two general groups as primary (chain breaking) antioxidants which delay or inhibit the initiation step by reacting with a lipid radical or inhibit the propagation step by reacting with peroxyl or alkoxyl radicals and as secondary (preventative) antioxidants that retard the rate of oxidation. Antioxidants also divided into two groups according to their origin as natural (e.g. tocopherols, ascorbic acids) and synthetic antioxidants [e.g.,BHT (butylhydroxytoluene), BHA (butylhydroxyanisole)] (Antolovich et al., 2002).

Antioxidants can deactivate radicals by two major mechanisms, HAT (Hydrogen Atom Transfer) and SET (Single Electron Transfer). Antioxidants with the HAT mechanism quench free radicals by hydrogen donation and with SET mechanism antioxidants transfer one electron to reduce any compound, including metals, carbonyls, and radicals (Prior et al., 2005). These mechanisms are shown with the equations below (Antolovich et al., 2002).

$$L^{\bullet}+AH \rightarrow LH+A^{\bullet} \quad (5.1)$$

$$LOO^{\bullet}+AH \rightarrow A^{\bullet}+LOOH \quad (5.2)$$

$$LO^{\bullet}+AH \rightarrow A^{\bullet}LOH \quad (5.3)$$

$$LOO^{\bullet}+A^{\bullet} \rightarrow LOOA \quad (5.4)$$

$$LO^{\bullet}+A^{\bullet} \rightarrow LOA \quad (5.5)$$

5.2 Antioxidant Activity of Phytochemicals

The primary constituents of phytochemicals that have the ability of contributing total antioxidant capacity of plants are the polyphenols, carotenoids, and traditional antioxidant vitamins such as vitamin C and E (Lako et al., 2007). Polyphenols are widely present in plant kingdom and possessing significant bioactivities just like the antioxidant activity by adsorbing and neutralizing free radicals (Djeridane et al., 2006). Polyphenols can be classified in natural antioxidants and take an important place in our diet (Boskou et al., 2006). Polyphenols are among the most efficient antioxidant molecules owing to the ability of stabilizing and delocalizing the unpaired electron of free radicals by donating an hydrogen atom from their hydroxyl groups. There are many constituents of phenolics retaining potential antioxidant properties such as preventing agents against some critical diseases, independently or in synergetic action (Rice- Evans et al., 1997, Villano et al., 2004). Among the phenolic compounds , bioflavonoids have important antioxidant activity because of their natural origin and importance as efficient free radical scavengers (Katalinic et al., 2006, Heim et al., 2002).

Main function of antioxidants on free radicals is, distrupting the free radical chain reaction or decomposing the lipid peroxides formed into stable end products (Madhavi et al., 1996). Antioxidants have two basic groups related with their action mechanisms. These two groups are primary and secondary antioxidants. Primary antioxidants help delay or inhibit lipid oxidation as free radical scavengers by donating hydrogen atoms or electrons so more stable products can be achived. Secondary antioxidant activities include several mechanisms such as binding of metal ions, scavenging oxgen, converting hydroperoxides to non-radical species, absorbing UV radiation or deactivating singlet oxygen and decreasing localized oxygen concentrations (Maisuthisakul et al., 2007, Tepe et al., 2006).

For the exact and effective usage of phytochemical antioxidants, lipid oxidation, the action mechanism of antioxidants and some other properties such as synergism and degradation should be known well (Madhavi et al., 1996).

5.2.1 Methods for Determination of Antioxidant Activity

Methods utilizing HAT reaction mechanisms

ORAC Method: measures antioxidant inhibition of peroxyl radical induced oxidations and thus reflects classical radical chain breaking antioxidant activity by H atom transfer. In the basic assay, the peroxyl radical reacts with a fluorescent probe to form a nonfluorescent product, which can be quantitated easily by fluorescence.

TRAP Method: This method monitors the ability of antioxidant compounds to interfere with the reaction between peroxyl radicals generated by AAPH or ABAP [2,2'- azobis(2-amidinopropane) dihydrochloride] and a target probe.

Chemiluminescence (CL) Method: The fundamental chemistry of CL assays is based on the reaction of radical oxidants with marker compounds to produce excited state species that emit chemiluminescence (chemically induced light). Compounds that react with the initiating radicals inhibit the light production. The most widely used marker is luminol that have extensively used to study radical reactions and is acceptable when single oxidants are being measured (Prior, et al. 2005).

PCL (Photochemiluminescence) Assay: The assay involves the photochemical generation of superoxide $O_2^{\cdot -}$ free radical combined with CL (chemiluminescence) detection. The assay is initiated by optical excitation of a photosensitizer (S), resulting in the generation of the superoxide radical anion.

$$S + h\upsilon + O_2 \rightarrow [\, S^{*}O_2 \,] \rightarrow S^{\bullet +} + O_2^{\bullet -} \quad (5.6)$$

LDL (Low–Density Lipoprotein) Oxidation: LDL is isolated fresh from blood samples, oxidation is initiated by Cu(II) or AAPH, and peroxidation of the lipid components is followed at 234 nm for conjugated dienes or by peroxide values for lipid hydroperoxides (Prior et al. 2005).

Methods utilizing SET reaction mechanisms

FRAP (Ferric Reducing Antioxidant Power): The reaction measures reduction of ferric to a colored product. The reaction detects compounds with redox potentials of <0.7 V, so FRAP is a reasonable screen for the ability to maintain redox status in cells or tissues. Reducing power appears to be related to the degree of hydroxylation.

Methods utilizing both SET and HAT mechanisms

TEAC or Other ABTS Assays: This method is based on the scavenging ability of antioxidants to the long-life radical anion $ABTS^{\cdot+}$. In this assay, ABTS is oxidized by peroxyl radicals or other oxidants to its radical cation, $ABTS^{\cdot+}$, which is intensely colored, and antioxidant capacity is measured as the ability of test compounds to decrease the color reacting directly with the $ABTS^{\cdot+}$ radical .Results of the compounds are expressed relative to Trolox.

DPPH Assay: DPPH radical is commercially available and does not have to be generated before assay like $ABTS^{\cdot+}$. This assay is based on the measurement of the reducing ability of antioxidants toward DPPH radical by measuring the decrease of its absorbance (Prior, et al.

2005).

The effects of the oxidative stress may be delayed or reduced by taking dietery supplements (Villeponteau et al., 2000). It is important to determine the antioxidant capacities of dietary antioxidants. Various kinds of methods are being used for measuring antioxidant capacity of substances such as physical, chemical and biochemical generator systems. Most of these methods have quite time consuming procedures up to several hours for a single sample and many substances contain both water-soluble and lipid- soluble antioxidants. However most of the methods have a single measuring principle that determines only one of the two substance classes (Matthias et al.)

CONCLUSION

Medicinal plants are the important natural raw materials in food, cosmetic, and pharmaceutical industries due to their several biological activities such as, antioxidant, antimicrobial, anticancer, and anti-inflammatory. The increasing demand and consumption of medicinal plants induced the large scale production and processing of plant products as raw materials for several industries. Processing of medicinal plant products need to follow a standardized quality arrangement. Quality here refers to the product in terms of technical specifications and to the organization of the production process and the continuity of service. The know-how and control of the production process and the coordination of all links are essential for good quality.

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CHAPTER 4

PLANTS DESERVING AS MUCH INTEREST AS LAVENDER FOR TURKEY

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INTRODUCTION

The increasing popularity of Lavender (Lavandula spp.) species in Turkey in recent years is due to the ease of cultivation and the abundance of usage areas. In addition, the fact that it is an environmentally friendly plant that many growers are not aware of is one of the most important of these advantages. This role in preventing erosion is due to the tap-rooted plant. It is also important that it ensures the utilization of barren lands where agriculture cannot be carried out. The rapid increase in production areas will translate into a greater gain by increasing the added value of the final product. In Turkey, this issue should be given more importance, and training and seminars should be given if necessary to increase awareness on issues such as processing and marketing of the product harvested from the field. It is known that its contribution to the country's economy is undoubted and despite this increase in production areas, production is still insufficient and cannot meet the domestic and foreign demand. For this reason, the increase in interest in lavender continues to be a positive development for Turkey. However, increasing the number of plant species cultivated in Turkey, which has an important position in terms of the plant kingdom and includes three different florae, will also bring this agricultural capacity of our country to the commercial dimension. There are more than 250,000 plant species in the world. It is estimated that 35,000-70,000 species are used for medical purposes in some cultures at different times. Developing countries, which make up the majority of the world's population, still rely on herbal medicines to meet their health needs. However, interest in herbal medicines has been increasing rapidly in the regions where modern medicines can also be reached in recent years *Guidelines for the Appropriate Use of Herbal Medicine*. (1998) named book.

Plants that are used in pharmaceutical production, dye production, flavor substances, cosmetic raw materials, spice production, and many other sectors and are the raw materials of these sectors are called medicinal and aromatic plants. The use of medicinal and aromatic plants is quite common in the world. Most of the plants in this group spread in the natural flora in many parts of the world. In addition, many of them have been cultivated and grown. This cultivation is also in large quantities for many countries and contributes to the economies of the countries.

It is thought that the maximum number of medicinal and aromatic plants cultivated in the world is approx. 200-300. According to the International Union for Nature Conservation (IUCN), some species are at risk of extinction in different parts of the world where medicinal plants are used extensively today, such as in Asia and Africa. According to data from IUCN, 15,000 species of medicinal plants in the world are endangered to different degrees. Turkey's flora is one of the most remarkable countries in the world with its high number of endemic species rather than the high number of species it has. 3.649 of totals of 11.466 plant species (31%) spreading in Turkey are endemic. However, the flora of Turkey has not yet been fully revealed. Although Turkey covers 0.6% of the world's land surface, it contains

2.5% of all plant species in the world. It is reported that 1/3 of the total plant species naturally found in Turkey's flora may have the potential to be used for medicinal and aromatic purposes. Some regions of our country are richer in terms of endemism than other regions. Mt. Taurus, Mt. Amanos, Uludağ, Mt. Erciyes, many plateaus of Anatolia, and salinized areas in the Salt Lake Basin are the most important sources of biodiversity in our country in the southern regions, especially in Mt. Kaçkar and Karçal of our Eastern Black Sea Region. In contrast, there are a total of 14,000 plant species on the European continent. The number of plant species owned by Germany, one of the European countries, is around 2500. Istanbul, which has a surface area of 5500 square kilometers, is more than that of England and the Netherlands with 2450 natural flowering plant species. It has been determined that there are over 2750 plant species in the flora of our Artvin province, which is the smallest province of our country. Although the number of medicinal and aromatic plants that are economically important and traded in Turkey is reported to be 347, it is estimated that this number is much higher and approximately 500 are used for medical and aromatic purposes and traded. It is known that approximately 200 plant species of 500 plant species used in Turkey and of economic importance have export potential. It can be said from the sector analyses that 90% of the medicinal and aromatic plants used and traded in our country are collected from nature in terms of the number of species and the remaining species are cultivated in terms of the *number of species*, and 50% of the total production of medicinal and aromatic plants in Turkey is used in the sector by cultivating *Book of Doğu Karadeniz Bölgesi Tıbbi ve Aromatik Bitkilerin Envanterinin Çıkarılması, Ticari Kullanımının Araştırılması ve Üreticilerin Eğitimi Projesi Eğitimi*. (2017).

Medical and aromatic plants and processed products are exported from Turkey to approximately 100 countries. Japan, the USA, the EU, Latin America, the Far East, and North Africa are among the countries that are exported. Among these countries, the USA, Canada, Vietnam, Germany, the Netherlands, Brazil, Italy, Belgium, France, Spain, and Poland are at the top of the list. Thyme is one of the most important medicinal and aromatic plants exported by Turkey. This is followed by bay leaf, cumin, anise, sage, carob, sumac, fennel, rosemary, mahaleb, licorice, and mint, respectively. Again, among the essential oils obtained by processing the medicinal and aromatic plants exported by Turkey, rose oil, thyme oil and citrus oil are followed. The world trade in medicinal and aromatic plants is growing. This growth shows that the demand for medicinal and aromatic plants is increasing day by day *Book of Doğu Karadeniz Bölgesi Tıbbi ve Aromatik Bitkilerin Envanterinin Çıkarılması, Ticari Kullanımının Araştırılması ve Üreticilerin Eğitimi Projesi Eğitimi*. (2017).

SAGE (*Salvia* sp)

Labiatae (Lamiaceae) is one of the 45 genera belonging to the family and is a common plant species in the Mediterranean Region. It has been stated that there are 900 species under the *Salvia* genus in the world. It is seen in the Americas and South-West Asian continents. It is stated that the *Salvia* genus contains 36 species on the European continent, 70 species in Iran, and 75 species within the borders of the former Soviet Union. In Turkey, there are 97 species, 4 subtypes, and 8 varieties. 51 of these species are endemic and their rates of endemism (52.5%) are quite high. Of the 97 species grown in Turkey, 58 (59.7%) are in Iran-Turan, 27 (27.8%) are in the Mediterranean, 5 (5%) are in the Euro-Siberian phytogeographical region, and the remaining 7 (7%) are in more than one phytogeographical region. *Salvia fruticosa*, *S. cryptantha*, *S. multicaulis*, *S. sclarea* and *S. tomentosa* are merchandised. Considering the natural spread of sage, which has a very high endemism rate, in Turkey, it has been observed that it is mostly concentrated in the central and southern regions, including the east and west part of these regions. Among these, it was determined that the most endemic species were located in the west of Eastern Anatolia, followed by the east of Central Anatolia, the east of the Mediterranean Region, and the west of the South Eastern Anatolia Region, respectively. It is known that *S. aethiopis*, *S. argentea*, *S. bracteata*, *S. candidissima*, *S. ceratophylla*, *S. microstegia*, *S. pinnata*, *S. sclarea*, *S. syriaca*, *S. verticillate* and *S. viridis* show more distribution in these regions. Plants under the *Salvia* genus are single or perennial and in herbaceous or shrub-like form. In particular, the flowers have two obvious lips and there are 4 stamens. Stamens have special structures. At the end of the elongated long arm, which is in the form of two connected arms, there is an efficient theca, and at the end of the short arm, there is an inefficient theca, which has turned into a plaque (Ceylan, A., 1996; İpek and Gürbüz, 2010).

The leaves (Folium Salviae) of *Salvia officinalis* L. (locally named as "Tıbbi Adaçayı", "Diş otu"), one of the traded species, are used as drugs, collected and dried at flowering time. This species is a 50-100 cm tall, purplish-blue flowering, simple leafy, perennial, and bushy plant. Its leaves are 3-8 cm long and 1-4 cm wide. Light threaded, with frequent fur on both sides and silver-colored. Its composition contains tannin, the bitter substance, and 1-2.5% essential oil. The essential oil contains 30-50% thujone, 15% cineol, 10% borneol. Its drug has been used as a therapeutic substance since the Middle Ages. It has antiseptic, tonic, stimulating, carminative and relieving in throat and nose diseases. It is not seen in the flora of Turkey, but successful results have been obtained in breeding trials in many regions (Baytop, 1999).

S. fruticosa Miller (Syn: S. *triloba* L. Fil.) (Locally named as "Anadolu adaçayı", "Elma Çalbası") is a perennial plant with a bush-like appearance that can reach 120 cm tall. Its branches are tilted and covered with white-colored fur. The leaves are greyish-white and strongly scented and have stems with plain or 1-2 tabs. 2-6 of the flowers stay together and are lilac-colored. It grows abundantly in Western and Southwestern Anatolian flora. In these regions, it is collected from nature and exported to many countries, especially the USA. It contains 3% essential oil, triterpenes, and flavone derivatives. The essential oil obtained from its leaves and flowering branches is called apple oil (Oleum *Salviae trilobae*). This oil is mostly obtained in Muğla and Fethiye regions. It has carminative, gastric, antiperspirant, and urinary effects (Baytop, 1999).

S. multicaulis Vahl (locally named as “Kürt Reyhanı”) is a perennial and purple-flowered species at a height of 15-50 cm. It grows abundantly in the Eastern and Southeastern Anatolia Regions (Baytop, 1999).

S. sclarea L. (locally named as “ayıkulağı”, “misk adaçayı”, “tüylü adaçayı”) is a two or perennial plant with purple or pale blue flowers that can grow up to 100 cm. The leaves are stalked, heart-shaped, and furry. Its flowering branches (*Herba Salviae sclareae*) carry tannin, resin, bitter substance, and essential oil between 0.3-0.9%. Flowering branches and leaves are used as 5% infusion as stomach, constipation, antiperspirant, and soothing (Baytop, 1999).

S. tomentosa Miller (Sage with big flowers) is a bush-like plant and can grow up to 100 cm. Its flowers are lilac, and its corolla is 25-30 mm long. The leaves are stalked, long, and oval and the bottom is round and heart-shaped. It grows in the outer region of Anatolia. It is collected intensively from nature in our country. Together with S. *fruticosa*, the amount of collection from nature is about 1.5 tons (Tutin, 1972; akt. *Adaçayı Türlerinin Tarımı ve Endüstrisi Fizibilite Raporu*, 2020; Baydar 2016; akt. *Adaçayı Türlerinin Tarımı ve Endüstrisi Fizibilite Raporu*, 2020).

It is produced in some European countries such as Albania, Bulgaria, Croatia, Germany, Poland, Romania, Serbia, Montenegro, and Spain and in the USA. However, 50% of the sage leaves circulating in the world markets are still collected from nature. One of the most important sage producers and exporters is Albania. It exports an average of 1.5 tons per year. The USA, on the other hand, is one of the important countries that imports sage and meets 55% of its needs from Albania. In Albania, it has been reported that 2300 farmers cultivate sage on an area of 2724 hectares. Germany is the second country to supply sage after Albania. Although Germany is actually a sage producer, it realizes most of its exports by reprocessing sage from Southeast European countries or Turkey *Adaçayı Türlerinin Tarımı ve Endüstrisi Fizibilite Raporu*. (2020).

It has been reported that sage cultivation in our country was carried out in an area of approximately 5600 decares in 2019. In the same year, the production amount was 1233 tons. This data is the average of the production area and quantities made in Adana, Antalya, Denizli, Düzce, Eskişehir, Karaman, Kayseri, Kütahya, Manisa, Muğla, Tekirdağ, Uşak and İzmir provinces (TUİK, 2020; akt *Adaçayı Türlerinin Tarımı ve Endüstrisi Fizibilite Raporu*, 2020).

According to TUİK's datas, 2020 sage is imported and exported as tea in small packages, as a different kind of tea from the product used as tea in small packages and as sage oil. The export amount of the product used as tea in small packages in 2020 was 9365 kg, 160.763 USD, and 1.117.447 TL. Its imports were reported as USD 3192 and TL 20,634 with 15 kg. It was observed that the export volume data of different kinds of tea from the product used as tea in small packages was 1.751.450 kg and 7.366.450 USD and 50.880.071 TL in 2020, and the import volume data was 2.801.491 USD and 19.059.364 TL for 1.115.748 kg. Almost all of these imports were made for processing and export in facilities in Turkey. While the export data of sage oil in 2020 were 24.328 kg, 171.440 USD and 1.154.404 TL, the import data were explained as 629 kg, 54.162 USD and 397.828 TL *Adaçayı Türlerinin Tarımı ve Endüstrisi Fizibilite Raporu*. (2020).

Sage grows best on hillside terrain, dry, sandy, and thick soils. It is mostly grown in Antalya, Denizli, and Kutahya provinces in our country. It can be said that cultivation can be done in places where there is a Mediterranean climate. However, since the ecological factors desired by sage grown for different purposes will also differ, it is important to choose the most suitable species for the ecological characteristics of the place to be cultivated. While the relatively temperate regions with the Mediterranean climate should be selected for Anatolian sage, musk sage can also be grown in the inner regions because it is more tolerant to cold.

THYME (*Thymus, Thymbra, Origanum, Coridothymus, Satureja*)

There are many types of thyme from the Labiatae family. In Turkey, nearly 100 plant taxa belonging to the genus *Thymus (*thyme*)*, *Thymbra* (locally named as “zahter”), *Origanum* (locally named as “İzmir kekiği”, “bilyalı kekik”, “mercanköşk”), *Satureja* (thymbra) are called thyme. The main components (with some exceptions) of essential oils of these genera are usually carvacrol or thymol or both. The number of species included in the genus *Thymus* in the world is about 220, 39 species (58 taxa) in Turkey, 43 species included in the genus *Origanum*, 23 species (27 taxa) in Turkey, about 30 species of the genus *Satureja*, 13 species (14 taxa) in Turkey, about 12 species of the genus *Thymbra*, 2 species (4 taxa) in Turkey and there is only species belonging to the genus *Coridothymus*, and this species is also found in Turkey. In Turkey, 44.2% of the species included in the *Lamiaceae* family, 65.2% of the species belonging to the *Origanum* genus, and 52.6% of the species belonging to the *Thymus* genus, and 28% of the species belonging to the *Satureja* genus are endemic. This information is an indication of how rich Turkey is in terms of these genera and how these genera have a gene center (Davis, 1988; akt. Bozdemir, 2019; Biskup and Saez, 2002; Kintzios, 2002).

Origanum syriacum var. bevanii **(locally named as "Suriye Kekiği", "Dağ Kekiği", "İsrail Kekiği"*)***

It naturally grows in the Southwestern Mediterranean and Southeastern Anatolia (Icel, Hatay, Kahramanmaras, and Amanos). In a sample collected in Kahramanmaraş, essential oil yield was found to be 3.7%. 43% of this was found to be carvacrol, 25% thymol, 13% terpinene, and 6% p-Cymene (Bozdemir, 2019).

Origanum onites **(locally named as "İzmir Kekiği", "Bilyalı Kekik", "Türk Kekiği")**

As it is known in Europe, "Turkish Oregano" is widely grown along the coasts of the Aegean and Western Mediterranean (Balıkesir, İzmir, Aydın, Mugla, Antalya) (up to 1400 m height). It was cultivated in the

Aegean Region. Our country has the largest share in thyme exports (approximately 80%). Linalool was found in 91-92% of the samples collected from Antalya and Isparta regions, and it is thought that what grows in this region is a chemotype (Baytop, 1991; akt. Bozdemir, 2019; Öğütveren et al., 1992; akt. Bozdemir, 2019).

***Origanum vulgare* subsp. *hirtum* (locally named as "İstanbul Kekiği")**

It grows in Marmara and Aegean regions (Bursa, Balıkesir, Canakkale, İzmir, Aydın, Mugla). It is considered a spice and medical tea. Essential oil yield varies between 3.6-5.7%. Although it has carvacrol-rich essential oil, it is possible to find plants in thymol and linalool chemotype. The flowering period of the plant usually coincides with July-August.

***Origanum minutiflorum* (locally named as "Sütçüler Kekiği", "Yayla Kekiği", "Toka Kekiği")**

It is an endemic species grown in the Mts. Taurus near Antalya (Saklıkent) and Isparta. It is exported in large quantities by collecting within the periods determined in a controlled manner for the continuation of the species. Essential oil yield is between 2-5%. It has carvacrol-rich essential oil It carries 40-80% carvacrol, 25% thymol, 13-8% terpinene, and 6% p-Cymene.

Origanum majorana (Sweet marjoram, locally named as "Alanya Kekiği", "Mercanköşk", "Tatlı Kekik", "Beyaz Kekik")

It is common in dry meadows, rocky and dry forests in the western (Thrace, Marmara, Aegean, and the Mediterranean) regions of our country. It blooms in July-September. In the Aegean region, cultivation is carried out for the production of essential oil in gardens. The rate of carvacrol is also quite high at the rate of 78-80%. There is no carvacrol in the samples grown in Europe and known as marjoram.

***Satureja hortensis* L (locally named as "süpürge kekiği", "çibriska")**

It is an annual herbaceous species that spreads in almost all regions of our country and can also be used as a drug. It can naturally be found on rocky and eroded slopes, gravel places, loose beaches, and fallow areas on the shores. It can be found at 1920 m above sea level. It blooms between June and September. Its flowers, which bloom from the beginning of summer to the autumn, are white or purple. The ratio of essential oil in the drug varies between 0.3-2.6% and there is especially carvacrol (20-65%) as a phenol derivative in the essential oil (Bozdemir, 2019).

***Thymus x citriodorus* (synonym *T. fragrantissimus, T. serpyllum citratus* and *T. serpyllum citriodorum*)**

Thymus citriodorus is reported to be a hybrid of *T. pulegioides* and *T. Vulgaris.* The ever-green species blooms in July-August. It is reported to be used in the perfumery industry and mouthwash as a compound.

The rich nectar in its flowers attracts honeybees (Huxley, 1999; akt. Bozdemir, 2019). In our country, the species with no natural spread is mostly used for landscaping purposes with its fresh lemon scent and flamboyant flowers. The species, also called lemon thyme or gold thyme, has been reported to be included in the geraniol type thyme group (Huang Jian et all., 2009).

***Thymbra spicata* (locally named as "Karakekik", "Karabaşkekik", "Sivrikekik")**

It is a species common in Thrace, Mediterranean coasts, Aegean, and Western and Southeastern Anatolia. Due to the antiseptic effect of high amounts of carvacrol, it is used as a medicine as well as spices and tea. The rate of carvacrol is 50-71%. The rate of an essential oil varies between 1-3.4 % (Bozdemir, 2019).

Table1. The amount of production and yield of thyme (TUİK, 2020)

Lines			Turkey-TR
Fruits, Beverages, and Spices	Yield and 01.28.19.00.01. (Thyme, Unprocessed) - Kg/Decare	2015	124
		2016	122
		2017	119
		2018	114
		2019	114
		2020	129
	Amount of Production and 01.28.19.00.01. (Thyme, Unprocessed) - Ton	2015	12992
		2016	14724
		2017	14477
		2018	15895
		2019	17965
		2020	23866

When Turkey's thyme production amounts and yields are examined, it has been observed that both increased between 2015 and 2020 (Table 1). However, even 23866 tons of thyme in 2020 do not meet the demand. Thyme agriculture is also very important for the continuity of the ecosystem, as increasing production areas means less collection from nature. Moreover, this is not the only reason to grow thyme. Its cultivation is quite effortless and because it is a perennial plant, input use will start to decrease after the first 2 years. As mentioned above, the presence of species and varieties adapted to all kinds of ecological conditions also makes it easier to make choices. The first condition of successful breeding is the right type and variety selection. After this stage, it should be determined which production material to start with. Thyme seedlings can be produced by seed or vegetative production. If production is to be made with vegetative propagation, rootstock oregano plants where cuttings can be taken are needed. If it is to be produced with seed, care should be taken to use improved seed. If cultivation is to be carried out under aqueous conditions, it is cultivated in October, November, or December; in areas where irrigation facilities are limited, the soil is plowed deeply (autumn surface tillage) after precipitation when conditions are suitable and disc harrow is applied. Before planting, fertilization is performed at the rate of 6-8 kg pure N and 4-5 kg pure P per decare. The planting distance is measured as 40x20. In the first year, the development is slow as the adaptation process to the field will take place first. Therefore, it harvests once, which may take up to October. In the following years, either 2 or 3 harvests can be taken according to the conditions and production techniques of the region. Harvesting is done by harvesting at least 10 cm above the soil surface. It is dried under appropriate conditions and traded in the form of herba or oil. In our country, it is one of the plants whose cultivation has been increasing in recent years. However, since it contains a large number of species and varieties, production is not sufficient to meet the demand. It is thought that it will come to its rightful place and contribute to the national economy by increasing the production areas and establishing more processing facilities.

ECHINACEA (*Echinacea* spp.)

The echinacea plant is found in the family *Asteraceae* (*Compositae*). Echinacea is a perennial herbaceous plant with a steep stem that can grow up to 60-180 cm, which begins to bloom in April-May. The body is cylindrical, the lower leaves are stalked, and the upper leaves are usually attached directly to the body. Its body and leaves are slightly furry. The leaves are oval spear-shaped and have 3-5 veins. The center of the echinacea plant is a round structure surrounded by radial flowers and has a cone head. The radial flowers around the round structure are pink, white, yellow, red, and usually purple. An average of 250-300 seeds are obtained from a ripe flower receptacle. The body rises from the root in the form of vertical pile root (*E. angustifolia*) or hairy root (*E. purpurea*). Echinacea species can regenerate and withstand drought, but they grow slowly (Mistríková, I., Vaverková, Š., 2007).

For this reason, it may be recommended to grow in areas where irrigation opportunities are limited. Echinacea, whose homeland is North America, has spread to South America, Canada, Europe, Russia, Africa, and the Pacific. This plant has accounted for about 10% of the medical plant industry in America in recent years. Echinacea, whose usage area is expanding, even participates in feed rations to increase the milk quality and the resistance of cattle to diseases in a natural way, and numerous studies are carried out in many countries on its usage areas and cultivation. In Tanzania, echinacea is produced as off-season cut flowers and exported to Europe. The echinacea plant is better known as a medicinal plant. There are various secondary metabolites in both the upperparts and underground organs of the plants included in the echinacea genus. The most common ones are active substances such as caffeic acid derivatives, flavonoids, alkylamides, polysaccharides, and essential oil (Mat, 2002). Quantities and ratios of secondary metabolites are affected by processes such as cultivation conditions, harvest time, drying, and storage. For example, while *E.purpurea* is hairy rooted, *E.angustifolia* is rooted in the pile and is mostly grown for the root. The metabolites in the herba and root parts of the economically important *E.purpurea, E.angustifolia* and *E.pallida* species are as follows;

- Phenolic compounds; Phenylprepanoids; echinacoside, cichoric acid, caftaric acid, verbascoside, chlorogenic acid, isochlorogenic acid, cynarine, Flavonoids; Tutoside, luteolin, kaempferol, quercetin, quercetagetin, apigenin, isorhamnetin,

Essential oils; germacrene D, borneol, bornylacetate, caryophyllene, caryophyllene epoxide, and palmitic acid, etc.,

Lipid compounds; polyacetylene, nitrogen compounds; alkylamides, alcoholoids, polysaccharides; inulin, etc. (Çalışkan and Odabaş, 2011).

This plant, which is known to increase the number of white blood cells that protect us against infections and strengthen our immune system, has been used for medical purposes from the past to the present. The echinacea plant has antiviral and antibacterial effects. The positive effects on human health in the USA and Europe have been the subject of much researches. Today, the use of the echinacea plant in the food sector is also increasing.

South Africa sells raw materials to some Western European countries and exports its extracts to Russia and North America. It is also seen that the echinacea plant has an important place in the world economy. Sales volume shows a rapid increase from year by year. According to World Health Organization (WHO) data, approximately 20,000 plants are used for medical purposes. In today's world, where the need for natural foods and medicinal plants increases, the use of echinacea, which is known to be important in terms of health, is also becoming widespread with many active ingredients in its content. Echinacea, the natural plant of North America, has spread from America to Europe, from Africa to the Pacific with the understanding of its benefits, and has gained millions of dollars of the industry that contains hundreds of products. In Europe, more than 280 different products made of *Echinacea purpurea* are sold. It is mostly used as an ointment, tincture, lotion, cream, liquid, and dry extracts and toothpaste. In the United States, the infusion of fresh and dry roots is more common as powdered roots or encapsulated dry herb. The increasing use of echinacea has threatened natural plant populations, and some states have banned or restricted the wild collection of *E. Angustifolia*. Australia, Germany, Russia, New Zealand, Ukraine, the Republic of South Africa have advanced in echinacea agriculture. Echinacea is a cool climate plant, but it can adapt well to summer temperature and dryness. They usually grow in poor, rocky, well-drained alkaline, and near-neutral pH soils. While some species of echinacea are resistant to arid soils, some species have less tolerance to dry land. These plants do not grow especially in areas with incomplete drainage in winter. The ideal soil requirement may vary according to the species, so they can grow at different pH levels. However, in general, they can grow at pH values of 6-7. According to some studies, while the higher essential oil is produced in arid, low-nitrogen soils, alkoloid level increases in moist, high-nitrogen soils. In many studies, the effect and importance of different soil types and different fertilization rates of this plant on yield have been revealed. Echinacea, which is a medicinal and aromatic plant, can be planted in the field in three ways: direct planting of seeds in the field, acclimatization of seedlings to the field by growing in trays, and vegetative production methods from root fragments. According to some researchers on these 3 cultivation systems, the lowest rhizome yield was obtained directly from seed planting and the highest levels from vegetative production. Researchers also report that controlled arid stress increases the dry weight of roots. Although different levels of dormancy are observed in echinacea seeds, the germination rates also differ according to their species. To break dormancy and increase germination, the stratification process, leaving it in a cold and humid environment, various chemicals and mechanical abrasion methods, and light can be used. Using several methods together can increase germination by affecting the seed. Although some echinacea species have very low germination rates, the germination rates can increase up to 70% by combining seeds with seed shell abrasion and keeping them cold and under the light. The most common cultivation method is the method of acclimatization of the seedlings to the field. Seedlings grown in violets should be surprised from the beginning of May. Plantation of the field can be done in autumn as well as in spring. The distance between plants varies especially depending on the soil quality. Different planting density such as 45x10, 30x30, 60x30 cm etc. are recommended. It can be reduced to 15 cm on the row, but increasing the distance between plants reduces the risk of fungal leaf disease and root rot. Fertilization in the cultivation of echinacea has great effects on the chemical composition of the plant. Various studies have been conducted on the fertilization of the echinacea plant. According to a study, it was observed that the total biomass yield depends on both the soil type and the amount of fertilizer and the fertilizer dose varies depending on the soil type used. According to another study, as a result of the observation they carried out by applying different doses of nitrogen (N), phosphorus (P), and potassium (K) fertilizers to the plant, it was observed that if the fertilizer dose exceeds the limits, the yield decreased, and even the root yield decreased. In some studies, 10-20 kg N, 10 kg P, 25 kg K per decare are recommended, while in New Zealand, 50 kg per decare is recommended for NPKS fertilizers 15-10-10-8 composite fertilizer. According to the result of another study, potassium fertilization has a significant effect on the echinacoside content, which is one of the important components of the echinacea plant and a value that shows its efficiency. In another study conducted in Egypt, the highest yield was obtained with low potassium and relatively high nitrogen application and they increased the alkylamide content in plant tissues.

The harvest of the echinacea plant varies in 2 different ways. These are varied as root harvest and upper part harvest according to the plant parts to be harvested. In *E. purpurea*, the highest yield was achieved at the beginning of flowering for one-year-old plants and at the full flowering in two-year-old plants (Lozykowska, 2003). In full flowering, which usually occurs in the middle of summer, leaf and flower harvesting is recommended for *E. purpurea*. Leaves and flowers are separated from the body and used as fresh or dried (Kindscher and Wittenberg 2006).

The production and agriculture of echinacea plants in Turkey are not carried out professionally. There is no information in TUİK data related to production in Turkey. Echinacea is a newly formed medicinal and aromatic plant with an economic use in Turkey. Echinacea is sold in open spaces in herbalists and grocery stores in teabags. Echinaceas sold in herbalists are collected from nature. It is also used as an ornamental plant in Turkey. It has been observed that the climate and soil requirements of the Echinacea plant can grow in many regions of Turkey, and it is appropriate to cultivate this plant especially in Eastern Anatolia, Southeastern Anatolia, and Central Anatolia regions. For example, it is cultivated in Akbucak village of Sarıkaya, Yozgat in the region of Central Anatolia (*Yozgat Tıbbi ve Aromatik Bitkiler Değerleniyor Projesi Fizibilite Raporu,* 2012).

Various academic studies have been carried out and continue to be carried out regarding the cultivation of the plant in our country. However, the data obtained so far show that this plant can be cultivated in our country. Namely; the results obtained in a study conducted with an experiment established in Aydın province show that *Echinacea purpurea* species is adapted to these ecological conditions and can be cultivated in regions with the same characteristics. The average plant height values according to different harvest times and plant densities were calculated between 57.12 and 74.19 cm. The highest values were obtained from the end of the flowering harvest. The highest average main branch lengths were obtained from the harvest at the end of flowering with 76.10 cm. The number of main branches varied between 1.46 pcs/plant and 9.26 pcs/plant among all species according to different harvest times, and the highest number of main branches was determined in the end-flowering harvest of *E. purpurea* species.

In plant densities, the maximum number of main branches was obtained from 80x20 cm plant densities and with the species of E. *purpurea*. The wider space occupancy of the herb of this species compared to other species and the increase in the distance between rows caused increasing the number of main branches. Green herb yield was obtained as 1460.1 kg/da with a plant density of 20x20 cm. The average drug yield of the herba was measured as 358.31 kg per decare at a plant density of 20x20 cm (Özcan, İ.İ., 2014). The drug yield of the flowers was determined as 158.45 kg per decare at a frequency of 20x20 plants. While the fresh root yield was 1580.7 kg per decare, the drug yield of the root was 736.1 kg per decare accordingly. The essential oil ratio varied between 0.051% and 0.117%, and the highest value was obtained at the end of the flowering harvest. Substances of 9-octadecanoic acid, ortho-cymene, β-pinene, germacrene D, octadecanoic acid, n-hexadecanoic acid, caryophyllene oxide, α-phellandrene, 1.5-epoxysalvial-4(14)-ene, α-pinene, 1-cyclopenthyl 3-fluorobenzoate, 4'-methoxyacetophenone, humulene epoxide II, gamma-curcumene, curcumene, 3.4-dimethyl-3-cyclohexen-1-carboxaldehyde, caryophyllene, dehydroxyisocalamendiol, limonene, widdrol, α-farnesene, β-longipinene, β-eudesmene, Nor-copaanone, 3.7-dimethyl-1.6-

octadien-3-ol, 1-nonanecarboxyl, myrtenal, aromadendrene, trans-4-keto-beta-iononane and 4-(1-imethylaminoethenyl)-pyridine were detected in the *essential oil of E. purpurea*.

Echinacea is a plant that can be recommended to growers who are looking for alternative products to include Turkey in this market, which has reached serious dimensions in the world. As the successful results of the first cultivations guided by expert teams are harvested, echinacea agriculture can become widespread by conducting experiments in different regions. To create added value, it is very possible to turn it into tea, drugs, etc. that are valuable in the world market and market them.

CUMIN

The word cumin can be used for many species. *Cuminum syminum* is real cumin. This species is cultivated in Turkey. *Carum carvi* L., locally known as "Karaman kimyonu" or “Frenk kimyonu” in Anatolia, is not cultivated in our lands. It grows naturally in the wetlands of Eastern Anatolia. Apart from these, black cumin (*Bunium persicum*, *B.bulbocastanatum* (Syn; *Carum bulbocastanum* et al.) and white cumin (*Cuminum setifolium*) are locally used species in Iran, Pakistan and Afghanistan. However, in recent years, black cumin seeds have also been sold on international markets and are priced higher. Although these two species aren’t present in our country, 20 taxa of the *Bunium* genus grow naturally with 12 sub-species. “Kefe kimyonu” (Laser trilobum) grows naturally in our country and is used locally. *Trachyspermum ammi* (Syn. *Carum copticum*) was once grown in small quantities in our country. Especially in India, it is grown as a source of thymol (Arslan, 2019).

Fructus Cumini is the harvested and dried fruits of *Cuminum syminum* L. (*Umbelliferae*) species cultivated in our country before full ripening. This species is an annual herbaceous plant with white or pink flowers, fragmented leaves, and a height of 50 cm. Its homeland is Egypt. The Mediterranean countries and Central Anatolia Region in Turkey (Eskisehir, Sivrihisar, Polatlı, Konya, Sivas, Kayseri, Kırsehir, Kırıkkale), Southeastern Anatolia Region (Sanliurfa), Inner Aegean (Afyon, Denizli) are among the regions where cumin is grown.

The appearance is 5-6 mm long, spindle-shaped, and has yellowish-brown grains. It is usually divided into two half fruits. Each half-fruit contains 5 easily visible, yellow-colored ribs. Between the ribs is brown-colored. The upper part is sparsely furry. It has a strong smell and special flavor. It contains fixed oil, essential oil (1.5-4%), resin, etc. The active ingredient of essential oil is cuminal (50%). It is used in alternative medicine and also as a spice due to its gastric, carminative, diuretic, stimulant, and sweating effects. (Baytop, 1999)

The ripe fruits of the *Carum carvi* L. (*Umbelliferae*) species (Fructus Carvi) are also used as spices in Europe. This species is approx. 100 cm tall, perennial and herbaceous plant, and has white or pink flowers, fragmented leafy, It is widely grown in Europe. It has carminative, milk boosting, and does good for menstrual disturbances. Fixed oil carries essential oil (3-9%) resin, etc. The active ingredient in essential oil is carvone and it contains approximately 60% of it.

It loves deep, topsoil-rich, and stony areas. It wants to have enough nitrogen and lime in the soil. It is resistant to prolonged droughts. But it doesn't like too windy places. It is not suitable for very sandy and clayey soils (Ceylan, 1996).

Cumin is grown in India, Turkey, Syria, China, Iran, USA, Mexico, Afghanistan, Pakistan, Sudan, Egypt, Morocco, Algeria, Libya, and some other countries. India is the largest producer, consumer, and exporter of cumin in the world. While cumin is an important export product for Iran, Turkey, Afghanistan, Pakistan, and Syria, it is an imported product for the UAE and Saudi Arabia. Reducing or even eliminating import values can be achieved by increasing production areas for Turkey.

Table 2. Cumin Production Data in Turkey (Anonymous, 2021).

	2015	2016	2017	2018	2019	2020
Total Production Area	270247	268849	267358	361761	321889	212132
Yield (kg/da)	63	69	72	67	63	66
Amount of Production (Ton)	16897	18586	19175	24195	20245	13926

In Turkey, cumin yield was reported as 66 kg/da and production amount as 13.926 tons in 2020. In the last two years, there has been a decrease in the amount of production, and it has been observed that there has been a decrease in the total production area in 2020 (Table 2).

According to the data on the basis of regions, 64 kg/da yield was obtained in the Mediterranean Region and Central Anatolia, while the production amount was 6 tons and 1295 tons, respectively. While the yield is 66 kg/da in the Western Anatolia, Western Black Sea, and Southeastern Anatolia Regions, the production amount in these regions is 12.232 tons, 9 tons, and 17 tons, respectively. While the lowest yield was in the Aegean Region with 62 kg/da, the highest yield was in Eastern Marmara with 86 kg/da. Production amounts in these regions are 262 tons and 105 tons, respectively (Anonymous, 2021)

Expanding the production areas of cumin will increase Turkey's importance in the global cumin market.

SUMAC (*Rhus coriaria* L.)

Sumac is a common name for flowering plants of the *Rhus* genus, derived from the Arabic and Syriac word "summāq", meaning "dark red", and belonging to the *Anacardiaceae* family, and having more than 250 species. When the general characteristics of the *Anacardiaceae* family are examined, it is seen that there are plants in the form of shrubs or trees, whose natural spreading area is temperate and warm climates (Köroğlu, 1989; Quattrocchi 1999 and USDA 2007 akt. Karadaş, 2019).

When the general characteristics of the *Anacardiaceae* family are examined, it is seen that there are plants in the form of shrubs or trees that find natural spreading areas in tropical and temperate regions and contain resins in their shells. Its leaves are helical or counter arrayed and consist of simple and partial particles. The flowers of the plant are in the form of clusters and the flowers are actinomorphic, hermaphrodite, or unisexual (Köroğlu, 1989). Morphologically, sumac has a vegetable structure seen in bush or tree form ranging from 1 to 3 m in height.

Sumac plants can grow in dry, stony, and rocky places, bushes, roadside slopes, and forested places at 600-1900 m altitude. It can be reproduced with seeds or vegetative (Browicz, 1982; Başoğlu ve Cemeroğlu, 1984; Baytop, 1999; Karadaş, 2019 akt. Davis, 1967)

Rhus species are important in terms of erosion control studies since they form a wide root system. This species can be used in roadside filling slopes, afforestation of non-deep soils eroded due to erosion, improvement of mine soils and other protection nature (Brinkman, 1974; Humphrey, 1983; Rowe and Blazich, 2003; Gezer ve Yücedağ, 2006; Göktürk ve ark., 2006 akt. Güvenç et all., 2017).

Although there are “derici sumağı” (*Rhus coriaria L.*), “boyacı sumağı” (*Rhus cotinus L.*) and *Rhus Chinensis L.* species in Turkey, the most common sumac species is “derici sumağı” *(Rhus coriaria L.*).

Rhus chinensis L. is found around Artvin. The sprawl of the "derici sumağı” (Rhus coriaria L.) extends from the islands of the Canary Islands and Madeira to Iran and Afghanistan through North Africa and Southern Europe. In Turkey, it grows wild in the Aegean, Mediterranean, and Eastern Anatolia regions. On the provinces basis;

sumac plant can be found in provinces such as Adana, Amasya, Ankara, Antalya, Artvin, Çanakkale, Denizli, Gaziantep, Gümüşhane, Hakkâri, İstanbul, İzmir, Karaman, Kastamonu, Mersin, Samsun, Siirt, Şanlıurfa and Tekirdağ in our country (Çiçek, 2015). It can reach 3m in height. It is a plant in the form of a bush. Alternatively, the leaves are in the form of compounds, dentate, or serrates. Its flowers are green. and bloom in April and May. Their young twigs are reddish-furred, And compound-leaved. Its fruit is spherical, feathery and when it is ripe it is red-colored. (Salim Çoban). It carries the active substance of gallotannin, which is commercially important in the parts above the soil and roots of sumac. Contains gallic acid and methyl/ethyl esters, flavonoids, anthocyanins, phenolic acids, essential oil, and minerals (Ayhan, and Altınkaynak, 2020). Leaves and fruits of the "derici sumağı" (*Rhus coriaria* L.) are used. Leaves and fruits have an antioxidant and antimicrobial effect. The composition of the sumac leaf (Folium Rhois coriariae) contains tannins, sugars, wax and flavone derivatives and yellow color substances (myricetin). It was determined that 21.7% tannin was found in Anatolian-origin leaves. It is a drug with laxative, styptic, and antiseptic effects. It is also used for tanning leather and dyeing woolen fabrics and carpet yarns. It is one of Turkey's export products. Sumac fruit (Fructus Rhois coriariae) is a dried ripe fruit of the species *Rhus coriaria L*. The fruit is in the form of pale red, single-seeded, furry, and spherical-shaped grains. Tannin (4%) carries essential oil, organic acids (citric, tartric, malic), and these compounds' salts. Therefore, its sour flavor is delicious. It is used in abundance as a spice (sumac extract), especially in Southern Anatolia (Baytop, 1999).

Being able to become an agricultural country again will be possible by identifying and studying the plants that spread in the natural flora of our country and/or the species that can grow under the ecological conditions of our country, bringing them into agriculture or increasing the production areas of those that are still being cultivated.

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CHAPTER 5

MICROBIOLOGY AND ANTIMICROBIAL PROPERTIES OF SPICES AND HERBS

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1. INTRODUCTION

Spices and herbs, whose history is almost as old as human history, are products of plant origin added to foods to give flavor. Although they were initially used in the manufacture of medicines for the treatment of diseases, in religious ceremonies, in the production of perfumes and cosmetics, and with their aphrodisiac effects; over time, they have been used for purposes such as protecting foods, increasing flavor, making foods more appetizing. Factors such as changing and developing dietary habits in recent years, people's search for a healthier life, increasing demand for local/ethnic dishes, tending to interesting tastes, emergence of new food products and developments in technology have increased the importance and usage area of spices and herbs (Akgül, 1993).

In order for a product to be considered as a spice; First of all, in order to add flavor to foods, one or more of the parts of the plant such as root, rhizome, onion, bark, leaf, stem, flower, fruit, seed should be used together, fresh or dry (Akgül, 1993).

Spices alone are not considered as foodstuffs. Although they are generally used in very small amounts in foods, they contribute significantly to the microbial properties of the food they are used because of the microbial load of flavors and spices.

In this section, information is given about the microbiological properties and antimicrobial properties of spices and herbs, which have a wide range of uses.

2. Microbiology of spice and herbs

The microbial properties of spices and herbs are important both for themselves and for the foods they are used as ingredients. Although they have antimicrobial properties against many saprophytic and pathogenic microorganisms, they are also an important source of contamination for foods due to the microbial load they contain (Tunçel, 2015).

Since spices and herbs are of vegetable origin, they are products that are in direct contact with the soil. The fact that the soil is the natural source of many important microorganisms, as well as fecal contamination from animals such as birds, rodents, insects, affect the contamination of spices with these microorganisms. Depending on environmental factors such as whether the soil is fertile or clayey, its type, ambient humidity and temperature, the number of microorganisms of soil can reach up to 10^{10} per gram. Especially spore-forming bacteria such as *Bacillus* and *Clostridium*, as well as other bacteria, coliforms, yeasts and especially mold spores can be found in very high numbers in the soil. *Acinetobacter, Alcaligenes, Artrobacter, Bacillus, Clostridium, Corynebacterium, Flavobacterium, Micrococcus, Pseudomonas, Streptomyces* are the most common bacteria in the soil. In addition, due to fecal contamination, various viruses from the soil and various enteric pathogenic bacteria such as *Salmonella*, *Shigella, Vibrio* are also an important source. These microorganisms in the soil can be directly transmitted to spices and herbal foods. For this reason, spices and other food materials that come into contact with the soil and have not undergone any washing process are considered as products with high microbial load (Aktuğ Gönül, 2015; Akın and Akın, 2021; Tunçel, 2015).

In addition to the number of bacteria, the number of molds can be high in spices. The high number of mold spores in the natural environment causes the mold load of spices grown in humid environments to be around 10^4-10^8 per gram. The presence of mycotoxigenic molds in these molds results in the synthesis of mycotoxins in the case of drying and storage under appropriate conditions (McKee, 1995).

Considering that the growing conditions of spices are generally humid and temperate climates with poor hygienic conditions, this causes the microbial load of spices to be high. At the same time, failure to take adequate hygienic precautions during harvest, transportation, processing and storage causes an increase in the microbial load. Although the bacteria, yeasts and molds mentioned above are frequently encountered in this microbial load, foodborne pathogens such as *Salmonella* spp., *Staphylococcus aureus, Bacillus cereus, Clostridium perfringens*, enteropathogenic *Escherichia coli* can also be encountered (Aktuğ Gönül, 2015; Akın and Akın, 2021; Tunçel, 2015).

Despite the positive developments in technology, some inadequacies in hygiene and food production techniques in enterprises make food safety even more important in terms of protecting public health. The World Health Organization (WHO) reported that approximately 30%

of the population in industrialized countries is affected by foodborne diseases each year, and at least 2 million people worldwide died from diarrhea in 2000 (WHO 2002a in Burt, 2004). WHO reported that in 2020, 1 out of every 10 people in the world got sick after eating contaminated food, and at least 420,000 people died every year as a result. It was stated that the number of children under the age of 5 in this group is 125,000 and carries 40% of the foodborne illness burden per year, and attention is drawn to food safety (Anonym, 2020).

Health is inextricably linked with food safety and food security. Unsafe food creates an important vicious circle, especially for children, infants, the elderly, pregnant women and those with chronic diseases. For this reason, it is of great importance that foods and all components used in foods are produced and consumed away from all kinds of disease factors. Among the factors that make food unsafe and cause food-borne diseases; it is of great importance to consume vegetables, fruits and foods of animal origin, especially raw, containing pathogenic bacteria, viruses and parasites grown in contaminated water. In this context, the microbial qualities of spices and herbs that are used and consumed in various ways in foods are also an important factor that directly affects the health of consumers (Aktuğ Gönül, 2015; Soyer and Bulut, 2016; Tunçel, 2015).

Spices are frequently produced at home in Turkey as in many countries. It is also produced by some companies by contract farming and then dried and presented to the domestic or foreign market. Drying processes, both at home and in operating conditions, have a significant effect on the microbial load. Inadequate and rapid drying is an opportunity for the reproduction of microorganisms that are transmitted from the growing conditions. In this case, the microbial load increases; In addition, if there are mycotoxigenic molds in the environment, it is possible for them to synthesize mycotoxins under certain conditions. For these reasons, drying conditions such as drying temperature, drying time, drying environment and storage conditions following the harvesting stage of spices are extremely important in terms of microbial growth and mycotoxin formation. As a matter of fact, mycotoxins such as Aflatoxin B1, B2, G1, G2, Ochratoxin A, *Fusarium* toxins, deoxynivalenol, zearalenone, patulin are frequently encountered in countries all over the world such as the United States, Oman, Qatar, Turkey, Indonesia, the Kingdom of Saudi Arabia, and European Union countries. (Al-Jaal et al., 2019; Erdoğan, 2004; Thanushree et al., 2019; Suman, 2021). Depending on the growing, drying and storage conditions, the microbial load of spices mostly consists of spore-forming bacteria and molds. However, as a result of the multiplication of bacteria, it is not uncommon to find that the spices are spoiled. Molds can develop and cause both mold and mycotoxin formation as mentioned above.

Mycotoxins, especially aflatoxin and ochratoxin in spices, cannot be removed by any method. Microbial load, including pathogens, can be transmitted to the food consumed depending on the way the spice is used. Since the use of spices is before and after cooking or at the consumption stages; In this case, the microbial load from the spices affects the microbial quality of the prepared food. The saprophytes and most of the vegetative cells of pathogenic bacteria in the spices added to the food before cooking die during cooking. However, saprophytes in spices added to the food after cooking or at the consumption stage may cause shortening of the shelf life of the food, and pathogenic bacteria may pave the way for various food poisonings (Jay, 1991).

Microbial quality of spices is an extremely important issue in terms of both extending the shelf life of food and protecting public health by preventing food-borne diseases. In many countries in the world, enteric diseases associated with the use of spices directly or in food have been encountered at various times. To give a few examples in this context;

- Between December 1973 and May 1974 in Canada, 17 people were affected by *Salmonella* Weltevreden in black pepper of Indian origin.
- Between November 1981 and August 1982 in Norway, 126 people were affected by *Salmonella* Oranienburg in black pepper of Brazilian origin.
- Between April and September 1993 in Germany, approximately 1000 people were affected by *Salmonella* Saintpaul, Rubislaw and Javiana in paprika originating from South America.
- England and Wales experienced poisoning from *Bacillus subtilis* and *Bacillus pumilus* in turmeric in 1995.

- In England and Wales, 8 people were affected by *Salmonella Enteritidis* PT4 in black pepper in August 1996.
- In 1997, 2 people were affected by *Bacillus subtilis* on peppers of Malaysian origin in New Zealand.
- In England and Wales in August 2002, 20 people were affected by *Salmonella* Braenderup in curry of Indian origin.
- Between October 2002 and June 2003 in Germany, 42 people were affected by *Salmonella* Agona in anise seeds originating from Turkey.
- A total of 87 people were affected by Salmonella Wandsworth and *Salmonella Typhimurium* in spice mix and broccoli powder between January and December 2007 in the United States.
- In 2007, 146 people were affected by *Bacillus cereus* in the spice mix in France.
- 14 people were affected by *Salmonella* Senftenberg in fennel between March 2007 and September 2008 in Serbia.
- In the United States, between November 2008 and April 2009, 87 people were affected by *Salmonella* Rissen in white pepper, and a total of 283 people were affected by S*almonella* Montevideo in black pepper and red pepper between July 2009 and April 2010.
- In Denmark, 112 people were affected by *Bacillus cereus* in white pepper in 2010 (Zweifel and Stephan, 2012; Van Doren et al., 2013).

3. Microbial quality of spices and herbs

As mentioned above, spices and herbs are products that are open to high microorganism contamination because they are of plant origin, grown in humid environments, especially in subtropical climates. For this reason, various studies have been carried out to determine the microbiological quality of spices for many years. While these studies generally reveal the total microbiological load of spices, some studies focus on the presence of pathogenic microorganisms and some mycotoxins. In this context, examples of some studies are given:

In a study to determine the microbiological quality of spices sold in Lebanon; total aerobic mesophilic bacteria (TAMB), sulfite reducing anaerobic bacteria, *C. perfringens*, coliforms, *E. coli*, yeasts and molds were found in 89%, 43%, 18%, 15%, 1% and 54% of the samples, respectively. All samples were negative for *Salmonella*. One per cent, 4%, 6%, 1% and 7% of the samples had unacceptable levels of TAMB, coliforms, sulfite reducing anaerobic bacteria, *E. coli*, yeasts and molds, respectively (Karam et al., 2021).

In the *Bacillus* and mold analyzes performed on 60 spice samples, consisting of black pepper, chilli pepper, cumin, coriander, turmeric, curry samples sold in the markets in Latvia (Lativa); prevalence of *B. cereus* in spices and herbs was found 76% and 24%, respectively, and *B. cereus* was found in nine (18%) black ground pepper samples with 2.08-3.09 log10 CFU/g. Prevalence of moulds in spices and herbs was 45/60 (75%) samples of spices and herbs. The levels of *B. cereus* and moulds in the local market were significantly higher ($p < 0.05$) than in the supermarket chain (Fogele et al., 2018).

Microbiological analyzes of 2833 retail spice samples in England 8,3% of samples were of unsatisfactory quality due to the presence of *Salmonella* spp., *E. coli* (ranging from $2.4x10^3$ to $1.0x10^7$ cfu g1) and/or high levels of *B. cereus* (ranging from 1.0x 10^4 to $2.3x10^7$ cfu/g). spp. were detected in 1.1% (31/2833) of retail samples (Sagoo et al., 2009).

In a study conducted in Poland on 60 samples of spices, herbs and seasoning blends; The total aerobic mesophilic count was not found to be more than 10^4 cfu/gr in 60% of the samples, and *Cronobacter* spp was found in only 10 samples. The highest contamination (TAMB) was found in samples of herbs and in ready seasoning blends, in 21.1% and 25.0% of which the total count of aerobic mesophiles was in the range of 10^5-10^6 CFU/g. Results indicate that good hygienic conditions in the production process of spices and herbs available on the Polish market. (Garbowska et al., 2015).

Berthold-Pluta et al (2019) found the highest prevalence (63.3%) of *B. cereus* in herbs and spices among nine food products in Poland.

In a study conducted in 180 spices and herbs in Ireland; a total viable bacteria count greater than 6 log cfu/g and 2-6 log cfu/g spore bacteria and thermophile were detected in 20% and 80% of the samples, respectively. *Pseudomonas* spp. and Enterobacteriaceae (2-6 log CFU/g) were detected in 33% or 23% of samples, respectively. Molds were detected in 50% of samples (1-3 log CFU/g) (Witkowska et al., 2011).

In a study conducted in Elazig, a total of 120 spice samples collected from the market were analyzed; as a result, total mesophilic aerobic bacteria count, coliform count, *Staphylococcus-Micrococcus* count, yeast-mold count, lactobacilli, Enterobacteriaceae and aerob spore forming mesophile were found 7.50-5.45, 3.54-2.03, 5.52-4.01, 3.13-2.81, 5.79-4.21, 4.02-2.34, 4.89-4.09, respectively. *Escherichia coli* was detected in a total of 14 samples, coagulase positive *S. aureus* was not detected in any of the samples (Demir et al., 2019).

In a study examining the hazards and data sources in the European Union spice and herb chain; Banach et al. (2016) reported that *Salmonella* and *Bacillus* spp are sources of danger especially in black pepper and dried herbs, and Aflatoxin B1 and Okratoxin A in chili powder, cayenne, paprika, and nutmeg.

B. cereus was detected in 64 (31.5%) of the 203 packaged and unpackaged spice samples in Turkey (Cufaoğlu ve Ayaz, 2022).

4. Antimicrobial Properties of Spices and Herbs

Natural antimicrobials from spices and herbs have a long history of use, starting in Egypt, China and India. Even though the first scientific study on antimicrobial effects of spices was conducted in the 1880s, some factors have increased the interest in plant-derived antimicrobials over the past decade. The increased demand for ready to eat foods and emergence of antimicrobial resistance have led scientists to search for more effective antimicrobial agents that can be alternative for chemical preservatives, which raise concerns for adverse effects they have on human health (Tajkarimi et al., 2010).

There are over 12,000 compounds isolated from plants that are mostly secondary metabolites and help plants in defense against microorganisms, insects, and herbivores. Some of these compounds provide flavor whereas others provide color or scent (Bor et al., 2016). Most of these compounds are phenols or their oxygen-substituted derivatives and they have antimicrobial properties (Hayek et al., 2013). Phenolics, phenolic acids, quinones, flavonoids, tannins, coumarins, terpenoids, and alkaloids are major groups of plant derived compounds most of which have antimicrobial effect on microorganisms (Lai & Roy, 2004). Examples of studies conducted on antimicrobial properties of spices and herbs over the last decade are listed in Table 1.

Table 1: Some studies conducted on antimicrobial properties of spices and herbs over the last decade

Tested Microorganisms	Spices and /or Herbs	Reference
Escherichia coli	Allium sativum (Garlic) Zingiber officinale (Ginger Allium cepa (onion) Coriandrum sativum (cilantro) Piper nigrum (black pepper) Citrus aurantifolia (key lime)	Rahman et al., 2011
Escherichia coli *Staphylococcus aureus*	Bitter fennel Ginger Turmeric Nutmeg Coriander Cubeb Dry black lemon Senna	Akrayi, 2013

Vibrio vulnificus *Micrococcus luteus*	Turmeric Cinnamon Cumin Garlic Ginger	Asimi et al., 2013
Escherichia coli, *Klebsiella oxytoca* *Klebsiella pneumoniae* *Hafnia alvei* *Raoultella terrigena*	Thymus vulgaris (thyme) Lavandula angustifolia (lavender) Melissa officinalis (Melissa) Ocimum Basilicum (Basil) Allium schoenoprasum (Chives) Petroselinum crispum parsley)	Dostalova et al., 2014
Vibrio vulnificus *Vibrio parahaemolyticus* *Vibrio cholerae*	Oregano	Gracia-Valenzuela et al., 2014
Bacillus cereus *Listeria monocytogenes* *Micrococcus luteus* *Staphylococcus aureus* *Escherichia coli* *Salmonella typhimurium*	Bay leaf Black pepper Coriander (seed and leaf) Cumin Garlic Mustard Ginger Onion Turmeric	Bag and Chattopadhyay, 2015
Escherichia coli *Staphylococcus aureus*	Cinnamon	Zhang et al., 2016
Salmonella spp. *Listeria monocytogenes* *Staphylococcus aureus* *Escherichia coli* *Enterobacteriaceae* *Enterococcus* spp. *Pseudomonas* spp	Basil Thyme Tarragon Rosemary Orange Parsley Nutmeg Lemon Garlic Cumin Cinnamon Black pepper Bay	García-Díez et al., 2016
Bacillus cereus *Serratia* sp. *Rhodotorula mucilaginosa* *Aspergillus flavus* *Penicillium citrinum*	Curcuma longa Zingiber officinale Mentha arvensis Withania somnifera Rauvolfia serpentina Emblica officinalis Terminalia arjuna	Dhiman et al., 2016

	Centella asiatica	
Escherichia coli *Staphylococcus aureus* *Candida albicans*	Piper nigrum (black pepper)	Kalunta, 2017
Salmonella spp. *Listeria monocytogenes*	Oregano Garlic	García-Díez et al., 2017
Staphylococcus aureus *Salmonella enteritidis*	A total of 67 spices	Zhang et al., 2019
Staphylococcus aureus	Fenugreek Black cumin Ethiopian cumin Garlic Cloves Ginger Coriander Aframomum Turmeric Cinnamon	Tura, 2019
Staphylococus aureus *Escherichia coli* *Salmonella Typhi* *Pseudomonas aeruginosa* *Klebsiella pneumoniae* *Citrobacter koseri* *Rhizopus* spp. *Aspergillus niger* *Aspergillus flavus* *Candida albicans*	Oxalis corniculata Artemisia vulgaris Cinnamomum tamala Ageratina adenophora	Manandhar et al.,2019
Escherichia coli *Salmonella* spp. *Pseudomonas* spp. *Staphylococcus aureus*	Garlic Ginger Turmeric	Sah et al., 2020
Escherichia coli *Salmonella Typhimurium* *Listeria monocytogenes* *Candida albicans*	Mentha piperita (mint) Ribes nigrum (currant) Nigella sativa (black seed) Origanum majorana (marjoram) Thymus serpyllum (thyme) Coriandrum sativum (coriander) Crocus sativus (saffron)	Okmen et al., 2020
Escherichia coli	Cinnamon (Cinnamomum	Köse, 2020

Enterococcus faecalis *Bacillus cereus* *Pseudomonas aeruginosa* *Salmonella typhimurium*	zeylanicum) Cumin (Cuminum cyminum L.) Thyme (Thymus vulgaris L.) Mint (Mentha spicata L.)	

4.1. Phenolics and polyphenols

Plant derived phenolic compounds are one of the most diverse groups of secondary metabolites. The hydroxyl groups in phenolic compounds can disrupt cell membrane structures and cause the leakage of cellular components (Xue, Davidson, & Zhong, 2013). Differences in the structural configuration of these compounds have an important effect on their antimicrobial action (Gyawali et al., 2014; Quinto et al., 2019). The position of the OH group is found to be effective on the antimicrobial property of phenolic compounds. For instance even though thymol and carvacrol have similar structure, differences in their antimicrobial effectiveness was observed (Dorman and Deans, 2000).

4.2. Alkaloids

Alkaloids can be present in any part of the plant. However specific compounds may be limited to certain parts. Alkaloids aid in keeping away herbivores and protect the plant from infection. Different mechanism of antimicrobial action has been proposed for different classes of alkaloids. Some classes act by inhibiting nucleic acid synthesis while others act by inhibiting cell division (Cushnie et al., 2014).

4.3. Flavonoids

Flavonoids can be found in photosynthesizing cells therefore occur widely in fruit, vegetables, nuts, seeds, stems and flowers (Cushnie and Lamb, 2005). In addition to providing attractive colors in flowers, flavonoids in leaves provide the plant protection from fungal pathogens and UV-B radiation (Harborne and Williams, 2000)

Flavonoids have been reported to have antimicrobial effect on viruses, fungus and bacteria. Antibacterial mechanism of flavonoids can be attributed to several actions: inhibition of nucleic acid synthesis, inhibition of cytoplasmic membrane function and inhibition of energy metabolism (Cushnie and Lamb, 2005)

4.4. Quinones

Quinones are aromatic compounds which are part of natural defense system of plants. They have been utilized as antifungals and antibacterial (Tran et al., 2004). Quinones have antiviral, antifungal and antibacterial activities (Martínez and Benito, 2005). They form complexes with amino acids and inactivate microbial proteins (Lai and Roy, 2004; Cowan, 1999). Furthermore these compounds may interfere with the utilization of substrates by microorganisms (Cowan, 1999).

4.5. Terpenes

Terpenes are a major part of plant essential oils (EO). Oxygenated terpenes are called terpenoids which causes membrane permeability and potassium ions leakage in microbial cells. Oxygenated terpenes such as thymol and carvacrol were reported to have better antibacterial activity than simple hydrocarbon monoterpenes (Sokovic et al., 2010). Changes in the position of -OH group might cause differences in the antimicrobial activity of terpenes (Griffin et al., 2005).

4.6. Tannins

Tannins are water soluble polyphenols which have the ability of sedimentation of gelatin from solution (Scalbert, 1991). Tannins have the ability to pass through the bacterial cell wall and interfere with the cell metabolism which results in the destruction of the cell (Kaczmarek, 2020). Other mechanisms involved in the antimicrobial activity of tannins are inactivation of microbial adhesions, enzymes, and cell envelope transport proteins as well as binding to polysaccharides (Cowan, 1999).

4.7. Coumarins

Coumarins represent a major category in secondary plant metabolites and they have been utilized for biochemical and pharmacological purposes (Kayser and Kolodsiej, 1999). Recently coumarins have received a considerable amount of attention due to their potential as antimicrobial agents. Naturally produced coumarins show structural differences from the parent molecule which have very low antimicrobial activity (Reen et al., 2018). However, compounds which have long chain hydrocarbon substitutions possess a high antimicrobial capacity (Tomasz Kubrak et al., 2017).

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CHAPTER 6

SOIL REQUIREMENTS OF SOME MEDICINAL AND AROMATIC PLANTS

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INTRODUCTION

Increasing demands for medicinal and aromatic plants has increased the interest in these plants. However, studies on cultivation of these plants and increasing production areas have brought about some questions that need to be answered. Soil comes forefront in some of these questions. As it is known, the factors influencing yields in plant production are gathered under two groups as of: genetic (internal) and environmental (external) factors. Environmental factors include entire external conditions and items influencing plant growth and development. Among these environmental factors, soil is the primary one. From this point of view, in this chapter, the definition, functions, management of soil and interactions with some medicinal-aromatic plants are presented.

1. SOIL

1.1. What is soil?

Soil is basically a part of lithosphere (earth's crust) cycle, in which weathering, transport, sedimentation and metamorphosis-like processes take place (Figure 1). In a broader sense, soil is defined as a living, three-dimensional, organic or inorganic-originated natural environment with varying solid, liquid and gas phases, a dynamic balance and in which plants, animals and microorganisms inhabited (Altınbaş et al., 2004). Soils, formed from different materials in different climate conditions, show a great diversity. Therefore, soil properties inevitably exhibit large variations.

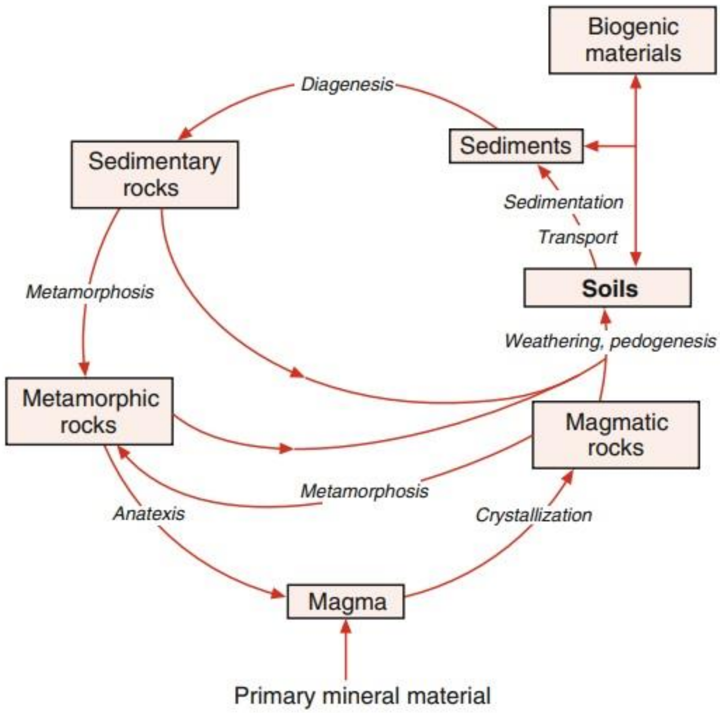


Figure 1: The position of soils in the cycle of the lithosphere (Blume et al., 2016)

Soil is a 3-dimensional concept and contains different horizons (layers) arranged on top of each other. Therefore, soils offer quite different physical, chemical and biological properties to vegetation cover on them.

1.2. Functions of soil for crop production

Soil is an interface between water, atmosphere and terrestrial ecosystem. To better understand the relationships between these systems and the role of soil in these relationships, a new approach was proposed for assessment of soils (Carter et al., 1997).

The function of soil in crop production is to feed the plant and ensure sustainable plant growth and development. This function of soil is basically related to efficiency of soils in providing the necessary nutrients, substrates and ambient to support the conversion of atmospheric CO_2 into organic molecules using energy from the sun (through photosynthesis).

The function of soil in crop production can be divided into several components as follows: providing a plant growth ambient; regulating the flow of water, gas and energy and serving as a buffer or filter system. Soil chemical, physical and biological properties should be taken into consideration while assessing these functional components (Table 1).

Table 1: Characterizing the main functional components of a soil in crop production

Functional component	Functional characteristics/processes
Medium of plant growth	Suitable medium for seed germination and root growth Absence of adverse chemical conditions (acidity, salinity, sodicity) Supply balance of nutrients Suitable medium for microbes (nutrient cycling, decomposition) Promote root growth and development
Regulate water	Receive, store, and release moisture for plant use Adequate water retention to buff'er and reduce effects of drought Adequate infiltration and storage capacity to reduce runoff
Regulate gases	Accept, hold, and release gases Adequate air movement and exchange with atmosphere
Regulate energy	Store release (recycle) energy rich organic matter
Buffer or filter	Accept, hold, and release nutrients Sequester energy compounds and/or biotoxic elements Detoxify substances harmful to plants

1.3. Soil properties

Soil properties are often examined under three groups: physical, chemical and biological. Physical properties include texture, structure, aeration, water retention and infiltration. Soil texture is defined as the distribution of primary particles. Primary particles are defined by the United States Department of Agriculture as sand (2.00-0.05 mm), silt (0.05-0.002 mm) and clay (less than 0.002 mm) (Garcia-Gaines and Frankenstein, 2015). Soils are divided into different texture classes based on amount of these primary particles (Figure 2).

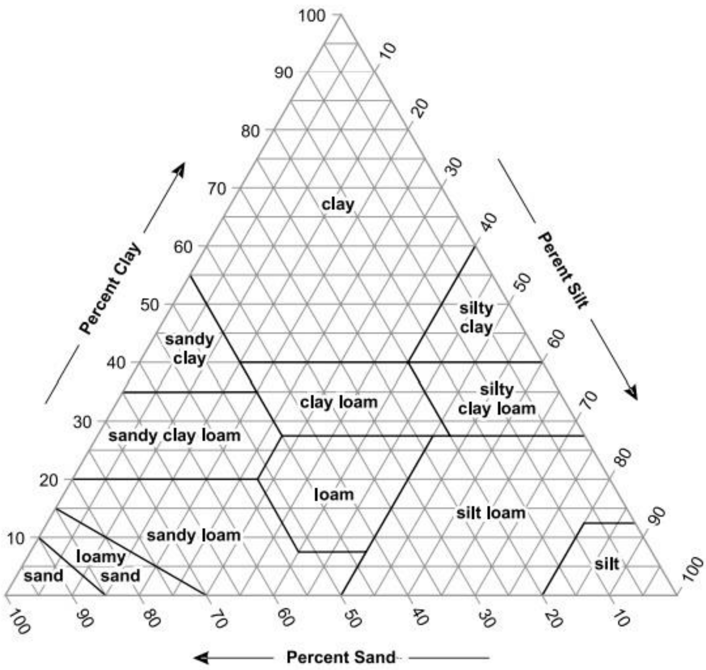


Figure 2: USDA textural triangle showing the percentages of clay, silt and sand in 12 basic texture classes (Soil Survey Division Staff, 2018).

Texture class of a soil reveals important information about the behaviors of that soil (Table 2).

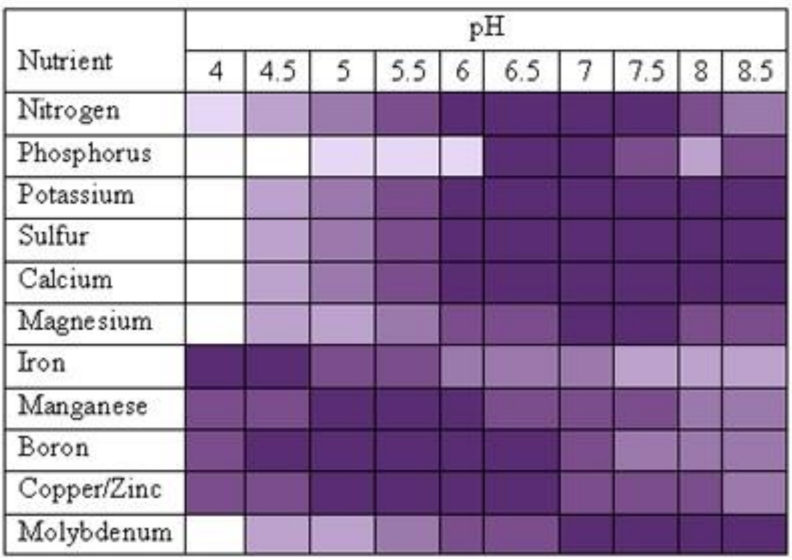
Table 2: Physical behaviors of soil with different textures (Osman, 2013).

Soil textural class	Infiltration	Water-holding capacity	Nutrient-holding capacity	Aeration	Workability	Leaching
Sand	Good	Poor	Poor	Good	Good	High
Silt	Medium	Medium	Medium	Medium	Medium	Medium
Clay	Poor	Good	Good	Poor	Poor	Low
Loam	Medium	Medium	Medium	Medium	Medium	Medium

Different sized primary materials such as sand, silt and clay in soils come together with cementing materials in the presence of many processes and form secondary formations constituting soil structure. A well-developed soil structure can also be interpreted as the ability of three phases in the soil to perform their functions in a balanced fashion. Negative affection or deterioration of soil structure brings about the deterioration of the balance of these three phases in the soil against each other.

Soil chemical properties include soil reaction, salinity and alkalinity. Soil reaction (pH) refers to concentration of H ions in the soil solution. High H concentrations indicate acidic soils and the other way indicates alkaline soils. Soil reaction has significant effects on availability of plant nutrients (Figure 3). Soil reaction is effective not only on plant nutrients, but also on the other elements (metals) that the plant does not need. With the decrease in soil reaction, especially metals dissolve and pose a threat to plants (Figure 4).

Especially in arid and semi-arid climate conditions, in soils where precipitation is insufficient but evaporation from the soil is high, salinity is an inevitable condition. In particular, use of poor-quality irrigation water and unconscious fertilization practices are among the causes of soil salinity. Technically, soil salinity begins when the soluble salt concentration of the soil solution exceeded a critical value. The alkalinity starts when the exchangeable sodium percentage of soil solution exceeded a certain threshold. Although it is possible to reclaim saline and alkaline soils, it requires technical skill and economic potential.



Darker shading indicates greater availability.

Figure 3: Availability of plant nutrients depending on soil reaction (Anonymous, 2021)

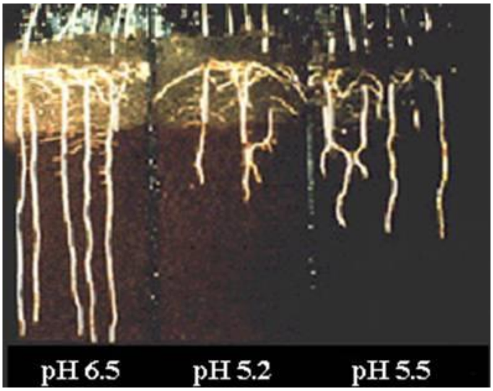


Figure 4: Cotton Root Growth Restriction Due To Acid Sub-Soil and Aluminum Toxicity (Anonymous, 2011).

2. SOIL REQUIREMENTS OF MEDICINAL AND AROMATIC PLANTS

2.1. Citrus Bergamia

The root system is made up of a tap-root, from which arises plagiotropic secondary roots; in sandy soils it may penetrate down to 5–6 meters but in clay soil the penetration is shallower (Rapisarda and Germano 2014).

The soils in which deep and strong roots are formed as to best intake available water and oxygen are preferred in bergamot cultivation. Proper pH range for bergamot cultivation is between 6.5 – 7.5. The pH is an important parameter in controlling the activity of microorganism responsible for conversion of organic matter into humus. Bergamot grows well also in sand soils as long as fertilized frequently and water loss was eliminated through proper irrigation procedures. Roots could penetrate deeper into the soil profile in sandy soils and fruit set increases accordingly (Gazea 2014).

In a study conducted on oil yield and chemical composition (quality) of bergamot (*Citrus bergamia* Risso) fruits, soil samples were taken from 25 bergamot orchard for 3 years to evaluate soil chemical and physical parameters and fruit samples were taken to determine oil yield and quality. Collected data were subjected to regression analysis in which pedological parameters were considered as independent variables and yield and essential oil components were considered as dependent variables. The results revealed that soil texture directly influenced the yield and mainly the bergamot oil components. High sand had an adverse effect by decreasing linalool and linalyl acetate percentages and increased limonene content, which is only marginally responsible for the odor (Intrigliolo et al., 1999).

2.2. Basil

Basil grows in different soil types with a pH of between 4.3 and 8.2. Basil prefers moderately fertile or humus-rich, well-drained loamy or sandy-loam soils. Soils with good physical properties and high-water holding capacity are suitable for basil cultivation. Submerged lands with poor drainage should always be avoided (Putievsky and Galambosi, 2005). Well-drained soils encourage vegetative growth (Pushpangadan and George, 2012).

2.3. Thyme

Thyme prefers light-textured, dry calcareous soils. They thrive in poor soils and can tolerate drought. If the soil pH is below 5.5, it is recommended to apply agricultural lime to the soil before planting (Stahl-Biskup and Venskutonis, 2012).

In a study conducted in Central Otago region of New Zealand, relationships between thyme spread and soil properties were investigated. Quite widespread of thyme was encountered in areas where sand content and average grain diameter increased. It was also observed in the same study that the thyme spread outward decreased with the decrease in sand content. It was observed that soil moisture was significantly lower in areas where thyme spread was encountered and increased from the edge of thyme spread to the outside (Nielsen et al., 2014).

2.4. Oil Rose

Although roses are not very selective in terms of soil, they prefer fresh, loamy soils rich in organic matter. These soils are easy to cultivate. Roses can generally be grown in any garden soils. However, they do not grow only in extreme conditions such as clay, sandy or very calcareous soils (Hüsnü et al., 2014). Oil rose shows quite a well development especially in sandy-loam, deep, slightly calcareous and permeable soils with sufficient organic matter contents and pH values of between 6-7 (Baydar, 2016).

2.5. Mint

Mint can survive in a wide variety of climate and soil conditions, but it is important to create suitable conditions for an economic production. The best soil types for growing mint are deep, well-drained, loose-textured, with sufficient organic matter content and a pH range of 6.0 to 7.5. Although mint prefers well-drained soils, it also requires soils that can retain sufficient moisture under normal irrigation regimes. High sand contents usually require more irrigation to keep mint roots moist. High clay contents reduce root penetration and tend to retain too much moisture, which causes root rot. Soil type also affects soil temperature, which is an important factor for a shallow-rooted crop such as mint. In fact, soil temperature is thought to have a greater effect on plant growth than ambient temperature because roots are more sensitive to extreme temperatures (Morris, 2007).

Taneja and Chandra (2012) indicated that mint required high levels of nutrients to grow, therefore, loamy-sandy loam soils rich in organic matter and high in nutrients, with a pH of between 6.5-8.0 are suitable. Ayhan and Altınkaynak (2020) stated that mint could practically be grown in any soils with a pH of between 4.5 - 8.3, but the soil should contain a normal level of moisture.

2.6. Blueberry

A natural blueberry soil is loamy or sandy loam (> 70% sand; < 15% clay), with a pH of about 5.5 and organic matter content of greater than 4%. Such soils also have a high polyphenol content and specific rhizosphere flora and fauna that may support blueberry plant growth and development (Gough, 1994).

When the soil pH starts to rise above 5.2, nitrogen is converted from the useful acidifying ammonium form into the nitrate form. In this case, since the availability of iron in the soil will decrease, it becomes unusable by the plant and iron chlorosis becomes a problem. Such a case also negatively influences chlorophyll synthesis (Gough, 1994) (Figure 5-6).

Figure 5: The row of yellowed plants in the foreground has high soil pH while the ones in the background are in lower soil pH (Pscheidt, 2008).

Low soil pH can also be a problem. At low soil pH, soil aluminum becomes more available, which inhibits the plant's nitrogen and phosphorus uptake and possibly also iron uptake (Pscheidt and Ocamb, 2021). It is already known that soil reaction influenced the diversity and solubility of many chemical substances (elements, compounds, etc.) in the soil (Kayıkçıoğlu, 2021).

Figure 6: These are symptoms of iron chlorosis from inadequate levels of iron due to a high soil pH (Pscheidt, 2008).

CONCLUSION

In this chapter, soil requirements of some medicinal and aromatic plants were emphasized. As can be inferred from the present examples, soil properties played as much important role as climate, water quality, genetic material etc. factors in cultivation of medicinal and aromatic plants. Knowing the soil for the target plant and choosing the appropriate soil accordingly will mean preventing the negative issues from the beginning.

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CHAPTER 7

SOME PLANTS OF AEGEAN REGION FROM TURKEY: PHYTOCHEMISTRY AND ITS USE IN HEALTH CARE

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Juniperus macrocarpa SİBTH. & SM.

Vulgar name

Prickly juniper, plum juniper, cade juniper, red berry juniper, cada

Classification

Order: Pinales; Family: Cupressaceae; Genus: *Juniperus*.

Origin

The genus *Juniperus* L. has a total of 52 species, with the majority in the temperate zone of the northern hemisphere of the world and 11 taxa including 8 species and three subspecies in Turkey. *Juniperus oxycedrus* L. (Cupressaceae) (prickly juniper, plum juniper, cade juniper, redberry juniper, cada) is a shrub or small tree native across to the Mediterranean region from Morocco and Portugal east to western Caucasus, growing on a variety of rocky sites from sea level up to 1600 m altitude (Orhan et al., 2011). Three subspecies: oxycedrus, macrocarpa (Sm.) Balland badia (H. Gay) Debeaux of *J. oxycedrus* are mentioned in the Flora Europea; in the Flora of Turkey two subspecies, oxycedrus (Joo) and macrocarpa (Jom) were found (Amaral-Franco, 1993; Farjon, 2000). After the revision studies made in Turkey, the subspecies known as *macrocarpa* has been changed to species epithet (Kandemir, 2018).

Uses in traditional or folk medicine

Juniperus false fruits, female cones -improperly called "berries" - are used as spice, mainly in European cuisine; they are used in Northern European and particularly Scandinavian cuisine to impart a sharp, clear flavour to meat dishes (Loizzo et al., 2007). Taviano et al. (2013)

indicated the phenolic profile and some biological properties of the ripe "berries" methanol extracts of Joo and Jom from Turkey as three fold higher in Jom (17.89 ± 0.23 mg GAE/g extract) than in Joo (5.14 ± 0.06 mg GAE/g extract). In folk medicine *J. oxycedrus* berries have widely been used in the treatment of gastrointestinal disorders, common colds, as expectorant in cough, to treat calcinosis in joints and as diuretic to pass kidney stone, against urinary inflammations, hemorrhoids, and as hypoglycemic; leaves and berries are applied externally for parasitic disease (Sezik et al., 1997, Loizzo et al., 2007; Akkol et al., 2009). Leaves, resin, bark and berry extracts of J. oxycedrus were found to inhibit the growth of numerous microorganisms (Karaman et al., 2003). At the same time, J. oxycedrus is commonly used for the preparation of traditional medicinal brandy in Dalmatia (Öztürk et al., 2011). In Turkey, Joo berries are consumed for treatment of diabetes; while powdered berries and leaves are used internally as tea (Orhan et al., 2012).

Although Jom has been reported to have a variety of uses in studies conducted in different countries, the essential oil composition of fruits harvested from Turkey is not found in any study. The essential oil composition of leaf samples harvested from different months of plants collected from the Ciftlik Village in Cesme - Izmir, Turkey, which is very close to the area fruit samples, were collected and it was revealed in a study conducted by Sezik et al. (2005). Because the berries of *Jom* are eaten in Turkey (Öztürk et al., 2011), and in folk medicine the ripe berries of this species were used as diuretic to pass kidney stones. In the present experiment the essential oils of the ripen and unripen berries of Jom growing in Turkey were focused and their chemical compotitions were determined (Tort S. et al., 2019).

Chemical composition of essential oils of berries

Table 1 shows sum up the yields (v/w, dried weight) of essential oil and chemical content (% w/w) of the different samples of Juniperus. The yield obtained from the unripen berries of *J. macrocarpa* was 0.03% (100 g berry), while ripe berries exhibited a lower yield with 0.006% (200 g berry) by Clavenger method. In the results of present study, the content of monoterpenes was lower in the ripe berries (5.15%) than in unripe berries (20.9%) with higher (1.2%) oxygenated monoterpene content in ripe berries (1.11%). Generally, the maximum yields were obtained bydistilling ripe berries of *J. phoenicea* ssp. *turbinata* and *J. communis* except for *J. oxycedrus* ssp. *oxycedrus* (Joo), whose maximum yield was obtained by distilling unripe berries. The content of monoterpenes was lower in the ripe and unripe berries (81.88 and 83.51%, respectively) than in the leaves (95.58%) and sesquiterpenes were higher in ripe and unripe berries, (14.79 and 13.89%, respectively) than in the leaves 1.00% (Angioni et al. 2003). Sesquiterpenes was lower (65.23%)content in unripe berries, while (90.66%) were present in ripe berries of Jom. Also in this study, sesquiterpenes were higher in ripe and unripe berries (90.66 and 65.23%, respectively) than monoterpenes (5.15 and 20.9%, respectively). In all samples, α-cedrol (49.87%) was the main component in ripe berries, and 30.04% in unripe berries while α-pinene was the main component (85.95% in leaves, 70.64% in ripe berries and 62.26% in unripe berries) in Joo (Angioni et al., 2003). In the present results α-pinene, α-campholene aldehyde, trans-pinocarveol, camphene, α-cubabene, germacrene-d, α-cedrol and γ -muurolene were similar in all berries. α-cedrol was higher in the ripe berries than unripe ones (49.87 versus 30.04%). The content of α-pinen was higher in unripe berries than ripe berries (18.81% versus 1.13%) of J. macrocarpa. D-germacrene was higher in the unripen berries than ripen ones (14.58 versus 0.90%). Trans-pinocarveol was higher in ripe berries than unripe berries (1.2 versus 0,54%) of Jom. In the present study β-pinen, sabinene, 3-carene, limonene, β-phellandrene, α-terpinolene, α-copaene, trans-α-bergamotene, germacrene, trans-caryophyllene, (-)-thujopsen, +calerene, β-cubanene, 3-thujen 2-ol, α-humulene, α-amorphene, bicyclo germacrene, γ -elemene, δ-cadinene, γ-cadinene, cadina-1,4 diene, copaene, valencene, caryophyllene oxide, salvial-4(14)-en-1-one, α-ylangene, limonene, β-silinene, α-longipinene, epi-bicyclosesquiphellandrene, trans-caryophyllene, solanesol were only found in unripe berries of J. macrocarpa, while α-cedrene, carvacrol methyl ether, (1R)-(-)-myrtenal, α-phellandrene, α-muurolene, cuparene, calacorene, β-caryophyllene were found in ripe berries of *J. macrocarpa*.

The seasonal differences of oils of Jom leaves were 84.6%, in May, 95.2% in August, and 0.1% in October samples rich in manoyl oxide (7.7 - 21.9%), α-pinene (7.2 - 11.1%), α-cedrol (2.3 - 9.7%), widdrene (2.1 - 5.7%), α-muurolene (4.1 - 4.8%), trans-verbenol (1.7 - 4.3%), germacrene D (1.5 - 4.1%), δ-cadinene (3.2 - 3.8 %), α-campholene aldehyde (1.7 - 3.2%), trans-pinocarveol (1.5 - 3.0%), cubebol (1.4 - 2.4%), caryophyllene oxide (1.5 - 1.9%), δ-cadinene (1.0 -1.8%), β-caryophyllene (0.7 - 1.8%), and epi-cubebol (1.0 - 1.4%). Main component of ripe and unripe berries was α-cedrol (49.87 and 30.04%, respectively), although it was present in August samples of leaves of the same species (Sezik et al. 2005). α-cedrol ratio was; in May (2.3%), in August (9.7%) and in October (3.4%) in the leaves of Jom likely as the berries of *J. macrocarpa*. Similarly in ripe berries α-pinene content was higher than unripe berries of Tunusian *Jom* while myricene, β-phellandrene, β-pinene, respectively in unripe berries (Medini et al., 2010).

Table 1. Percentage composition of essential oil of dry ripen and unripen fruits of *J. macrocarpa*.

Compounds	RI_a		% content		Identification method
	Ripen	Unripen	Ripen	Unripen	
			Monoterpenes		
α-pinen	1048 1017		1.13 18.81		GC-MS
Carvacrol methyl ether	1522		1.4		‘’
α-campholene aldehyde	1081 1592		0.96 0.22		‘’
α-phellandrene	1071		0.93		‘’
Camphene	1055 1049		0.43 0.09		‘’
(1R)-(-)-myrtenal	1178		0.30		‘’
3-carene					‘’

	1034	1.01	
β- pinen	1080	0.55	‘’
α-terpinolene	1525	0.17	‘’
Sabinene	1019	0.05	‘’
Oxygenated monoterpenes			
Trans-pinocarveol	1027 1554	1.2 0.54	GC-MS
3-thujen 2-ol	1538	0.23	GC-MS
Caryophyllene oxide	1573	0.34	GC-MS
Sesquiterpenes			
α- cedrol	1583 1563	49.87 30.04	GC-MS
β-caryophyllene	1505	29.57	‘’
α-cedrene	1087	4.75	‘’
γ- muurolene	15.35	2.54	‘’
α- cubabene	15.80 1082	0.98 0.17	‘’
α- muurolene	1025	1.04	‘’
D-germacrene	1510 1568	0.90 14.58	‘’
Cuparene	1543	0.58	‘’
Calacorene	1551	0.43	‘’
δ- Cadinene	1559	3.80	‘’

β- Cubenene	1062	0.66	‘’
Copaene	1567	0.54	‘’
(-)-Thujopsen	1583	0.49	‘’
β-silinene	1575	0.45	‘’
α-humulene	1548	2.29	‘’
Cadına-1,4 diene	1518	0.39	‘’
α-longipinene	1525	0.37	‘’
γ-muurolene	1568	2.27	‘’
epi-bicyclosesquiphellandrene	4520	1.69	‘’
trans-caryophyllene	1544	1.68	‘’
Valencen	1542	1.53	‘’
α-amorphene	1528	1.12	‘’
Bicyclo germacrene	1557	1.04	‘’
α-ylangene	1538	0.66	‘’
trans-α-bergamotene	1575	0.29	‘’
+calerene	1029	0.26	‘’

Salvial-4(14)-en-1-one	1837	0.22	‘’
α-copaene	1508	0.21	‘’
Limonene	1077	0.19	‘’
Germacrene	1518	0.12	‘’
β-phellandrene	1015	0.09	‘’
γ-elemene	1538	0.08	‘’

a Retention indices in elution order from DB-5 colum.

According to the present results, unripe berries were rich in α-cedrol (30.04%), α-pinene (18.81%), germacrene-D (14.58%); α-cedrol (49.87%), β-caryophyllene (29.57%), α-cedrene (4.75%) were identified from ripe berries. It was concluded that the yield and the composition of the *J. oxycedrus* essential oils depend on the origin of the plant; e.g. while the leaves from Elaphonios (Greece) were rich in α-pinene (26.94%) and α-cedrole (13.88%) (Stassi et al., 1995), α-cedrol was shown only in berries of *J. macrocarpa*. β-Myrcene, α-pinene, and DL-limonene and germacrene D were indicated in berries of different countries (Guerra-Hernandez et al., 1987; Cavaleiro, 2001; Koukos et al., 2002; Salido et al., 2002; Valentini et al., 2003; Asllani, 2004,; Hajdari et al., 2014). The variations were related to genetic and climatic factors, soil conditions, phase of growth (vegetative or flowering stage), and part of the plant (Nemeth, 2005).

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A relict endemic shrub from tertiary period

Flueggea anatolica Gemici

Vulgar name

Kadıncık çalısı

Classification

Order: Malphigiales, **Family:** Euphorbiales, **Genus**: Fluegga.

Origin

Flueggea is primarily an Old World genus. The genus *Flueggea* has almost 15 species worldwide, with extending into warm temperate zones at tropics and subtropics regions.

The overall distribution of the genus is relicttual. *F. anatolica* is closely releated to *F. virosa* is a widespread paleotropically the nearest species to *F. anatolica*, being present around the Nile river in Egypt. *F. anatolica*, can be regarded as a Tertiary elict and Southern Anatolia harbours other such species, e.g. *Ajuga postii* and, further away in SW Anatolia, *Liquidambar orientalis* (Gemici and Leblebici, 1994).

Flueggea anatolica (Gemici and Leblebici, 1994; Gemici, 1993) is a relict paleoendemic or conservative endemic shrub emnant from Tertiary and includes Euphorbiaceae (Lawrence, 1971) which consists of monoic or dioic herbs, brushes and trees which have laticifer. Leaves are alternate, rarely decussate and verticillate, simple or united, most of all stipulate. Flowers are solitary or in groups of spika or panicula. Sepals at male flowers are in 0-5 numbers, free or united; petals 0-6, sometimes united. They have one or a lot of stamens. Sepals at female flowers are 0-6, free, petals are 0-6 and gynekeum has one pistyll.

Flueggea anatolica is a dioic brush which can reach 5 m height of up. They have never thorns or hairs. Leaves are spirally arranged, petioled and oval or elliptic shaped, 2.5-6.5 cm × 1.5-3.5 cm long. Flowers are at the leafy branches with the groups of 13 flowers, female flowers are in the groups (Güner et al., 2000; Gemici and Leblebici, 1994; Gemici, 1993).

F. anatolica is known only from the type locality and from an area of approximately 7000 m^2. The number of individuals is approximately 500. Therefore, it should be regarded as belonging to World Conservation Union (IUCN) Critically Endangered (CR) threat category (IUCN, 2001).

Plant specimens were taken from the north of Tarsus (Icel) valley of Kadincik (37°05' N, 34°47' E) in 1998 and autenticated by Yusuf Gemici of the Section of Botany, University of Ege (Gemici: 6330). Voucher specimens have been deposited in the Herbarium of the above-cited department (No; EGE 33639).

Uses in traditional or folk medicine

The medicinal use of Flueggea sp. comes from bergenin, a C-glucoside of 4-O-methyl gallic acid. Bergenin isolated from aereal parts of *Flueggea virosa* exhibited antiarrhythmic activity (Pu et al., 2002) and bergenin and norbergenin, two isocoumarins isolated from the leaves and roots of *Flueggea microcarpa* Blume gave significant protection again pylorus ligation and aspirin induced gastric ulcers in rats because of the increased prostaglandin production (Dahanuka et al., 2000). The roots of *Flueggea virosa* Roxb. Ex Willd, have been used for a treatment of rheumatism, pruritus, cephalic eczema, leucorrhoea injuries and is known as a traditional Chinese medicine (Li and Zhi, 1984). Flueggenins A and B, C, C-linked dimeric indolizidine alkaloids isolated from the roots *F. virosa* and showed strong cytotoxicity, only A showed weak activity against the P-388 tumor cell line (She et al., 2006). Bergenin was found also to inhibit the powdery mildew isolated from *Flueggea microcarpa* Blume and have antifungal effects against the plant pathogenic fungi, namely, *Alternaria alternata, A. brassicae, A. carthami, Fusarium udum, F. oxysporum* f.sp. *ciceri, Curvularia lunata* and *Erysiphe pisi* (Prithiviraj et al., 1997).

Because of the resistance acquiries and genetic transmitting abilities of bacteria to drugs which are utilized as therapeutic agents, antibacterial and antifungal drugs have gain great importance in drug industry. Although new synthetic chemical antibiotics have been produced last three decades, resistance to these drugs by microorganisms has increased (Cohen, 1992). The use of plant extracts and phytochemicals, both with known antimicrobial properties, can be of great significance in therapeutic treatments by studies conducted in different countries (Ikram and Inamul, 1984; Almagboul et al., 1985; Sousa et al., 1991; Kubo et al., 1993; Shapoval et al., 1994; . Izzo et al., 1995; Digrak et al., 2011). The microbial traits of many plants come from the secondary metabolism of plants known as phenolic compounds which are parts of the essential oils (Jansen et al., 1987) as well as tannins (Saxena et al., 1994). In this study, chloroform extracts prepared from the leaves of *Flueggea anatolica* plant were evaluated for the first time for antibacterial and antifungal activities (Gemici et al., 2010). F. anatolica is facing a threat of extirpation as well as the other tertiary endemics, like *Liquidambar orientalis*.

Antimicrobial and antifungal activity:

The antimicrobial activity of *F. anatolica* Gemici was given in Table-1. As can clearly be seen from this Table-1, the extract provided from the leaves of *F. anatolica* were found to be effective against *Echerichia coli* ATCC-12228, *Pseudomonas aeroginosa* ATCC-27853, *Proteus vulgaris* ATCC 29905 as gram-negative bacteria and *Candida albicans* ATCC-10239 yeast-like fungus, showing MIC values 0.0025 µg/mL for *E. coli* and yeast-like fungus and 0.005 µg/mL for *P. vulgaris* and *P. aureginosa*. However, *F. anatolica* was not effective against *B. subtilis* ATCC-6633, *S. thyphimirium* CCM 5445 and *S. aureus* ATCC-6538-P as gram-positive bacteria.

Table-1.Antimicrobial effect of *Flueggea anatolica* GEMICI

Microorganisms	Minimum inhibitory concentration (MIC)		
	Extract (µg/mL)	Gentamycin (µg/mL)	Clotrimazole (µg/mL)
Bacillus cereus CCM 99	-	1.25	n.t*
Escherichia coli ATCC 12228	0.0025	1.25	n.t
Salmonella thyphimirium CCM 5445	-	1.25	n.t
Staphylococcus aureus ATCC 6538-P	-	1.25	n.t
Proteus vulgaris ATCC 29905	0.005	1.25	n.t
Pseudomonas aureginosa ATCC 27853	0.005	2.5	n.t
Candida albicans ATCC 10239	0.0025	n.t	0.78

*: not tested.

The microorganism *E. coli* which is already known to be multi-resistant to drugs had its growth inhibited by the extract of *F. anatolica*. On the other hand, *P. aeroginosa* (Chandler et al., 1982) which is also resistant to different antibiotics, had its growth inhibited also by *F. anatolica* extract. Such results are interesting because the control of these bacteria was noticed to be very difficult by therapeutic means (Chandler et al., 1982). While the control of resistant bacteria is becoming a threat to human health, the studies regarding the mode of action for these compounds in the bacterial cell should be done. The synergistic effect of *F. anatolica* extract from the association of antibiotic against resistant bacteria will lead to new choices for the treatment of infectious diseases. This effect enables the use of respective antibiotic when it is no longer effective by itself during therapeutic treatment. Many plant phenols are reported as fungi-toxic agents and the action of bergenin isolated from *Flueggea microcarpa* (Kumar et al., 1985) can be declared to be similar to that of other phenols. Yeast and antifungal activity evaluate together and tannins can be toxic to filamentous fungi, yeast and bacteria (Cowan, 1999). Condensed tannins have been determined to bind cell walls of ruminal bacteria, preventing growth and protease activity (Jones et al., 1994).

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Styrax officinalis **L.**

Vulgar name

Tesbi shrub, snowdrop bush, bear nut.

Classification

Order: Ericales**, Family:** Stracaceae, **Genus:** *Styrax officinalis*.

Origin

Styrax officinalis L. (Styracaceae) is a small deciduous tree (up to 4 m) only found around the Mediterranean region and in East and South-Eastern Asia (Fritsch, 1999). When the distribution of this plant in Turkey and the Mediterranean region was compared with world distribution, it was concluded that they originally had the same environmental distribution in North America before the continental drift that occurred at the beginning of the Cretaceous when North America was separated from Europe (Melville, 1967). The presence of a tropical species on both continents has been ascribed to the fact that climate and physiological formations of the Mediterranean region and California are similar. Because the evolution rate of this species was rather slow with a high adaptability to terrestrial habitats, the interregional variations were greater than the inter-continental variations (Vardar & Oflas, 1973). Moreover, the distribution of this species was demonstrated not only in the Mediterranean region, but also in the sub-Mediterranean region and even in terrestrial zones such as Konya, located in the western part of Central Anatolia, and Adıyaman, located in the northern part of South-Eastern Anatolia.

Uses in traditional or folk medicine

At first glance, it is a lower element of forest areas with a wide distribution and has seeds rich in oil content, making it industrially important. Benzofuran glycosides were isolated from the seeds of *Styrax officinalis* (Anıl, 1980; Akgül & Anıl, 2003), and benzofurans and sterol were isolated from the seeds of *Styrax obasia* Siebold &

Zucc. (Lee et al., 2008). In addition, *Styrax officinalis* is known to produce resinous material usually secreted when the barks and trunks are injured by sharp objects (Correa, 1931). The species, a relict dating from Mesozoic era, has resinous materials such as "Siam benzoe" from *Styrax tonkinensis* (Pierre) Craib ex Hartwich, "benzoe" from *Styrax benzoides* Craib, "Sumatra benzoe" from Styrax benzoin Dryand., and "storax" from *Styrax officinalis* L. (Tschirsch, 1923; Perkins, 1907; van Steenis, 1932; McKechnie, 1959; Milne & Milne, 1967). However, species distributed in Turkey do not include resinous material or resinous channels (Zeybek, 1970). *Styrax* and benzoin balsams have been widely employed since ancient times by the Romans (Gianno et al., 1990; Modugno et al., 2006), Egyptians, and Phoenicians to treat chronic infections of the respiratory tract, due to the therapeutic and pharmacological properties of the species which include disinfectant, expectorant, and vulnerary activities (Modugno et al., 2006). Nowadays, their use is extended to perfumery and fixative agents, whilst their antioxidant and organoleptic properties are valued in the cosmetic and food industries for conservation and improvement of flavour (Fernandez et al., 2003, 2006a, 2006b; Castel et al., 2006). Due to the great economic importance of its resinous benzoin substance, in the present study we have tested different agents such as boric acid and cocarboxylase (thiamine diphosphate), extensive stimulators of resin channels, in order to increase the amount of benzoin volatile oil in in vitro grown stem tissues of *Styrax officinalis*.

Chemical composition of essential oils of petiol calli

Tissue culture is one of the biotechnological methods applied for the production of volatile compounds such as essential oils, flavours, and volatile isolates in addition to volatile aldehydes and alcohols that are more easily produced by cultured, genetically modified microorganisms (bacteria, algae, and fungi, including yeast) (Guanaris, 2010; Namdjoyan et al., 2012; Yamaner et al., 2013). Benzoin is a hydroxy ketone attached to 2 phenyl groups. It appears as off-white crystals and has a light camphor-like odour. It is synthesised from benzaldehyde in the benzoin condensation. Benzoin is not a constituent of benzoin resin obtained from the benzoin tree (*Styrax*) or tincture of benzoin. The main component in these natural products is benzoic acid (Adams & Marvel, 1941).

It is indicated that even under the optimum induction conditions the yield of essential oil by in vitro plant tissues and cells was generally less than that achieved by the intact untreated plant, and the inability of cultured plant cells and calli to accumulate significant amounts of monoterpenes could be due to the combined effect of lower enzymatic activity and their higher catabolic rate (Falk et al., 1990). Because they are the enzymes of the volatile aldehyde and alcohol synthesis path, the activity of lipoxygenase and hydroperoxide lyase has been found in in vitro-cultured plant tissues (Matsui et al., 1996; Williams & Hardwood, 1998; Fauconnier et al., 2001). Therefore, we obtained successive increases with the applied induction media, one with excess boron plus niacin (120%) and the other with cocarboxylase enzyme (231%), depending on the intact plant benzoin content (90%).

Because the species of the genus *Styrax* were not commonly studied for their essential oil and resin contents, it is not easy to compare our results with the results of other studies. To date, all of the studies have been performed on the leaves of *Styrax officinalis*. The volatile oil contents of *Styrax japonica* were determined by Kim and Shin (2004) and those of *Styrax officinalis*, known to be rare in France (they are found only in a few locations in the south-east of France) were reported by Tayaub et al. (2006). The oil composition obtained by steam distillation of leaves exhibited high levels of 2-hexenal (64%), n-hexanal (4.6%), nerol (4.6%), 3-hexen-1-ol (4.3%), and trans-2-heptenol (2.6%). Only one paper concerned with essential oil composition of stem of *Styrax* from south-eastern France indicated that oxygenated monoterpenes were prominent in all of the plant organs. The major compounds of the essential oils of the leaves were 2-hexenal (17.6%), linalool (11.9%), and geraniol (5.5%). While linalool was the major compound (26.4%) of the volatile oils of the flowers, tridecanal (9.8%), dodecane (9.6%), α-terpineol (17%), and eugenol (9.9%) were also present (Tayaub et al., 2006). Natural essential oils are usually mixtures of terpenoids (mainly monoterpenoids and sesquiterpenoids), aromatic compounds, and aliphatic compounds. *Styrax* is an aromatic plant that produces high levels of essential-oil–containing aliphatic aldehydes. Decanol, the dominant aldehyde that contributes to the flavour of the benzoin tree, was identified as a natural source of aliphatic aldehydes, which could be useful as food additives and in the perfume industry. Benzyl alcohol, one of the better known aromatic alcohols, which occurs in storax (a resin obtained from the Styrax officinalis tree) and also in balsam of Peru and balsam of Tolu—either in the free state or as an ester in combination with cinnamic or benzoic acid (Maki & Takeda, 2000) was found in the stem tissue of calli, with or without applied enzymes. Ethylbenzene and propylbenzene (in enzyme-applied calli) and p-xylene (in calli with or without applied enzymes) occurred as aromatic hydrocarbons. Methylcyclopentane and 1,1-dimethylcyclopentane were found as monocyclic terpene cyclopentane derivatives (Crane, 1955) in enzyme-applied calli and calli with or without enzymes applied, respectively. In addition to these compounds, methylcyclohexane and cyclohexane were the monocyclic terpene hydrocarbons determined in Styrax stem tissues with or without enzymes applied.

In this preliminary tissue culture study of *Styrax officinalis* from West Anatolia, the major essential oil components of excess boron- and niacin-induced stem calli were hexane (58.33%), 3-methyl-2-pentene (16.10%), and cyclohexane (8.88%). The volatile oil composition was changed by cocarboxylase enzyme application, and the compounds hexane (62%), methylcyclopentane (19.09%), cyclohexane (12.04%), 2-hexanone (0.04%), ethylbenzene (0.03%), and 1-chloro-2-methylpropyl benzene (propene) were provided. Cyclohexane was found in each of the different calli tissues, but its ratio increased to 12.04% with enzyme application; acetone (0.03%), ethyl acetate

(4.10%), and dichloromethane (0.17%) contents were high as compared with the results of boron-plus-niacin–induced calli tissues. Decane and benzyl alcohol were present in the 2 different calli, but percentages decreased with enzyme application.

Apart from their nonoxidative and oxidative decarboxylation of 2-ketoacids, the formation of chiral 2-hydroxy ketones has been established for thiamine diphosphate dependent enzymes (Pohl et al., 2004). The cause of the increase in benzoin resin content is thiamine diphosphate enzyme. *Styrax* benzoin resins can only be produced after deep incisions have been made into the bark of the trees belonging to the genus *Styrax* (family Stracaceae), which are endemic in numerous East Asian countries such as Indonesia (Sumatra and Java), Laos, Thailand, and Vietnam. For the first time on record benzoin was identified in *Styrax officinalis* distributed in Turkey (Kemalpaşa), and the benzoin content of in vitro grown plant materials increased both excess-boron-plusniacin and cocarboxylase treatments (Demiray et al., 2013).

The major essential oil components of excess boron and niacin and also cocarboxylase-enzyme–induced stem calli are compared in **Table 1**. Hexane (58.33%– 62.19%), cyclohexane (8.88%–12.04%), acetone (0.02%–0.03%), dichloromethane (0.16%–0.17%), and acetonitrile (0.03%–0.04%) were found in both calli induced with media supplemented with enzymes and in those without any enzymes. Increases in the ratio of compounds were seen, as mentioned above. However, 1,1-dimethylcyclopentane (0.56%–0.25%); decanol

(0.02%–0.01%); acetic acid, butyl ester, or butyl acetate (0.03%–0.02%); p-xylene (0.03%–0.02%); l-butanol (0.56%–0.42%); and benzyl alcohol (0.04%–0.02%) ratios decreased with enzyme application while they were also present in the 2 different media. While 3-methyl-2-pentene, ethyl acetate (16.10%); ethyl acetate, acetic acid, ethyl ester (3.98%); propanoic acid, ethyl ester, or ethyl propanoate (0.01%); 4-methyl2-pentanone (0.06%); benzene, 1,2 dimethyl-xylene (0.02%); and benzyl chloride (0.28%) were only present in calli induced with excess boron and niacin, cyclopentane (1.19%), methylcyclopentane (19.09%), ethyl acetate (4.10%), 2-hexanone (0.04%), propanenitrile (0.01%), and (1-chloro-2 methyl) propylbenzene (0.15%) were only found in excess boron and niacin-with-cocarboxylase–induced *Styrax* stem calli (Table 1).

Table 1. GC-MS values of stem calli of *Styrax officinalis* with and without cocarboxylase enzyme; nd: not determined, RI[a]: polar retention index value; RI[b]: apolar retention index value.

Compounds	Nodal bud calli	Nodal bud calli + cocarboxylase enzyme	Identification methods	RI[a]	RI[b]
Hexane	58.3	62.19	GC-FID, GC-MS	599	572
Cyclopentane	-	1.19	GC-FID, GC-MS	580	575
Methylcyclopentane	-	19.09	GC-FID, GC-MS	575	571
3-Methyl-2-pentene	16.10	-	GC-FID, GC-MS	nd	nd
1,1-Dimethylcyclopentane	0.56	0.25	GC-FID, GC-MS	714	709
Cyclohexane	8.88	12.04	GC-FID, GC-MS	647	639
Methylcyclohexane	0.02	0.02	GC-FID, GC-MS	656	651
Acetone	0.02	0.03	GC-FID, GC-MS	459	454
Ethyl acetate	-	4.10	GC-FID, GC-MS	589	583

Ethyl acetate, acetic acid, ethyl ester	3.98	-	GC-FID, GC-MS	nd	nd
Dichloromethane	0.16	0.17	GC-FID, GC-MS	415	408
Benzene	0.02	0.02	GC-FID, GC-MS	638	635
Propanoic acid, ethyl ester, or ethyl propanoate	0.01	-	GC-FID, GC-MS	nd	nd
Decanol	0.02	0.01	GC-FID, GC-MS	1272	1743
2-Hexanone	-	0.04	GC-FID, GC-MS	805	760
4-Methyl-2-pentanone	0.06	-	GC-FID, GC-MS	nd	nd
Acetonitrile	0.03	0.04	GC-FID, GC-MS	466	461
Toluene	0.25	-	GC-FID, GC-MS	747	743
Propanenitrile	-	0.01	GC-FID, GC-MS	nd	nd
Acetic acid, butyl ester, or butyl acetate	0.03	0.02	GC-FID, GC-MS	1492	1480
Ethylbenzene	-	0.03	GC-FID, GC-MS	nd	nd
p-xylene	0.03	0.02	GC-FID, GC-MS	844	842
Benzene, 1,2-dimethyl-xylene	0.02	-	GC-FID, GC-MS	nd	nd
1-Butanol	0.56	0.42	GC-FID, GC-MS	558	553
Benzyl chloride	0.28	-	GC-FID, GC-MS	nd	nd
1-Chloro-2-methylpropyl benzene	-	0.15	GC-FID, GC-MS	nd	nd
Benzyl alcohol	0.04	0.04	GC-FID, GC-MS	1034	1032

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Chronanthus orientalis Heywood&Frodin (Lois.) **(Fabaceae): An Endemic Species of Turkey**

Vulgar name

Oriental clover

Classification

Order: Fabales, Family: Fabaceae, Genus: *Chronanthus orientalis*.

Origin

Turkey has about 10,750 vascular plant taxon and come to the fore in this aspect of geography. Floristic richness of this nearly 3,500 is endemic. This number forms 32 % of the total flora. Families contain more taxa of the flora of Turkey are: Compositae (1,215 taxa) and Leguminosae (Fabaceae) (1,071 taxa) and they constitute approximately one-fifth of our country's flora. In flora of Turkey, Leguminosae family are included in second place with around 400 endemic taxa. This study will form the basic material of the *Chronanthus orientalis* (Lois.) Heywood & Frodin includes also Leguminosae family. Genus *Chronanthus* contains only 2 species in the world. One of them, *Chronanthus biflorus* (Desf.) Koch, has the expansion in east-south Spain, Balarik Islands and the northwest Africa. Other species of in the single locality (Izmir Bozdag) known to grow (Davis, 1965-82) and takes place in the category of vulnerable according to Turkey Red Book (Ekim et al., 2000) is *Chronanthus orientalis* (Lois.) Heywood and Frodin. The name of *Chronanthus orientalis* is given to the plant as a result of new data provided to with the recent morphological and molecular systematic studies on the genus *Cytisus* by considering the nuclear and plastid DNA characters in mind (Cristofolini and Troia, 2006). According to the new nomenclature *Cytisus oritentalis* Desf. (Greuter et al., 1989; Davis, 1965-82) is synonym of our plant nomenclatured as *Chronanthus orientalis* (lois). Heywood and Frodin.

Uses in traditional or folk medicine

When used as dry and fresh, they have cardiotonic, cathartic, antioxidant, diuretic, emetic, purgative effects (Dang, 2007; Van Beek and Breteler, 1993). Quinolizidine alkaloids show a wide range of biological activities: they can inhibit the multiplication of viruses (Wink, 1987), the proliferation of bacteria (Wink, 1984; Tyski et al., 1988; De la Vega et al., 1996) and the growth of certain fungi (Wink, 1984; Wippich and Wink, 1985). Some allelopathic (phytotoxic) effects of quinolizidine alkaloids have been described, including the inhibition of the growth of competing plants[13-15] (Wink, 1983; Wink and Twardowski, 1992; Múzquiz et al., 1994). They can also deter a number of herbivores (nematodes, caterpillars, beetles, aphids, locusts, snails, rabbits and cows) but also pollinators such as bees (Gegear et al., 2007). Some are directly toxic or mutagenic (Wink, 1984; 1994). Deterrent or toxic effects of quinolizidine alkaloids such as sparteine, lupanine, cytisine and 13-tigloyloxylupanine against phytophagous insects have been evaluated in some detail on some Lepidoptera. Several authors suggest that acetylcholine receptors and Na+ /K+ channels are modulated by these compounds (Paolisso et al., 1985; Korcz et al., 1987; Wink, 1992; Wink, 1993). Tri- and tetracyclic quinolizidine (lupine) alkaloids have been used in folk medicine of eastern Asia and are nowadays of medical interest because of their oxytoxic and antiarrhythmic (sparteine, lupanine), hypoglycemic (lupanine), hallucinogenic (cytisine, N-methylcytisine), teratogenic (anagyrine) and inhibitory efects of natural killer cell growth (Raschack, 1974; Wink, 1987). Many publications have appeared in the last few years reporting the use of sparteine as a very efficient chiral diamine, demonstrating promising potential for asymmetric transformations of organometallic reagents to achieve enantioselective deprotonation, polymerization and carbonyl addition reactions (Rush et al., 1996; Klein et al., 1995; Lautens et al., 1993). The characteristics of quinolizidine alkaloids is known to be allelochemicals which are toxic to a variety of herbivores (Keeler, 1969; 1976; Wink, 1988; 1993; 1993; Wink and Witte, 1991) .

Chemical composition of *Chronanthus orientalis*

As a result of studies made so far on the phytochemistry of genus *Cytisus*: quinolizidine alkaloids (QA), (spartein, Lupa), fenetilaminler, isaflavonlar [genistein (Viscardi et al., 1984)], flavonoids, volatile oil, caffeic acid, p-coumaric acids, tannin and pigments were found. The characteristics of quinolizidine alkaloids is known to be allelochemicals which are toxic to a variety of herbivores (Keeler, 1969; 1976; Wink, 1988; 1993; 1993; Wink and Witte, 1991). Whereas alkaloid profiles are usually rather constant within a species, some variation is found in the patterns of different organs such as leaves as compared to seeds (Dolinger, 1973; Kinghorn et al., 1980;

Meissner and Wink, 1992; Wink, 1992; Wink, 1992; 1993). Quantitatively alkaloid levels vary diurnally and during the growth cycle (Wink and Witte, 1984). A previously reported postulate concerning the evolution of quinolizidine alkaloids and the detailed consideration of the chemical composition led to a revised dendrogram showing proposed phylogenetic relations within the subfamily Papilionoideae in general and the tribe Genisteae in particular (Salatino and Gottlieb, 1981). In the genera *Genista* and *Cytisus* (both commonly called broom) as well as *Laburnum*, quinolizidine alkaloids, including cytisine and sparteine, are common (Wink, 2003). The hepatotoxic pyrrolizidine alkaloids are found in this family (e.g., in members of the genus *Crotalaria*) (Mattocks, 1986).

The underivatized alkaloid mixture extracted from herb of *Chronanthus orientalis* Heywood and Frodin was investigated by capillary GC/MS for the first time. Among the known Fabaceae alkaloids of four structure types were identified. We identidied 11 alkaloids (one of them tentatively) (Table-1) (Güner et al., 2012) (Fig. 1). Some components remained unidentified due to the lack of reference substances and library spectra. The main alkaloids were sparteine (61.43 %) (Fig. 2), lidocaine (5.32 %) (Fig. 3), oxosparteine (4.65 %) (Fig. 4), lupanine (0.72 %) (Fig. 5). Spartein found (61.43 %) (Fig. 2) in C. orientalis comprised the major alkaloid of plant. The second major one was lidocaine. Here we can take attention to the lidocaine as being the new compound special to this species in the fabaceae family. By the way the alkaloids which are derived from ornithine and lysine are named "quinolizidine alkaloids" (Mann et al., 1994). They are characteristic secondary metabolites of the family of Fabaceae (Leguminosae) and are especially abundant in the tribes genisteae, sophoreae and thermopsideae (Wink et al., 1995). The genus *Cytisus* is known to produce this type of alkaloids (Wink, 2003).

Table-1 GC-MS analysis of *C. orientalis* alkaloids

Retention time	Relative (%)	Compare with Wiley GC/MS library*	Wiley GC/MS library (%) comparison*
10.773	61.43	Sparteine	91
11.002	7.70	-	-
11.227	1.54	-	-
11.357	5.54	-	-
11.559	1.88	-	-
11.842	5.32	Lidocaine	96
12.845	1.26	-	-
14.039	4.65	Oxosparteine	88
14.875	0.72	Lupanine	90
17.959	2.83	-	-
18.351	1.33	n-Octylphtalate	94

*Compounds with high comparison in Library scanning are identified.

We subjected to GC-MS analysis the underivatized alkaloid mixture, encouraged by the excellent results of Erdemoglu et al. (2009). These authors applied for the first time GC-MS to underivatized fabaceae alkaloids (from *G. vuralii* L. growing in Turkey) and demonstrated its advantages over the analysis of silylated samples, especially in identifying minor components.

Ten quinolizidine alkaloids were identified by capillary GCMS, namely, N-methylcytisine, cytisine, tetrahydrorhombifoline, 17-oxosparteine, 5,6-dehydrolupanine, lupanine, 17-oxolupanine, anagyrine, baptifoline and 13α-tigloyloxylupanine from *Genista vuralii*. 5 alkaloids (anagyrine, cytisine, N-formylcytisine, N-methylcytisine and lupanine) have been isolated and identified in aerial parts of *Genista tenera* (Martins et al., 2005). In our samples, we found only two of them: lupanine and oxosparteine. According to Martinez-Herrera et al. (2001); more than 25 alkaloids were detected from *L. flavoculatus*, *L. kingii*, *L. odoratus*, *L. pusillus* and *L. shockleyi* and sparteine, β-isosparteine, isolupanine, 5,6-dehydrolupanine, lupanine and anagyrine were found while lupanine and sparteine were detected as major alkaloids in *C. orientalis*. Ghania (2007) have determined the alkaloid profile of the plant *Cytisus purgans* growing in Algeria by GC-MS and improved the presence of lupinine, camoensidine, lupanine, sparteine, multifloine, aphylline, angustifoline, isolupanin, anagyrine, martine, ammodendrine, retamine, alkaloids. 44 quinolizine alkaloids were isolated from Egypt spreaded various species of Lupinus and lupanine and spartein was also identified in *C. orientalis* (El-Shazly et al., 2001; Wink and Carey, 1994) Quinolizidine alkaloids are the systematic markers of Papilionaceae subfamily and Genisteae tribus and this phylogenetic association was made by drawing the dendrograms of two plants (Salatino and Gottlieb, 1991). Alkaloid pattern of *Cytisophyllum sessilifolium* (Fabaceae-Genisteae) was revealed both the quinolizidin and adenocarpin alkaloids as being the important chemotaxonomic character for this species (Greinwald et al., 1991). Alkaloid patterns of *Genista cinerea* was demonstrated chemical dichotomy for the species of the section Spartioides: one group of species contained the α-pyrydone alkaloids cytisine. Spartioides: one group of species contained the α-pyridone alkaloids cytisine, Nmethylcytisine and anagyrine as major alkaloids, while the other group contained lupanine, 13-hydroxylupanine and its esters as main compounds (Van et al., 1995). The quinolizidin type alkaloids as common in Chronanthus orientalis as: 17-oxospartein and lupanin contained *Genista vuralii* demonstrated an antibacteraial effect against *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Staphylococcus aureus* and *Candida albicans*, *Candida krusei* antifungal effect (Erdemoglu et al., 2009). When we examined all above mentioned studies by different investigators included the structure of 170 quinolizidine alkaloids of *Orbanche rapum genistea* (Rascol et al., 1982), did not coincide any results of lidocaine alkaloid except found as a major alkaloid used as topical anaesthesia (Tan et al., 2011) in *Chronanthus orien*talis endemic species (Güner et al., 2012).

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Euphorbia anacampseros var. *tmolea*: An Endemic species of Turkey against *Aedes aegypti*

Vulgar name

Sütlüağu

Classification

Order: Euphorbiales, Family: Euphorbiaceae, Genus: *Euphorbia anacampseros* var. *tmolea*. M.S. Khan

Origin

The genus *Euphorbia* is the largest in the spurge family (Euphorbiaceae), comprising about 50 tribes, 300 genera and more than 2000 species; probably the highest species richness with a world-wide distribution (Mwine et al., 2013). They are widely distributed throughout both tropical and temperate regions and range in morphology from small, annual or perennial herbaceous plants to woody shrubs, lianas, trees and large desert succulents (Webster, 1994). In Turkey 108 'Euphorbia' taxa are known, 14 of which are endemic species. One of the endemics, *Euphorbia anacampseros* var. *tmolea* Boiss., occurs on Bozdag in Ödemis, Izmir, Turkey. It is a glabrous, glaucous, decumbent-ascending perennial herb or subshrub common to rocky slopes (sometimes present in *Pinus brutia* or *Quercus* forest), mountain steppe, phrygana, lake and stream sides, at elevations of 600-1900 m. It has several or simple stems arising from a woody stock reaching 30-45 cm tall and it has cauline leaves suborbicular, ovate, rhombic, obovate or obtrullate (Davis, 1982). Due to the rich cultural heritage and relatively rich flora in Turkey.

Uses in traditional or folk medicine

Some *Euphorbia* species such as *E. amygdaloides* L., have been used medicinally to treat skin diseases and wounds in different provinces (Özbilgin and Saltancitoglu, 2012).

Chemical Composition and Mosquitocidal Activity of n-Hexane and Methanolic Extracts

Control of the mosquito larvae is largely dependent on continued applications of organophosphates (chlorpyrifos, temephos and fenthion), insect growth regulators (diflubenzuron and methoprene) (Yang et al., 2002) and *Bacillus thuringiensis isrealiensis* (Lacey, 2007). Frequent use of synthetic insecticides has disturbed natural biological systems and led to insecticide resistance and amplified environmental and human health concerns (Lee et al., 2001). This warrants the need for the development of new strategies for selective control of mosquito populations. Plants are a good source of alternative agents for control of mosquitoes (Mathew et al., 2009; Rahuman et al., 2009) because they are rich in bioactive chemicals which are biodegradable. The *Euphorbia* genus is known to contain a wide variety of terpenoids, ranging from mono-, sesqui- and diterpenes to triterpenoids, flavonoids and steroids known for their toxicity or potential therapeutic activity (Tang et al., 2012). Taking this into consideration, we investigated the chemical composition of hexane and methanol extracts from *E. anacampseros* var. *tmolea* and their efficacy against 1st instar larvae and adult female *Aedes aegypti* L.

Volatile composition of the n-hexane and methanol extracts from E. anacampseros var. tmolea was analyzed by head space-solid phase microextraction (HS-SPME) coupled with gas chromatography-mass spectrometry (GC-MS). Chemical characterization of the methanolic extract was determined by LC-ESI-MS/MS. Both extracts were bioassayed against 1st instar larvae and adult female *Ae. aegypti*. The main components identified from the *E. anacampseros* var. *tmolea* n-hexane fraction were 1,8-cineole (27.5 %), p-cymene (25 %), γ-terpinene (12.8 %), limonene (9.9 %). Methyl hexanoate (18.8 %), methyl nonanoate (13.3 %), dimethyl succinate (6.5 %), methyl octanoate (6 %) and methyl phenylacetate (5.3 %) were identified from the methanolic fraction. The n-hexane extract showed 100 % mortality at 0.1 μg/μL against 1st instar larvae of Ae. aegypti and the methanolic extract exhibited 83.3 % mortality at 5 μg/mosquito against adult female *Ae. aegypti*. The bioassay-guided study demonstrates that n-hexane and methanol extracts of *E. anacampseros* var. *tmolea* contain compounds with natural mosquito larvicidal and adulticidal activity.

The n-hexane and methanolic extracts were evaluated for larvicidal and adulticidal activity against *Ae. aegypti* (Table1). The n-hexane extract produced larvicidal activity at each screening concentrations of 1, 0.5, 0.25 and 0.1 µg/µL, while the methanolic extract did not show any larvicidal activity at the same concentrations. However, the methanolic extract showed higher adulticidal mortality than the hexane extract, although both had activity above 70 % at the screening dose.

Subsequently, the volatile composition of n-hexane and methanolic extracts from *E. anacampseros* var. *tmolea* was identified using headspace-solid phase microextraction (HS-SPME) and GC-MS systems. Forty-four compounds in total were characterized in the n-hexane and 36 in the methanolic extracts (Table-2). Monoterpene hydrocarbons, p-cymene (25%), γ-terpinene (12.8 %), limonene (9.9 %), myrcene (3.2 %), α-pinene (2.3 %) and oxygenated monoterpenes, 1,8-cineole (27.5 %), linalool (3.4 %) and camphor (1.7 %) were the main components of n-hexane extract, while the methanolic extract was dominated mostly with linear esters, methyl hexanoate (18.8 %), methyl nonanoate (13.3 %), dimethyl succinate (6.5 %), methyl octanoate (6 %), methyl pentanoate (3.7 %), dimethyl malonate (3.1 %), methyl heptanoate (2.9 %) and with an aromatic ester methyl phenylacetate (5.3 %).

Table-1. Mosquitocidal activity against 1st ınostar and adult felmale *ae. Aegypti* or l1952 straın

Samples	Mortality (%)				
	Larvicidal activity*				Adulticidal activity**
	1 µg/µL	0.5 µg/µL	0.25 µg/µL	0.1 µg/µL	5 µg/mosquito
n-Hexane extract	100	100	100	100	76.7 ± 15.3
Methanol extract	0	0	0	0	83.3 ± 11.5

*In larval bioassays, positive control permethrin at 0.04 ng/µl; negative control solvent control (DMSO) had 0 mortality.

**In adult bioassays, two positive control permethrin doses were included at 0.19 ng (60 ± 10 % mortality) and 0.86 ng (100 % mortality) in all assays; negative control solvent control (acetone) had 0 mortality.

Table-2.Volatile composition of *E. anacampseros* var. *tmol*ea

RRI	Compound	n-Hexane extract (%)	Methanolic extract (%)	Identification method
1032	α-Pinene	2.28	-	RRI, MS
1090	Methyl pentanoate	-	3.7	RRI, MS
1076	Camphene	0.2	-	RRI, MS
1197	Methyl hexanoate	-	18.8	RRI, MS
1118	β-Pinene	1.3	-	RRI, MS
1132	Sabinene	1.0	-	RRI, MS
1159	δ-3-Carene	1.1	-	MS
1174	Myrcene	3.2	-	RRI, MS
1188	α-Terpinene	1.4	-	RRI, MS
1203	Limonene	9.9	-	RRI, MS

1213	1,8-Cineole	27.5	-	RRI, MS
1255	γ-Terpinene	12.8	-	RRI, MS
1280	p-Cymene	25.0		RRI, MS
1290	Terpinolene	0.4	-	RRI, MS
1382	cis-Alloocimene	0.1	-	MS
1296	Methyl heptanoate	-	2.9	RRI, MS
1360	1-Hexanol	-	0.4	RRI, MS
1398	2-Nonanone	0.3	-	MS
1399	Methyl octanoate	0.1	6.0	RRI, MS
1400	Nonanal	0.3	-	MS
1406	α-Fenchone	0.4	-	MS
1437	α-Thujone	0.2	-	RRI, MS
1443	2,5-Dimethylstyrene	0.1	-	MS
1450	trans-Linalool oxide (Furanoid)	0.1	-	MS
1452	1-Octen-3-ol	0.3	0.5	MS
1474	*trans*-Sabinene hydrate	0.1	-	MS
1475	*Menthone*	1.9	-	RRI, MS
1487	*Citronellal*	0.2	-	RRI, MS
1475	*Acetic acid*	-	0.4	RRI, MS
1500	*Methyl nonanoate*	0.1	13.3	RRI, MS
1503	Isomenthone	0.7	-	MS

1505	Dihydroedulane II*	-	0.4	MS
1510	Dimethyl malonate*	-	3.1	RRI, MS
1532	Camphor	1.7	-	RRI, MS
1553	Linalool	1.4	-	RRI, MS
1562	Octanol	-	0.4	RRI, MS
1565	Linalyl acetate	0.1	-	RRI, MS
1573	(E,E)-3,5-Octadien-2-one	-	0.2	MS
1586	Pinocarvone	0.1	-	RRI, MS
1591	Bornyl acetate	0.3	-	RRI, MS
1591	2-Methyl propanoic acid	-	0.3	MS
1601	Methyl decanoate	-	1.3	RRI, MS
1602	Dimethyl succinate*	-	6.5	RRI, MS
1602	6-Methyl-3,5-heptadien-2-one	-	1.3	MS
1611	Terpinen-4-ol	0.3	-	RRI, MS
1621	2-Octen-1-ol	-	0.1	MS
1625	4,4-Dimethyl but-2-enolide	-	0.4	MS
1638	Menthol	0.1	-	RRI, MS
1631	γ-Pentalactone	-	0.2	RRI, MS
1641	Methyl benzoate	-	0.9	RRI, MS
1645	*cis*-Isodihydrocarvone	tr	-	MS

1648	Myrtenal	0.1	-	MS
1651	γ-Butyrolactone	-	0.2	RRI, MS
1662	Pulegone	0.1	-	RRI, MS
1664	Nonanol	-	0.2	RRI, MS
1670	trans-Pinocarveol	0.1	-	RRI, MS
1687	Methyl chavicol	0.3	-	RRI, MS
1706	α-Terpineol	0.1	-	RRI, MS
1719	Borneol	0.1	-	RRI, MS
1726	γ-Hexalactone	-	0.4	RRI, MS
1751	Carvone	0.3	-	RRI, MS
1762	Pentanoic acid	-	0.4	RRI, MS
1779	Methylphenyl acetate	-	5.3	MS
1802	Cumin aldehyde	0.1	-	RRI, MS
1815	Methyl dodecanoate	-	0.7	RRI, MS
1871	Hexanoic acid	-	1.2	RRI, MS
1896	Benzylalcohol	-	0.2	RRI, MS
1937	Phenyl ethyl alcohol	tr	0.4	RRI, MS
1977	Heptanoic acid	-	0.1	RRI, MS
1984	Benzothiazol	0.1	-	MS
1996	2-Acetylpyrrole	-	0.1	MS
2004	o-Cresol	-	0.1	RRI, MS

2022	Methyl tetradecanoate	-	0.3	RRI, MS
2192	Nonanoic acid	-	tr	RRI, MS
2226	Methyl hexadecanoate	-	0.1	RRI, MS

RRI Relative retention indices calculated against n-alkanes % calculated from TIC data

tr Trace (< 0.1 %)

Identification method based on the relative retention indices (RRI) of authentic compounds on the HP Innowax column; MS, identified on the basis of computer matching of the mass spectra with those of the Wiley and MassFinder libraries and comparison with literature data

*Tentative identification

*Purchased from Sigma-Aldrich Co., St. Louis, MO, USA.

The chemical composition of methanolic extract of *E. anacampseros* var. *tmolea* was also investigated with LC-MS/ MS. Four compounds (1-4) were determined according to their molecular ion peaks and MS fragmentation behaviours (Table3; Fig. 1) (Demiray et al., 2017). Compound 1 showed molecular ion peak at m/z 367 which fragmented the base peak ion at m/z 193 due to the loss of a feruloyl unit. Other fragment ions at m/z 149 and 134, formed after the loss of a methyl group, was led to the identification of this peak as 3-feruloylquinic acid (1) (Clifford et al., 2003). Compounds 2-4 were determined as quercetin derivatives which were previously identified in Euphorbia species (Pisano et al., 2016). Compound 2 showed pseudo molecular ion peak at m/z 463 and a base peak ion at m/z 300 which was formed after the loss of a glucose unit. Other fragments at m/z 271, 255 were also observed. The base peak ion and further fragments are characteristic for quercetin. These data led to identifying compound 2 as quercetin glucoside. Similar identifications were done for compound 3 and compound 4 which have the same quercetin aglycone. Compound 3 presented molecular ion peak at m/z 477 and showed product ion at m/z 301 due to the loss of a glucuronic acid moiety, so compound 3 was identified as quercetin glucuronide. Compound 4 was identified as quercetin rhamnoside due to a loss of a rhamnosyl unit (-147) from molecular ion peak at m/z 447 (Smara et al., 2014).

Due to the disadvantages associated with synthetic pesticides, including development of pesticide resistant strains, ecological imbalances and harm to non-target organisms, there is a renewed effort to develop substances of plant origin which are considered to be more environmentally friendly due to their innate biodegradability and lower toxicity to most organisms (Frederich et al., 2002). Several researchers have investigated the application of plant extracts to fight malaria vectors. For example, *Achyranthus aspera* (Bagavan et al., 2008), *Azadirachta indica* (Aliero, 2003), *Jatropha curcas*, *Euphorbia tirucalli*, *Euphorbia hirta*, *Phyllanthus amarus* and *Pedilanthus tithymaloides* (Rahuman et al., 2008), *Piper nigrum* (Siddiqui et al., 2005), *Chenopodium album* (Sharma et al., 2006), *Solanum xanthocarpum* (Mohan et al., 2005), *Ajuga remota* (Sharma et al., 2004), *Thymus capitatus* (Mansour et al., 2000), *Tagetes erectes*, *Cleome icosandra*, *Ageratum conyzoides*, *Eichhornia crassipes* (Saxena et al., 1992). Larvicidal activity of ethyl acetate, butanol and petroleum ether extracts of five species of Euphorbiaceae plants, *Jatropha curcas*, *Pedilanthus tithymaloides*, *Phyllanthus amarus*, *Euphorbia hirta* and *Euphorbia tirucalli* were previously tested against the early fourth instar larvae of *Ae. aegypti* L. and *Culex quinquefasciatus* (Say) (Rahuman et al., 2008). Previous studies reported that E. tirucalli have shown larvicidal activity against *Ae. aegypti* and *Cx. quinquefasciatus* (Rahuman et al., 2008; Yadav et al., 2002) and *E. lactea* latex had larvicidal activity against three mosquito vectors, *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti* (Samidurai and N. Mathew, 2014). Bioassay-guided fractionation of ethyl acetate extract of *E. lactea* latex resulted in an active fraction and identified the chemical constituents by GC/MS analysis as a tricyclic sesquiterpene and an aliphatic hydrocarbon (Samidurai and N. Mathew, 2014).

Table-3. Chemical composition of *E. anacampseros* var. *tmolea* methanol extract

Compound	Rt	[M-H] m/z	Fragments	Compounds	Reference
1	9.7	367	193, 149,134	3-Feruloylquinic acid	[23]
2	11.0	463	300,271,255,179, 151	Quercetin glucoside	[24]
3	11.3	477	301, 273,179, 151	Quercetin glucuronide	[25]
4	12.1	447	300, 271, 255	Quercetin rhamnoside	[24]

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Mitragyna speciosa Korth (Rubiaceae)

Vulgar name

Kratom

Classification

Order: Gentianales, Family: Rubiaceae, Genus: *Mitragyna speciosa* (Korth.) Havil.

Origin

Mitragyna speciosa is an evergreen tree in the genus *Mitragyna* that can grow to a height of 25 m (82 ft). Its trunk may grow to a 0.9 m (3 ft) diameter (Eisenman, Sasha, 2014). The trunk is generally straight, and the outer bark is smooth and grey (Eisenman, Sasha, 2014). The leaves are dark green and glossy (Warner et al., 2016) and can grow to over 14–20 cm (5.5–7.9 in) long and 7–12 cm (2.8–4.7 in) wide when fully open, are ovate-acuminate in shape, and opposite in growth pattern, with 12–17 pairs of veins (Eisenman, Sasha, 2014). The flowers, which are deep yellow, grow in clusters of three at the ends of the branches (Rahman, 2021). In The calyx-tube is 2 mm (0.08 in) long and has five lobes; the corolla-tube is 2.5–3 millimetres (0.098–0.12 in) long (Eisenman, Sasha, 2014). *Mitragyna speciosa* is indigenous to Thailand, Indonesia, Malaysia, Myanmar, and Papua New Guinea (Rech et al., 2015). It was first formally described by the Dutch colonial botanist Pieter Korthals in 1839, who named it *Stephegyne speciosa*; it was renamed and reclassified several times before George Darby Haviland provided the final name and classification in 1859 (Eisenman, Sasha, 2014).

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Uses in traditional or folk medicine

Mitragyna speciosa Korth (Rubiaceae), endemic to tropical Southeast Asia, has opium-like effects and coca-like stimulancy. Traditionally, *M. speciosa* has been used as a remedy to cure diarrhea, cough, muscular pain and fatigue. *M. speciosa* is also frequently used by drug addicts seeking relief during opioid withdrawal stage (Takayama, 2014; Jansen and Prast, 1988; Khor et al., 2011; Adkins et al., 2011).

Chemical composition of *Mitragyna speciosa* (Korth.) Havil.

A number of chemical and pharmacological studies have been carried out on this plant and many indole and oxindole alkaloids have been reported (Takayama, 2014). The present phytochemical study on M. speciosa leaves, aimed at the discovery of alkaloids with interesting skeletons, resulted in the isolation of 11 indole and oxindole alkaloids including two previously undiscovered compounds. Structure elucidation of these alkaloids was achieved by NMR, CD, and MS spectroscopic data analyses. The structures of **1–6** are shown in Figure 1. An alkaloid enriched fraction from the methanol extract of the leaves of M. speciosa[5] was fractionated using silica gel (22''x1.5'') column chromatography (CC) with gradients of $CHCl_3$/ MeOH into 16 fractions (Frs. 1–16). Frs. 2–4 were combined (2.7 g) and subjected to CC [silica gel (36''x1''), hexanes/acetone/NH_4OH, (208:90:1)] to isolate mitragynine (1.7 g). Fr. 5 (2.4 g) was divided into nine subfractions (Frs. 5A–5I) using CC [silica gel (40''x1.5''), hexanes/acetone, (7:3)]. Corynoxine B (14 mg) was purified from fraction 5E (501 mg) along with an impure material (Fr. 5EA) by CC [silica gel (35''x0.75''), hexanes/acetone/NH_4OH, (208:90:1)]. Compound **5** (108 mg) was obtained as an upper band from preparative thin layer chromatography (PTLC) [silica gel plate (0.5 mm), hexanes/acetone/NH_4OH, (208:90:1)] of fraction 5EA. The contents of the lower band were applied to PTLC [silica gel plate (0.5 mm), $CHCl_3$/EtOAc (7:3)], followed by reverse phased HPLC [C-18 silica, MeOH/H_2O, 65:35] to purify compounds **2** (2 mg), 3 (11 mg), and 4 (77 mg). Speciogynine (45 mg) was purified by PTLC [silica gel plate (0.5 mm), hexanes/acetone/NH_4OH, (208:90:1)] of fraction 5I. Speciociliatine (650 mg) and corynoxine (44 mg) were obtained from fractions 7 and 8 by CC [silica gel (36''x1''), $CHCl_3$/MeOH (49:1)] followed by PTLC [silica gel plate (0.5 mm), hexanes/acetone/NH4OH, (180:120:1)]. Compound **6** (28 mg) was obtained from fraction **8** by CC [silica gel (40 x 0.75), hexanes/acetone/NH_4OH, (180:120:1)] and compound **1** (17 mg) was purified from fractions 10 and 11 (138 mg) by PTLC [silica gel plate (0.5 mm), $CHCl_3$/MeOH/NH_4OH, (28:15:1)]. Compound **1**[6] was obtained as a yellow solid ($[\alpha]^{22}_{D}$ -149.0 (c 0.13, MeOH)). The molecular formula of compound **1** was inferred to be $C_{23}H_{30}N_2O_5$ from a protonated ion $[M+H]^+$ at m/z 415.2224 in the HR-ESI-ToF-MS (calcd for $C_{23}H_{31}N_2O_5$, 415.2233). The UV spectrum showed absorptions at 291, 240, and 220 nm. The IR spectrum exhibited absorption due to conjugated ester carbonyl function at 1700 cm^{-1}. The ^{13}C NMR spectrum exhibited 23 resonances which were differentiated as four methyl, five methylene, seven methine, and seven quaternary carbons. The characteristic resonances for three methoxy groups [δ_H/δ_C 3.83 (s)/55.5 (9-OCH_3), 3.81 (s)/61.6 (17-OCH_3), and 3.69 (s)/51.4 (22-OCH_3)], a primary methyl [δ_H/δ_C 0.71 (t, J = 7.2 Hz)/11.2 (CH_3-18)], an oxygenated olefinic bond in conjugation with the oxo group [δ_H/δ_C 7.34 (s)/160.1 (CH-17) and dC 112.1 (C-16)], and an iminic quaternary carbon [δ_C 182.9 (C-2)] were found in the ^1H and/or ^{13}C NMR spectra. The resonances for a 1, 2, 3-trisubstituted phenyl ring with an ABC spin system [δ_H/δ_C 6.70 (br d, J = 8.0 Hz)/108.8 (CH-10), 7.27 (t, J = 8.0 Hz)/130.6 (CH-11), 7.21 (br d, J = 8.0 Hz)/114.3 (CH-12), d_C 126.5 (C-8), 155.9 (C-9), and 154.6 (C-13)] and an oxygenated quaternary carbon [δ_C 82.1 (C-7)] along with five aliphatic methylenes and three aliphatic methines were also observed. The ^1H and ^{13}C NMR data (See Tables 1 and 2) were assigned with the help of HSQC, ^1H–^1H COSY, and HMBC (Fig. 2) spectra. NMR data analyses showed that **1** had the same planer structure as that of 7-hydroxyspeciocilliatine (Kitajima et al., 2006). Literature reports indicated that the ^{13}C NMR resonances of an ethyl group were the key to determining the configuration at C-20. The reported ^{13}C NMR resonances of the ethyl group are δ_C 18.9–20.5 (C-

19) and δ_C 12.6–13.3 (C-18) for C-20 S and δ_C 24.2–24.4 (C-19) and δ_C 11.2–11.3 (C-18) for C-20 R (Kitajima et al., 2006; Sakakibar et al., 1998). Based on the chemical shifts of C-20 ethyl group [dC 24.2 (C-19) and dC 11.2 (C-18)], the configuration at C-20 in **1** was assigned to be R. The CD spectrum of **1** showed negative cotton effects at 316, 272 and 216 nm and found to be partially comparable to that of 7-hydroxyspeciociliatine, for which negative cotton effects at 307 and 256 nm and positive cotton effect at 230 nm were reported.7 The reverse cotton effects at lower absorbance could be due to the opposite configurations at C-20 in 1 and 7-hydroxyspeciociliatine (Kitajima et al., 2006). Consequently, the structure of 7β-hydroxy-7H-mitraciliatine (**1**) was established as shown in Figure 1. Compound 29 was obtained as a yellow solid ([α] ($^{27}{}_{D}{}^{38}$ (c 0.05, MeOH)). The molecular formula of compound **2** was inferred to be $C_{22}H_{26}N_2O_5$ from a protonated ion $[M+H]^+$ at m/z 399.1913 in the HR-ESI-ToF-MS (calcd for $C_{22}H_{27}N_2O_5$, 399.1920). The UV spectrum showed absorptions at 290, 239, and 220 nm. The absorptions in the IR spectrum at 1623 and 1706 cm^{-1} supported the amide carbonyl and conjugated ester carbonyl functions. The ^{13}C NMR spectrum displayed 22 resonances, which were differentiated as two methyl, five methylene, eight methine, and seven quaternary carbons. The ^1H and/or ^{13}C NMR spectra of **2** showed characteristic resonances for two methoxy groups [δ_H/δ_C 3.70 (s)/61.4 (17-OCH_3) and 3.59 (s)/51.0 (22-OCH_3)], an oxygenated olefinic bond adjacent to an oxo group [δ_H/δ_C 7.20 (s)/159.7 (CH-17) and δ_C 111.3 (C-16)], and an external double bond [δ_H/δ_C 5.50 (dt, J = 18.0, 10.8 Hz)/138.5 (CH-

19), 4.98 (br d, J = 18.0 Hz) and 4.95 (br d, J = 10.8 Hz)/116.2 (CH_2-18)], a 1,2,3-trisubstituted phenyl ring [δ_H/δ_C 6.57 (br d, J = 8.5 Hz)/111.6 (CH-10), 7.06 (t, J = 8.5 Hz)/129.4 (CH-11), 6.41 (br d, J = 8.5 Hz)/101.0 (CH-12), δ_C 116.6 (C-8), 154.4 (C-9), and 140.6 (C-13)], a conjugated ester carbonyl carbon [δ_C 168.2 (C-22)], and an amide carbonyl carbon [δ_C 179.2 (C-2)]. The ^{1}H and ^{13}C NMR data assignment was done by analyses of the HSQC, ^{1}H–^{1}H COSY, and HMBC spectra. When the NMR spectroscopic data of **2** were compared with those of isospeciofoline (**3**), the resonances for an ethyl group were found missing in **2** showing instead for an external double bond. The sharp signals at δ_H 11.86 and δ_H 11.74 in the ^{1}H NMR spectra of **2** and **3** indicated a non-acidic phenol because of intramolecular hydrogen bonding between C-9 hydroxyl and lone pair of N-4, which ultimately supported the S configuration at C-7 (Hemingway et al., 1975). Furthermore, the comparative analyses of the CD spectra of **2** and isospeciofoline (**3**) (Hemingway et al., 1975) supported the R, S, S, and S, absolute configurations at C-3, C-7, C-15, and C-20, respectively, due to the positive cotton effects at 293, 243, and 214 nm and negative cotton effect at 262 nm. Finally the structure of **2** was elucidated as shown in Figure 1 and named as isospeciofoleine. Compounds **3–6** were identified as isospeciofoline (**3**), isorotundifoline (**4**), paynantheine (**5**), and 3-isopaynantheine (**6**) by analyses of their NMR, mass, and CD spectroscopic data and were found to be reported previously from Mitragyna species (Hemingway et al., 1975; Shellard et al., 1978; . Shellard and Lala, 1978; Beckett et al., 1966). Herein the ^{1}H and ^{13}C NMR data of **3–6** are also reported first time. Five other known alkaloids were identified as speciogynine, speciociliatine, corynoxine, corynoxine B, and mitragynine by comparing their NMR spectroscopic data with those previously reported (Kitajima et al., 2006; Sakakibar et al., 1998).

A new indole alkaloid, 7β-hydroxy-*7H*-mitraciliatine (**1**) and a new oxindole alkaloid, isospeciofoleine (**2**) together with nine known alkaloids were isolated from *Mitragyna speciosa* and characterized by NMR, CD, and MS spectroscopic data analyses. The ^{1}H and ^{13}C NMR spectroscopic data of isospeciofoline (**3)**, isorotundifoline (**4**), paynantheine (**5**), and 3-isopaynantheine (**6**) were also reported for the first time (Ali et al., 2014). [14].

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5. An alkaloid enriched fraction (3.7 g) was obtained by usual acid base treatment of the methanolic extract (70 g) of the leaves of *Mitragyna speciosa* (550 g) (Voucher No. 12433).

6. 7β-Hydroxy-7H-mitraciliatine (**1**). Yellow powder; $[\alpha]^{22}_{D}$ -149.0 (c 0.13, MeOH); UV (MeOH) ʎmax nm (loge): 291 (3.37), 240 (3.80), 220 (3.99); IR cm^{-1} : 3491, 1700, 1631, 1593, 1485, 1434, 1270, 1244, 1133, 1107, 1074, 1006; CD (MeOH) ʎmax nm (De): 216 (-1.70), 272 (-3.49), 316 (-1.86); ^{1}H NMR: see Table 1; ^{13}C NMR: see Table 2; HR-ESI-ToF-MS m/z: 415.2224 $[M+H]^{+}$, (calcd 415.2233 for $C_{23}H_{31}N_{2}O_{5}$).

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9. Isospeciofoleine (2). Yellow powder; $[\alpha]^{27}_{D}$ 38.0 (c 0.05, MeOH); UV (MeOH) ʎmax nm (loge): 290 (3.18), 239 (3.86), 220 (4.08); IR cm^{-1} : 3300, 1706, 1623, 1481, 1432, 1279, 1236, 1205, 1145, 1138, 1107; CD (MeOH) ʎmax nm (De): 214 (8.13), 243 (1.41), 216 (-1.21), 293 (0.93); ^{1}H NMR: see Table 1; ^{13}C NMR: see Table 2; HR-ESI-ToF-MS m/z: 399.1913 $[M+H]^+$, (calcd 399.1920 for $C_{22}H_{27}N_2O_5$).

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Stachys tmolea subsp. ***tmolea*** Boiss., **an endemic species of Turkey**

Vulgar name

Smutty tea.

Classification

Order: Lamiales, Family: Lamiaceae, Genus: *Stachys tmolea* subsp. *tmolea* Boiss.

Origin

The genus *Stachys* L. is one of the largest representative genera of herbs and shrubs of the Lamiaceae (Labiatae) family, and involves about 300 species (Rechinger and Hedge 1982, Greuter et al., 1986), in the subtropical and tropical regions of both hemispheres excluding Australia and New Zealand (Evans, 1996; Salmaki et al., 2012). The species name arises from the Greek and means ‘‘an ear of grain” attributing to the inflorescence spike found in many members. The genus is represented in Turkey by 83 species (109 taxa) belonging to 12 subsections, 15 sections and 2 subgenera and 55 of which are endemic (Bhattacharjee, 1982; Davis et al., 1988; Duman, 2000; Özhatay et al., 2009; Akcicek, 2010; Radulovic et al., 2007, Dündar et al., 2013, Bastürk et al., 2015). *Stachys tmolea* Boiss., as being a Labiatae member with basal rosettes of sterile shoots, is an endemic species of Turkey which is named tmolea as being the ancient name of Boz mountain (in Ödemis, Izmir) by Boissier who collected the species (Avcı, 2004). Flowering stems are simple or with few branches, densely adpressed-tomentose, lanate-villous above. Species are distinguished from the other *Stachys* species with its lower cauline leaves being oblong-lanceolate to oblanceolate, narrowed towards base; base usually attenuate to rounded, rarely subcordate and calyx tube ± regular with distinctly visible veins; stem patently pilose with dense glandular hairs; corolla creamish-white (Davis et al., 1988). The species is a listed endangered species in Turkey (Güner and Akçiçek, 2014).

Uses in traditional or folk medicine

Stachys species have a history of use as a traditional medicines. Decoctions or infusions of some of *Stachys* species, locally known as ‘‘mountain tea’’, are applied as tonics to heal skin or taken by orally for stomach disorders in Anatolia (Ozturk et al., 2009). The aerial parts of *S. tmolea* are known as ‘‘smutty tea” (sürmeli çayçe) in the Ulus mountains (Balıkesir) (Güner and Akçiçek, 2014) and ‘‘quester” (kestire) in the city of Bilecik, Turkey where the plant is consumed as a hot tea for the treatment of colds (Koyuncu et al., 2010). Many *Stachys* species are used for the healing of skin, stomach, ulcer, asthma, rheumatic deseases and vaginal tumors (Goren et al., 2011a,b). Some of the species have been reported as having anti-inflammatory, antibacterial, antianxiety, antioxidant or antinephritic properties.

Chemical composition of the essential oil and n-hexane extract of *Stachys tmolea* subsp. *tmolea* Boiss., an endemic species of Turkey, and their mosquitocidal activity against dengue vector *Aedes aegypti*

Essential oils are mixture of volatile and hydrophobic secondary metabolites of plants consist of terpenes and phenylpropanoids. These compounds have a lot of different bioactivities including the antioxidative, cytoprotective, larvicidal, insecticidal, and antiparasitic activities. The hydrophobicity of these compounds combat some diseases like American and African trypanosomiasis, leishmaniasis, and arboviruses, specially dengue (Luna et al., 2019) as crossing the membranes of parasites and the blood-brain barriers. Results obtained from studying the 361 essential oils of 269 plant species against denge virus displayed a larvicidal activity with LCs < 100 mg/L in a review (Dias and Moraes, 2014). In this study; the chemical composition of essential oil obtained from the aerial parts of S. tmolea subsp. tmolea was analyzed by GC-FID and GC-MS. The composition of the 79.3% total essential oil yielded monoterpene hydrocarbons in trace amounts, sesquiterpene hydrocarbons (10.2%), oxygenated sesquiterpenes (22.6%), fatty acids (14.6%), diterpenes (8.2%), alkanes (2.6%) and others (21.1%). Hexahydrofarnesyl acetone 15.1%, viridiflorol 9.9%, hexadecanoic acid 7.4%, 9-geranyl-p-cymene 6.1%, tetradecanoic acid 2.8%, cadalene 2.6%, valeranone 2.3% and 1,5-epoxy-salvial(4)14-ene 2.3% were the majority of compounds in the oil. In contrast, the n-hexane extract was characterized mainly by hydrocarbons, aliphatic alcohol, aldehydes, carboxylic acids and phenylpropane. The volatile compounds present in the n-hexane were measured by headspace solid phase microextraction (HSSPME) and followed by GC-MS. The identified components accounted for 82% and major components were identified as 3,4- dimethyl decane (16.0%), 3-methyl-3-pentanol (14.5%), 2-methyl 2-pentanol (12.1%), 1,4-bis(1,1-dimethylethyl) benzene (11.7%), heptanal (9.6%), acetic acid (5.9%), nonanal (2.7%) (Table 2). Both the essential oil and n-hexane extract were screened for the insecticidal activity against *Ae. aegypti*. The n-hexane extract produced 90% ± 10 mortality against adult female *Ae. aegypti* at 5 lg/mosquito, while essential oil demonstrated 12.5% ± 3.6 mortality at the same concentration in the adulticidal bioassays. Neither n-hexane extract and nor essential oil showed larvicidal activity at 1, 0.5, 0.25 and 0.1 lg/lL against 1st instar *Ae. aegypti*. Control mortality in these experiments was 0% for solvent only and 100% for the 0.62 ng/mosquito permethrin positive control . Studies on the essential oil composition of *Stachys* species are numerous (Khanavi et al., 2004; Cavar et al., 2010; Giuliani et al., 2009; Hajdari et al., 2011; Ali et al., 2010). In a study on twenty two *Stachys* species, b-caryophyllene, germacrene D, a-cadinene and caryophyllene oxide were the major constituents (Goren et al., 2011a,b). The essential oil of *S. tmolea*, which 93.2% of the composition was determined, exhibited a high proportion of sesquiterpenes (58.4%) ensued by oxygenated sesquiterpenoids (21.9%). Of the 28 constituents detected, the most amplewere germacrene D (22.2%), b-caryophyllene (19.7%) and valeranone (8.5%), acadinene, spathulenol, caryophyllene oxide (Goren et al., 2011a,b). The essential oil content of aerial parts of *S. parviflora* was analyzed by GC-FID and GC-MS systems. Twenty-three constituents, representing 99.9% of the oil, were identified. Epi-a-muurolol (48.4%) and (Z)-caryophyllene (11.2%) were the major constituents of the oil. Oxygenated sesquiterpenes (71.4%) was the major fraction of the essential (Bashi et al., 2013). Sesquiterpenes such as spathuleol, T-muurol, elemene, cadinol, a-eudesmol, isoledene, caryophyllene was found in higher percent in an endemic species of *S. rupestris* (Erdogˇan, 2014). *Stacyhs iberica* subsp. iberica essential oil was characterized by hexadecanoic acid (41.5%), %), phytol (8.2%) and germacrene D (9.7%) (Goger at al., 2016) whereas *S. iberica* subsp.

stenostachya essential oil was rich in linalyl acetate (42.2%), linalool (18.9%), geranyl acetate (8.2%), and a-terpineol (5.3%) as the main components (Kaya et al., 2001). It clearly showed that the oil compositions of two taxa are different (Goger et al., 2016). In conclusion, the essential oil and n-hexane extract of *S. tmolea* had different chemical composition. In addition, the chemical composition in this analysis of *S. tmolea* was different than a previous study of the essential oil (Goren et al., 2011a,b). It is the fact that different geographic regions, seasons, harvest periods, properties of soils and climatic conditions strongly affect the secondary metabolite content of the plant species, especially essential oil composition. We also observed (Demiray et al., 2019) differences in the insecticidal activity. The n-hexane extract produced 90% mortality whereas the essential oil showed only 13% mortality against adult *Ae. aegypti*. Further studies need to plan on the n-hexane extract of the aerial parts from S. tmolea to identify the constituents responsible for the activity against adult *Ae. aegypti*.

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CHAPTER 8

SEPARATION OF ESSENTIAL OILS BY MEMBRANE PROCESSES

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1.0 Introduction

In recent years, increasing attention has been paid to the development and use of natural products. Among these high value compounds, essential oils (EOs) appear in the great portion during the last decade owing to their associated biological activities such as antioxidant, anti-inflammatory, antimicrobial, antifungal, antiviral and antineoplastic, etc. (Spricigo et al., 2001). At present, a variety of aromatic plant essential oils have been considered as important "green natural active substance". EOs are the volatile secondary metabolites of natural plant, which are composed of a wide variety of components, including terpenes, oxygenated terpenoids, aromatic and phenolic components (Chen et al., 2020; Liu et al., 2021). EOs consist of complex mixture of volatile and non-volatile substances, which are lipophilic in nature and broadly classified into carotenoids alkaloids, phenolic acids, flavonoids, monoterpenes, isoflavones, and aldehydes (Rehman, et al., 2021). Table 1 presents the main EOs in world market and their plant (Silvestre et al., 2019).

Table 1. Main essential oils traded in world market and source plant (Adapted from Silvestre et al., 2019)

Essential oil	**Specie(s)**
Orange (Brazil)	Citrus sinensis (L.) Osbeck
Cornmint (India)	Mentha arvensis L. f. piperascens Malinv. ex Holmes
Eucalyptus (cineole kind)	Eucalyptus globulus Labill., E. polybractea R.T. Baker; Eucalyptus spp.
Citronella grass	Cymbopogon winterianus Jowitt e C. nardus (L.) Rendle

Peppermint	Mentha x piperita L.
Clove	Syzygium aromaticum (L.) Merr. e L. M. Perry
Cedar (USA)	Juniperus virginiana L. and J. ashei Buchholz

Noteworthy that EOs have a high number of crucial and supportive roles in various fields such as food, health, cosmetic, pharmaceutical, and agriculture etc. EOs have particularly application fields for industry, mainly regarding cosmetics and food industry. The current trend of reducing the use of synthetic products (particularly pesticides and synthetic food preservatives) in favor of ‘natural’ alternatives make the essential oils and their components as subsititute of synthetic products (Silvestre et al., 2019).

In food industry, EOs are applied also as additives and supporting agents in biodegradable films and in food preservation, both in direct application or associated to active packaging due to the ability to be applied in active packaging to increase the shelf life of the packed products, to contribute with the aroma, to enhance some package property, or to act as a barrier to water diffusion (Silvestre et al., 2020). The active components of EOs act as free radical scavengers and have an important action for oxidation process during food processing, transportation, and storage (Rehman, et al., 2021).

EOs intake could reduce the chances of high blood pressure, cancer, obesity, cardiovascular diseases and diminish the risks of age-related muscular disorders. Their biological properties in a supportive way inside the body, provide a sensation of well-beingness. For instance, it was observed that rosemary essential oil intake by mice enhanced their locomotor activity (Rehman, et al., 2021).

EOs are used as flavoring and aromatizing compounds and in the synthesis of chemicals. Due to the biocide properties, EOs are largely employed in agriculture to be used as an alternative to the agrochemicals in order to control agricultural pests, such as fungi and insects, bacteria (Sivestre et al., 2020).

The main disadvantage of using EOs is their intrinsic volatility and susceptibility of photodegradation by UV radiation (UVA/UVB), which turns the EOs and their components ineffective in-field uses and where there is a high incidence of sunlight (Silvestre et al., 2019; Silvestre et al., 2020). EOs are mostly produced by steam distillation of plant parts (leaves, flowers, branches), by mechanical cold-pressing of the peels of citrus fruits, of by dry distillation, after separation of the aqueous phase by physical processes (Silvestre et al., 2020). EOs are industrially processed and their components are purified/separated by vacuum fractional distillation, mostly. The vacuum is employed to reduce the boiling point of the EOs, preventing the thermal decomposition of the thermolabile compounds. However, this is a very costly process, whose control parameters need to be strictly controlled for the process to be successful (Sivestre et al., 2020).

The pervaporation is seen as an innovative and economical alternative to several classic separation processes, such as liquid-liquid extraction, distillation (azeotropic, extractive, fractional), and in the purification of mixtures whose separation is difficult or costly by the traditional methods. Pervaporation act as a new alternative to obtain EOs and their components serving less cost and less technologically challenging way, where the current separation processes are, in general, quite costly material (Silvestre et al., 2020).

Literature is lack of separation processes and purification of EOs and their components, as well as the use of purified fractions of EOs and so that this chapter focuses on the separation of EOs by employing membrane processes.

2.0 Membrane Processes

Membrane processes are widely employed in various industries such as the food industry, nono-electronic, chemical, pharmaceutical, textile, and fuel cell industries (Charcosset, 2021). The broadest definition of the membrane is a region of discontinuity interposed between two phases. The role of the membrane in separation processes is to act as a selective barrier where it should permit preferred passage of a certain component out of the mixture (Hwang and Kammermeyer, 1975).

Membrane-based processes can be categorized based on the process driving force. Table 1 shows the driving forces of membrane processes. Particles and dissolved components are retained (partially) dependent on size, shape, and charge.

Table 2. Driving force of membrane processes (Ho and Sirkar, 1992; Strathmann, 2001; Van Der Bruggen *et al.*, 2003)

Membrane processes	**Driving Force**	**Transport mode**
Microfiltration (MF)	Hydrostatic pressure gradient	Convection
Ultrafiltration (UF)	Hydrostatic pressure gradient	Convection
Nanofiltration (NF)	Hydrostatic pressure gradient	Convection
Reverse osmosis	Hydrostatic pressure gradient	Diffusion
Dialysis	Concentration gradient	Diffusion
Electrodialysis (ED)	Electrical potential gradient	Migration
Pervaporation (PV)	Concentration gradient, temperature gradient	Diffusion

2.1 Applications of membrane processes in the essential oil industry

Essential oils contain the majority of the volatile, low molecular mass aroma constituents derived from a plant. Because of their economic value, it is, therefore, necessary to implement a non-destructive extraction technique for the separation and recovery of essential oils. Up to now, distillation, solvent extraction, gas stripping, and supercritical fluids are among the most diffused traditional processes. Among extraction operations, distillation can be used if aroma compounds are highly volatile or solvent extraction if they are hydrophobic and present a higher affinity for an organic solvent than for the aqueous effluent. Both of the traditional processes named above present some disadvantages: distillation is a quite expensive process because it is highly energy consuming and not always adapted to thermo-sensitive molecules and solvent extraction requires a high interfacial exchange area (leading often to a stable emulsion) to enhance the mass transfer. In the last decades, membrane technology has been applied to extract aroma compounds from aqueous solutions. Membrane processes exhibit some advantages, mainly maintaining lower operational costs and avoiding thermal or oxidative degradation of products. The PV, VP, NF, RO, and MD are, in particular, the most representative membrane-based processes applied for bioactive compounds, aroma, and flavors' recovery and separation.

2.1.1 Pervaporation (PV)

Pervaporation is a membrane process where certain components in the feed solution preferentially permeate through a dense or molecular-sieving porous membrane and evaporate downstream. A feed liquid mixture contacts one side of a membrane; the permeate is removed as a vapor from the other side. Transport through the membrane is induced by the vapor pressure difference between the feed solution and the permeate vapor. The mass transfer occurs selectively across the membrane to the gas side. Because various species permeate at different rates through the membrane, a substance in the feed stream with a low concentration can be greatly enriched in the permeate. As a result, separation occurs, with the efficacy of the separation effect determined by the membrane's physicochemical structure (Baker, 2012; Fleming and Slater, 1992; Wang *et al.*, 2016). Another advantage of PV is separation does not require the use of additional chemicals and involves no regeneration step, which renders it a promising clean technology for the extraction of VOCs from aqueous solutions (Du *et al.*, 2021)

Du et al. prepared poly(ether-block-amide, PEBA) and polydimethylsiloxane (PDMS) membranes and applied them for extraction of volatile organic compounds (VOCs) present in perilla, namely, limonene, linalool, and perillaldehyde from aqueous solution. The effect initial concentration of VOC, and operation temperature on PV. The authors reported that increment on initial concertation improved the VOC fluxes for both membranes. The authors also stated that VOC flux and the water flux increased with an increase in the operating temperature (Du *et al.*, 2021).

Figoli et al. extracted bergamot essential oil from bergapten by using an ethanol-water mixture and Pervap 1070 membrane. The authors reported that an enhancement in temperature improved the diffusion rate of permeating molecules and thus increased the permeating flux. Moreover, the authors also reported that as the ethanol concentration increased, the total flux increased as well, owing to increased polymer swelling (Figoli *et al.*, 2006).

Rostami et al. prepared the polyphenylsulfone/graphene nanocomposite membrane for the pervaporation separation of cumene from water. The addition of graphene by 1% (mass percent) to the organic polymer membrane matrix (polyphenylsulfone) led to an increase in the cumene flux from 1.9 to 3.5 gMH .Then, with raising the Gr content to 3.5%, the cumene flux increased to 9.4 gMH. However, with a further increase in Gr concentration and reaching 4% by weight, the cumene flux decreased significantly and reached 4.6 gMH. Furthermore, increase in graphene concentration from 0% to 3.5%, the separation factor increased from 347 to 1566 (Bakhshandeh Rostami *et al.*, 2021). The various application of PV is summarised in Table 3.

Table 3. Separation of essential oils by PV

Source	**Main Results**	**Reference**
Bilberry juice	Enrichment factor increased with higher membrane thickness.	(Diban *et al.*, 2008)
Kiwifruit juice	The higher temperature increased the volatile fraction permeation fluxes.	(Figoli *et al.*, 2010)
Orange juice	Feed flow rate had no significant effect on PV performance. Increasing feed temperature led to higher flux and enrichment factors. An increment in permeate pressure caused the flux and enrichment factor of some aroma compounds.	(Aroujalian and Raisi, 2007)
Pomegranate aroma compounds	Increasing the aroma concentration in the feed solution increases the total and partial fluxes but the aroma selectivity dropped. Permeation fluxes all increase with the increase in the feed temperature.	(Raisi *et al.*, 2009)

2.1.2 Reverse osmosis (RO)

RO is a pressure-driven membrane process where a semi-permeable membrane rejects dissolved constituents present in the feed water. Size exclusion, charge exclusion, and physical-chemical interactions between the solute, solvent, and membrane all contribute to membrane rejection (Malaeb and Ayoub, 2011).

The RO processes have been applied to the separation of essential oils. Spricigo et al., combined supercritical fluid extraction with RO to separate nutmeg essential oil. The supercritical CO_2 first passed through the essential oil-containing cell then essential oil containing CO_2 reached to RO membrane containing cell and essential oils collected as retentate. The effect of temperature, applied pressure, and feed stream essential oil concentration on the separation performance was investigated. Authors reported that the average retention of essential oil by the RO membrane was 96.4% and it was not affected significantly by any of the process variables (Spricigo *et al.*, 2001).

Sarmento et al. tested three different RO membranes (SG, CG, and AG produced by Osmonics) for the separation of lemongrass, orange, and nutmeg essential oils. The supercritical CO_2 extraction and RO hyphenated technique were applied for separation. The effect of oil concentration and transmembrane pressure on essential oils retention was investigated. Results demonstrated that the performance of SG membrane was better than other membranes and 88 – 90 % retention of Lemongrass oil at low pressure (1 MPa) was achieved (Sarmento, 2004). Table 4 summarizes some other RO application on essential oil separation.

In such studies, supercritical extraction was applied for the extraction of essential oils and then RO membranes were used to retentate the essential oils. Results showed that the supercritical extraction – RO hybrid technique can be applied for the separation of the essential oils. Results also showed that retention index (rejection rate) may be decreased which may be due to affinity between the polymer of the membrane and the compounds of the oil, promoting the diffusion of the oil through the membrane during the fractionation process (Donelian *et al.*, 2016).

Membrane separation methods combined with supercritical extraction of essential oils may be a viable option for lowering solvent recirculation costs (Sarmento, 2004). The advantage of supercritical extraction is the complete removal of the solvent (CO_2) when it leaves the critical point and becomes a gas (Silvestre *et al.*, 2020).

Table 4. Various applications of RO for essential oil separation

Membrane	Essential oil	Main findings	Reference
SG: thin film AK: polyamide CE: cellulose acetate	D-limonene	SG membrane presented the highest limonene retention factor. AK membrane retention factor dropped to zero after 80 min.	(Carlson *et al.*, 2005)

		HL membrane reached a stabilized value of 0.3 after 75 min	
SW-30	polyphenols from cocoa seeds	Retention of polyphenols by BW-30 was greater than 90%.	(Sarmento, Luiz A.V. *et al.*, 2008)
BW-30	Patchouli oil	Retention of the essential oil 95% After 30 mins. retention slightly drops at the end of the separation process.	(Donelian *et al.*, 2016)
CG, SG, and AG	Lemongrass essential oil	The SG membrane showed good resistance to the severe pressure conditions. Retention index of up to 88%.	(Sarmento, L.A.V. *et al.*, 2004)

4.0 Conclusion remarks

Membrane separation processes are very frequently, economically preferred over classical processes. The membrane separates different components according to the sizes, interactions with the membrane surfaces, and other components of the mixture. The membrane performance is compared with permeate flux, retention factor (retention rate), separation factor, and long-term stability. The performance of the membrane is affected by applied pressure (or transmembrane pressure), temperature, membrane composition. The quality of the final product is depending on the retention of flavor and aroma components, which may have been affected by the selected membrane properties (size and composition).

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CHAPTER 9

MEDICINAL AROMATIC PLANTS AND THEIR USE IN MEAT AND MEAT PRODUCTS

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1. INTRODUCTION

Aromatic plants and herbs have been widely used in traditional medicine, gastronomy and religious rituals since ancient times (Socaci et al., 2019). Medicinal plants are those used in traditional and official medicine, whereas aromatic plants are those used for their aroma and flavor, and the majority of them are also known as "medicinal and aromatic plants" because they have aromatic properties and are used for medicinal purposes (Giannenas et al., 2019; Gökçe & Efe, 2016).

Meat and meat products are rich in protein and lipids, have suitable moisture content and thus susceptible to lipid and protein oxidation regarding to their nutritional composition (Valencia et al., 2008). Since the oxidative changes in meat have negative impacts on product quality, they are highly undesirable. To solve this problem of oxidative decay in meat, synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ) and propyl gallate (PG) are conventionally used (Filipčev, 2019). Plants are generous resources that provide humans valuable bioactive substances and so different plant products are valued as natural antioxidants to maintain and improve the overall quality (Shah et al., 2014).

Aromatic herbs and their derivatives are potential natural alternatives to synthetic antioxidants and preservatives. Because they are natural, they are particularly interesting for use to food manufacturers who prefer "clear labels" in minimally processed foods, organic foods, and functional foods, They can be added directly (in fresh or dried state) to food or their components may be extracted and added to food in the form of essential oils (EOs) or extracts (Filipčev, 2019).

In this chapter, some of the aromatic and medicinal plants used in meat and meat products and the effects of them on the quality were reviewed.

Thyme, Rosemary, Oregano, Sage and Lemonbalm (*Lamiaceae* family)

Thyme (Thymus vulgaris L.) is an aromatic plant, has attracted attention as a medicine and therapeutic agent worldwide. Main pharmacological effects are attributed to carvacrol and thymol that are the main bioactive components of thyme (Mehdipour et al., 2013). Thyme essential oil (EO) contains more than 60 ingredients and most of them have antiseptic, carminative, antioxidant and antimicrobial properties (Nieto et al., 2010). Thyme extracts and essential oil was used as natural antimicrobials especially in broiler diets against *Salmonella* and other harmful bacteria. Mehdipour et al. (2013) concluded that thyme can increase the number of Lactobacillus bacteria and decrease coliforms; also decrease TBARS and increase water holding capacity, but it has no effect on the growth performance of Japanese quail when used as a feed supplement. In another study, the presence of antioxidant compounds in the thyme-containing diet delayed discoloration, lipid oxidation and bacterial counts, while also imparting a better appearance to the fresh lamb meat (Nieto et al., 2010). Fratianni et al. (2010) concluded that thyme essential oil can effectively reduce the deterioration of chicken meat and extend the shelf life of the fresh product when stored at 4 °C. In the study by Solomakos et al. (2008), during storage at 10 °C, an inhibitory activity against *E. coli* O157:H7 was observed in thyme essential oil-treated (at a level of 0.6%) minced beef meat.

Rosemary (*Rosmarinus officinalis*) is an evergreen aromatic herb native to the Mediterranean region, but due to its adaptive nature, can be readily grown across the world (Alirezalu et al., 2020; Aziz et al., 2021). Rosemary extracts contain antioxidant compounds, the most active being phenolic diterpenes such as carnosol, carnosic acid, rosmanol, epir- somanol isorosmanol, methyl carnosate and other phenolic acids, such as rosmarinic acid (Hernández-Hernández et al., 2009; Serdaroğlu & Yildiz-Turp, 2004). Since rosemary is a good natural antioxidant source, it has been added in foods to extend shelf-life in the form of fresh or dried leaves, essential oil, and aqueous and alcoholic extracts from leaves (Hać-Szymanczuk et al., 2017; Yeh et al., 2019). The beneficial effects of rosemary extract have been extensively studied and reported on various meat types (Table 1).

Sage (Salvia officinalis) is a variety of aromatic herb widely cultivated in many parts of the world. Sage is the dried leaf of a mint family. The major antioxidant compounds in sage include carnosol, carnosic acid, rosmadial, rosmanol, epirosmanol, and methyl carnosate (Ghorbani & Esmaeilizadeh, 2017; L. Zhang et al., 2013; W. Zhang et al., 2010). As being known for its culinary values, sage also is a potential natural preservative to be used in food applications (Ivanišová et al., 2021).

Oregano (Origanum vulgare L.) is an aromatic Mediterranean plant like rosemary. The essential oil of oregano mainly consists of carvacrol, thymol and their precursors, c-terpinene and q-cymene. It has strongp antioxidant properties and contains molecules that have specific effects on animal metabolism and physiology. The effect of oregano is mainly attributed to carvacrol and thymol which make the bacterial cell membrane permeable and react with lipid and hydroxyl radicals (Kirkpinar et al., 2014). Oregano as raw material as well as oregano essential oil is used in various food including salads, meat products, oils and milk products (Ivanišová et al., 2021).

Lemon balm (*Melissa officinalis* L.) is a herb with sweet, fresh,and strong lemon aroma, growing in the Mediterranean region, western Asia, southwestern Siberia, and northern Africa. (Lara et al., 2011; Lee et al., 2014). Lemon balm is used in medicine, cosmetics and food industry (Salamon et al., 2019). Lemon balm is a good potential source of rosmarinic, caffeic and protocatechuic acid, luteolin, monoterpenoid aldehydes, essential oils (citral), sesquiterpenes, and tannins (Lee et al., 2014). Besides antioxidant effect, lemon balm has antigenotoxic effect and in vitro antimicrobial activity against several gram- positive and gram-negative microorganisms (Fratianni et al., 2010).

The studies on the antioxidant and antimicrobial effects of rosemary, oregano and sage extracts and/or essential oils in meat and meat products were summarized in Table 1.

Green tea (*Camellia sinensis*)

Tea, is a perennial, evergreen and cross-pollinated plant bearing white flowers and green fruits with two to three seeds and is consumed usually as the water extract of *Camellia sinensis* (Quelhas et al., 2010; Seidavi et al., 2020)**.** Green tea is nutritionally valuable, contains essential nutrients, including amino acid of which L- theanine accounts for more than half of the total amino acid, and has polyphenol catechin which can make up 30% of dry weight (Quelhas et al., 2010; Seidavi et al., 2020)**.** Green tea is used in more than 160 countries every day, for drinking but recently, has been noted for its health benefits, especially its potential for preventing and treating cardiovascular diseases (Kumudavally et al., 2008). Green tea is also used to improve the preservation of meat products because of the high polyphenol content. Especially, one of the main polyphenolic constituents of green tea, epigallocatechin gallate, has the highest antioxidant capability (Farahat et al., 2016).

The use of green tea in different ways has been investigated in various studies. The use of dietary green tea extract in broilers increased the body weight, feed efficiency, carcass weight and dressing percentage and decreased caecal coliform bacteria count (Erener et al., 2011). The ethanolic extract of green tea in fresh mutton was found to inhibit spoilage microflora significantly (Kumudavally et al., 2008). The effect of green tea marinade was examined on the formation of heterocyclic aromatic amines (HAs) in pan-fried beef cooked at 180–200 °C for 4 min each side. In this study, marinating in green tea resulted in a significant reduction of PhIP and AαC levels when compared to unmarinated samples (Quelhas et al., 2010). A novel approach has been studied to incorporate green tea extract into polyethylene by extrusion technology. The shelf-life of fresh meat in active package was significantly extended for 3 days compared to control samples (Wrona et al., 2017). In another study, addition of green tea catechin (200 mg/kg) to raw fish oil containing sausages reduced lipid oxidation significantly after 7 days of storage (Valencia et al., 2008). Green tea extract (300 mg/kg) reduced lipid oxidation and redness loss in raw low sulphite beef patties and delayed rancid flavour development in cooked patties (Bañón et al., 2007).

Table 1. Application of rosemary, oregano and sage in meat and meat products

Plant extract	Concentration	Meat type/treatment	Results	Reference
Sage	0, 0.05, 0.1 and 0.15% (w/w)	Chinese-style sausage	improved the oxidative stability of Chinese-style sausage with no negative effects on sensory attributes.	(L. Zhang et al., 2013)
Oregano and sage essential oils	Control, oregano 3% and sage 3% (w/w)	Porcine and bovine ground meat samples	significantly reduced the oxidation.	(Fasseas et al., 2008)
Rosemary	0, 0.025, 0.050% (w/w)	Fermented goat meat sausage	0.050% concentration showed an effective protection against oxidation.	(Nassu et al., 2003)
Rosemary	10,000 ppm	Dry-fermented sausages	decelerated oxidation compared to controls.	(Erdmann et al., 2015)
Rosemary and green tea	Rosemary (R: 1500, 2000, 2500 ppm) and green tea (G: 100, 200, 300 ppm)	Fresh pork sausage	R and G improved oxidative stability. R2500 and G300 had fewer PPC than the control Greater consumer acceptability scores in R and G when compared to the control.	(Schilling et al., 2018)
Chitosan–thyme and chitosan–rosemary essential oils	1% chitosan (C), 1% chitosan–thyme (CT) and 1% chitosan–rosemary (CR)	Turkish fermented sausage (sucuk)	Lower TBARS values were determined for CT and CR.	(Demirok Soncu et al., 2020)
Rosemary, oregano, and thyme	2 g/kg	Dry-cured fermented sausage	an antagonistic activity against *P. nordicum* based on the reduction of the OTA accumulation.	(Álvarez et al., 2020)
Rosemary	1 g/kg	Dietary supplementation of pigs	Significantly improved the polyunsaturated fatty acid content of the meat.	(Liotta et al., 2014)
Sage, lemon balm and oregano	of pig ́s diet supplementation with 100 ml of lemon balm or 100 ml of sage or 60 ml of oregano per day	Pork	The redness a* was improved significantly by sage extract. All three extracts improved significantly antioxidative stability in 5-days stored pork	(Bahelka et al., 2011)
Sage and garlic	0, 0.1 g sage, 0.1 garlic, 0.1 g sage and 0.1 g garlic/100 g	Chicken meat	Sage has a sufficient radical scavenging capacity available for the lipid phase.	(Mariutti et al., 2008)
Sage	0, 2.0% water extract from sage, 2.0% 40% (vol/vol) ethanol extract from sage, 2.0% 70% (vol/vol) ethanol extract from sage, and 0.1% essential oil from sage	Chicken	The growth of mesophilic aerobic bacteria and psychrotrophic bacteria, coliforms, and *Enterobacteriaceae* was significantly restricted by all sage preparations tested. The most effective inhibitory effect was demonstrated by sage essential oil, despite insignificant differences	Cegielka et al. (2019)

			between the preparations.	
Thyme and lemon balm essential oils	0.5 % thyme EO 0.5 % balm EO	Chicken breast slices	Both EO reduced DPPH radical formation in the meat, decreased the natural microflora. Balm EO significantly limited the growth of *Salmonella* sp., and thyme EO effectively inhibited the growth of *Escherichia coli.*	(Fratianni et al., 2010)
Rosemary and lemonbalm	30 mg RE/100 g meat 100 mg LBE/100 g meat	Pork meat patties	The patties with natural extracts showed higher a*-values than control and BHT samples. RE samples had the lowest TBARS values and hexanal content	(Lara et al., 2011)
Myrtle, rosemary, nettle, lemon balm hot-water extracts	10 % for each extract	Beef patties	All extracts slowed down the lipid oxidation of beef patties. Myrtle and rosemary extracts showed the highest antioxidant effects. The effects ofnettle and lemon balm extracts were lower	(Akarpat et al., 2008)
Lemon balm extract	0,0.1,0.5 and 1.0%	Hamburger patties	Positive sensorial effect, 1.0% LBE retards lipid oxidation significantly	(Lee et al., 2014)

As a result, it can be concluded that green tea is succesfully used in packaging materials of several meat products (Borzi et al., 2019; Song et al., 2020; Wrona et al., 2017);with direct addition to meat and meat products (especially in ground meat or patties) (Lee et al., 2012; Murali et al., 2012; Mustafa, 2013; Nissen et al., 2004; Schilling et al., 2018; Zhou et al., 2019) and via feeding treatments of broilers (Farahat et al., 2016; Hossain et al., 2012; Mirshekar et al., 2009; Sarker et al., 2010; Zhong et al., 2015).

Onion and Garlic (Allium spp.)

Plants of the Allium family are important sources of dietary flavonols (Santas et al., 2008). Onion and garlic are two major members of this family that are widely used to enhance the flavor of meat dishes

(Yang, Lee, Moon, Paik, & Ahn, 2011). Both garlic and onion possess strong antioxidant and flavor properties because of their high phenolic and sulfur compounds, respectively. Allicin is known as the main ingredient of garlic which rapidly decomposes to several volatile organosulphur compounds with bioactivities and has antimicrobial activity against both gram-positive and gram-negative bacteria (Kirkpinar et al., 2014; W. Zhang et al., 2010). The studies about the use of onion and garlic in meat and meat products were focussed on feeding supplementation (Ao et al., 2011; Chen et al., 2008; Kirkpinar et al., 2014; Manasri et al., 2012; Onibi et al., 2009; Yan et al., 2011); direct addition to irradiated meat products (Kim et al., 2014; Yang, Lee, Moon, Paik, & Ahn, 2011; Yang, Lee, Moon, Paik, Nam, et al., 2011), sausages (Olesen & Stahnke, 2000; Sallam et al., 2004) , raw chicken meat(Tareq et al., 2018) and marination (Cao et al., 2013; Tang & Cronin, 2007).

Grape (*Vitis vinifera* L.) and Pomegranate *(Punica granatum* L.)

Pomegranate (Punica granatum) has been used in medicine for many centuries since it is an important source of bioactive compounds and (Dua et al., 2016). Several parts of pomegranate has biological (antioxidant, anticancer, antimicrobial) properties and regarding to these properties, pomegranate parts such as seeds, juice, pericarp, bark and leaves have been used to enhance meat and meat products quality (Miguel et al., 2010). In the study by Qin et al. (2013), it was found that pomegranate rind powder had the highest antioxidant activity among pomegranate juice and pomegranate seed powder. And pomegranate rind powder treated group had the lowest standart plate count in ground pork meat stored at 4°C for 12 days. Naveena et al. (2008) have reported the antioxidant activity of pomegranate fruit juice and pomegranate rind powder extract in chicken meat patties. It was also reported in another study that pomegranate rind powder extract at the levels of 2,5% and 5% could protect chicken meat balls against lipid oxidation, retard microbial growth with higher organoleptic quality (Chandralekha et al., 2012). In the study carried out by Devatkal et al. (2010), pomegranate rind extract showed highest antioxidant activity in cooked goat meat patties stored at 4°C for 12 days.

Grapes (Vitis spp.) are among the world's most commonly manufactured fruit crops and economically important plant species due to its diverse uses in production of wine, grape juice and other food products (Georgiev et al., 2014; Unusan, 2020). Grape seed and grape pomace, by-products of wine and grape juice industry, are rich in flavonoids and proanthocyanidins (Mielnik et al., 2006; Sáyago-Ayerdi et al., 2009). Many positive effects on human health have been described for flavonoids including anti-inflammatory, anti-carcinogenic and cardioprotective properties (Georgiev et al., 2014). Grape pomace and grape seed extract have been studied in various types of meat. Some studies on the application of grape by-products in meat and meat products were summarized in Table 2.

Ginger (*Zingiber officinale* Roscoe)

Ginger (*Zingiber officinale*) is native from Asia and is extensively used around the world as a spice, flavoring agent, and herbal remedy and in traditional medicine (Beristain-Bauza et al., 2019; Draszanowska et al., 2020; Wen et al., 2020). The most important bioactive component of ginger are the gingerols that have high antioxidant and antimicrobial activity (Al-Mashhadani, 2014; Beristain-Bauza et al., 2019; Wen et al., 2020). Ginger rhizome is also a good source of “zingibain”, a thiol proteinase (Saranya et al., 2016). So, ginger is used to enhance the tenderness of meat in several studies (Abdel-Naeem & Mohamed, 2016; Moon, 2018; Naveena et al., 2004; Naveena & Mendiratta, 2004; Suryanti et al., 2015; Tsai et al., 2012) besides prolonging shelf life (Al-Mashhadani, 2014; Anandh & Lakshmanan, 2014; Barbosa et al., 2009; Cao et al., 2013; Draszanowska et al., 2020; Singh et al., 2014; Tanabe et al., 2002; Wen et al., 2020).

Fenugreek (*Trigonella foenum-graecum* L.)

Fenugreek is an annual herb of *Leguminasea* that is a good source of dietary protein for human and animal consumption (Mamoun et al., 2011; Wagh et al., 2015). It is rich in calcium and can be used as vegetable, herbs, or as spice and applied in medical uses to reduce blood sugar and to improve digestion (El-Aziz & Abdel-Raheem, 2018). Since fenugreek is a good source of antioxidants such as coumarin, fenugreekine, nicotinic acid sapogenins, phytic acid, scopoletin and trigonelline, it is one of the natural feed additives

(Abdel-Wareth et al., 2021; El-Aziz & Abdel-Raheem, 2018; Kirubakaran et al., 2016; Mamoun et al., 2011; Pałka et al., 2021; Qureshi et al., 2016; Toaha et al., 2016). Fenugreek seed extracts have been also used in patties, burgers and nuggets to inhibit microbial load and prolong shelf life (Devatkal et al., 2012; Hegazy, 2011; Hettiarachchy et al., 1996; Kausar et al., 2021; Mc Carthy et al., 2001a, 2001b). Fenugreek seeds are also used to produce a paste called as "Çemen" in Turkey (Işikli & Karababa, 2005). Çemen (cement) as the coating material of Pastirma,a traditional dried meat product produced from whole muscle, is the major ingredient of the products and plays an important role on microbiological quality and charactersitic aroma and flavour (Karabiyikli et al., 2015).

Table.2 Application of grape in meat and meat products

	Concentration	Meat type/treatment	Results	Reference
Grape seed extract	0,0.4,0.8, 1,6 g/kg	Cooked turkey breast meat	Oxidative stability improved.	(Mielnik et al., 2006)
Grape pomace	0, 5, 10, 15 and 20% GP/kg DM	Dietary supplementation/ shelf life of lamb meat	the highest antioxidant activity and the lowest total viable bacterial counts, lipid and protein oxidation values during the shelf-life period in the 20% GP/kg-diet finished lamb meat	(Chikwanha , Moelich, et al., 2019)
Grape pomace	0, 5, 10, 15 and 20% GP	supplementation in lamb diets	inclusion of 12.2% GP in lamb finishing diets improved lamb productivity, without affecting meat quality	(Chikwanha , Muchenje, et al., 2019)
Grape seed proanthoc yanidins	0, 10, 20, or 40 mg/kg BW/day GSPs.	Supplementation in lamb diets/*longissimus dorsi* muscle quality	As supplementation with GSPs increased the total antioxidative capacity.	(Mu et al., 2020)
Grape pomace	GSE, 50mg grape seed extract kg^{-1}; GP-5, 5% dried red grape pomace kg^{-1})	Dietary treatment/ shelf life of lamb meat	From day 7 of storage, an improvement in TBARS values was observed for GSE and GP-5, compared with control	(Guerra-Rivas et al., 2016)
Grape pomace silage	0,50,75,100 % GPS	Dietary treatment/ lamb meat quality	Lambs fed with GPS had greater lipidic and proteic meat stability with no changes in sensory parameters of meat.	(Martins Flores et al., 2021)
Grape pomace	5, 15, and 30 g/kg	Dietary treatment/ chicken meat quality	Increased content of GP in the diet, reduced the lipid oxidation in breast and thigh meats at 4 and 7 days	(Goñi et al., 2007)
Grape seed extract	0.01, 0.03, 0.05, 0.1, 0.3, 0.5 %	Beef frankfurters	Increased level of grape seed extract decreased TBARS levels	(Özvural & Vural, 2012)

Clove and Cinnamon

Cloves are dehydrated and unextended flower buds of *Syzigium aromaticum L*. and they are significant aromatic compounds used in foods. The antioxidant activity of clove has been associated with tannins, sesquiterpenes, and triterpenoids(Zahid et al., 2020). Clove buds contain approximately 15 to 20% volatile essential oils dominated by eugenol (Suliman et al., 2021). Addition of clove extract in cooked beef patties reduced protein and lipid oxidation when compared with BHT at refrigerated storage (Zahid et al., 2020). In another study with clove oil (CO), 2% CO addition to minced meat extended shelf-life of minced meat to 5 days during refrigerated storage compared to all groups especially to control (Hassanien et al., 2016). In the study carried out by Kumar & Tanwar (2011) it was concluded that for preparation of chicken nuggets, at 0.1% level (w/w) clove powder can be used in meat emulsion for the beneficial effects on physico-chemical and sensorial qualities (Kumar & Tanwar, 2011). In another study, clove essential oil supplementation to bull diets at a level of 450 mg/kg dry matter was protected meat against lipid oxidation(Torrecilhas et al., 2021).

Cinnamon (*Cinnamomi cassiae cortex*) has long been used as a medicinal herb as well as an ingredient in foods. The essential oils in cinnamon bark have been found to be primarily composed of cinnamaldehyde and other biologically active substances such as cinnamyl acetate, cinnamyl alcohol, eugenol, carvacrol (Sang-Oh et al., 2013). Regarding to these properties, cinnamon was investigated as a feed additive and natural antioxidant in meat and meat products. Mehdipour et al., (2013) supplemented cinnamon powder and cinnamon oil to Japanese quail diet and concluded that at a level of 200 mg/kg cinnamon oil could be an alternative as an antioxidant and antimicrobial. Ciftci et al. (2010) who studied the effect of cinnamon oil supplementation to broiler diets on the quality of thigh meat is in agreement with Mehdipour at al. (2013). The antioxidant and antimicrobial effects of cinnamon oil was also investigated as direct addition to ground lamb meat and it was concluded that cinnamon bark oil at the levels of 0.025% and 0.05% has a preservative effect during cold storage.

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CHAPTER 10

CUMIN (*Cuminum cyminum* L.)

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INTRODUCTION

There are approximately 30 species of fruits and seeds that are widely used as spices in the world (Bagchi and Srivastava, 2003). Spices are bionutienst that increase the aroma and taste of foods. Their antioxidant activity also helps to preserve foods from oxidative spoiling, increasing their shelf-life. The usage areas and amounts of spices vary according to cultures and countries. Spice are also used for treatment with the chemical compounds they contain. India is known as the land of spices. Cumin is a traditional used spice from middle ages because it was an symbol of love and loyalty. Cumin is the second well-known spice after the black pepper in the World.

History and origin of cumin

Cumin is a spice that has been used since ancient times. It is known that cumin was found in the pyramids dated to 5000 years ago. There are references in the bible (Isaiah 28:27) about the threshing of cumin with a stick. Cumin is mentioned in the works of Hippocrates and Dioscorides.

Cumin is native of Egypt and Asia. It was essentially cultivated in Iran and Mediterranean region. Cumin widely growing in Khorosan, in Iran.

Romans consumed the ground seed for medicinal purposes with bread, water or wine. During the Middle Ages in Europe, cumin was one of the most common spices used. Around that time, it was considered a symbol of love and fidelity. Wedding guests carried cumin in their pockets, and married soldiers were sent off to war with a loaf of cumin bread baked by their wives. Cumin's use for fortifying is also represented in certain Arabic traditions in which a paste of ground cumin, pepper and honey is thought to have aphrodisiac properties. While cumin is still used extensively in Indian and Middle Eastern cuisines, it became less popular in Europe after the Middle Ages. Interest in its health promoting properties are, however, now increasing interest in this spice worldwide.

Etimology of cumin

The descriptive term could be from Syrian language that would be the Sumerian word "gamun". Etymology connects the statement with the Persian town, Kerman. The common name of this crop is very similar in most countries,

Table 1: Common names of cumin (Kafi et al., 2006).

Language	Names of Cumin
Hindi	Jeera, Safaid jeera
Turkish	Kimyon, Acem kimyonu, Kemnon
Arabic	Kamoun, Kamun
Chinese	Kuming, Xiao hui xiang, Zi ran
Bulgarian	Kimion, Kimion italianski, Kimion rimski
Greek	Kimino
Indonesian	Jinten, Jin ten putih
Japanese	Kumin, Umazeri
English	Green cumin, White cumin, Cumin
Italian	Cumino, Cumino bianco
Urdu	Jirah, Zeera, Zira
German	Kreuzkummel, Weifier Kreuzkummel, Romischer Kummel, Mutterkiimmel

Botany of cumin

Cumin belongs to Apiaceae family which also named as Umbelliferae. Apiaceae is a grand family consisting of around 300 genera and over 3000 numbers of species. Cumin has 2n=14 chromosome number.

Cumin an annual, pubescent (except fruit) and herbaceous plant grown to a height of 15-50 cm. It produces many branches on stems with long divided deep green leaves. Inflorescence a compound umbel consists of three to six radially single umbel each of which has three to five flowers. The flowers of cumin are tiny, rose or white, and bear in umbels. The fruit is an oval shaped schizocarp. Seeds of the fruits are two in number. Cumin seed is elongated approximate 6mm long and yellowish-brown in colour. Cumin seed resemble caraway (*Carum carvi*) and fennel (*Foeniculum vulgare*) seed.

Usage of cumin

Useful parts of cumin plant are leaves, flowers and seeds. Cumin seeds and its oils are important economic parts of the plant. Cumin seed is a well-known spice with a strong aromatic odor and warm-bitter taste (20). The plant and its products have many uses in food, cosmetic, pharmaceutical industries.

Cumin is commonly used in Indian, Iranian, Mexican, Turkish and Middle Eastern meals. The seeds are used as whole and are dry or fried roasted before usage. Cumin is one of the essential ingredient in Indian curry powder and garam masala. In Mexica it is used with chili con carne and in Morocco with lamb. Cumin is especially used with Turkish street food which is called kokorec (grilled sheep's intestines). Cumin powder can be added to lemon and olive oil based marinades for chicken, lamb, pork.

Cumin is common flavor in confectionery and is also used as preservative in food processing. Mediterranean countries have a strong tradition of using aromatic plants and essential oils to conserve food. Cumin seed oil is used as fumigant and additive in the storage of foodstuffs due to its high antibacterial and antifungal activity against various patogenic microorganisms (Li and Zi-Tao, 2004).

Cumin-containing beverages such as cumin tea, cumin water, cumin-flavoured energy drinks are some of the innovative and value-added products.

Usage of the cumin seed in terms of health have been established based on its nutrient content. The cumin seeds are a good source of iron, zinc, manganese, potassium, essential amino acids, proteins, and other unsaturated fatty acids

Dry plant residues left in the field after seeds at harvest can be used as animal feed. One ton of dry matter can be obtained from one hectare of cumin field. A significant amount of cumin forage is obtained annually in large production areas such as India. Cumin forage added to animal feed has been shown to provide satisfactory benefits in milk yield, but there has not been enough research on this subject (Kafi et al., 2006).

Composition of cumin seed

Cumin is one of the most valuable medicinal plants. It is used both in the food industry and in the pharmaceutical industry with its many components important for health. Cumin seed several vitamins and minarals (Table 2).

Table 2: Nutritional content of 100 g of cumin seeds.

Content	Per 100 g
Energy	1.567 KJ (375 Kcal)
Carbohydrates	44.24 g
Sugars	2.25 g
Protein	17.81 g
Dietary fiber	10.5 g
Fat	22.27 g
Saturated fatty acids	1.535 g
Water	8.06 g
Vitamin A	64 µg (7 %)
Vitamin B6	0.435 mg (33 %)
Vitamin B12	0.00 µg (0.0 %)
Vitamin C	7.7 mg (13 %)
Vitamin E	3.33 mg (22 %)
Folate (vit. B9)	10 µg (3 %)
Riboflavin (vit. B2)	0.327 mg (22 %)
Niacin (vit. B3)	4.579 mg (31 %)
Calcium	931 mg (93 %)
Potassium	1788 mg (38 %)
Phosphorus	499 mg (71 %)
Magnesium	366 mg (99 %)
Iron	66.36 mg (53 %)
Zinc	4.8 mg (48 %)
Sodium	168 mg (7 %)

Composition of cumin volatile oil

There are many factors that affect the quality of cumin essential oil. Agronomic conditions, method of essential oil extraction, area of cultivation, date of harvesting, type of cultivars and storage conditions could affect chemical properties of cumin essential oil. The cumin seeds include amino acids, aldehyde (60%) fats, glycosides and flavonoids (22%), volatile oil (2-5%) and the yellow colored fresh oil contains cuminaldehyde as its major component. Cuminaldehyde, limonene, α- and β-pinene, 1, 8-cineole, o-and p-cymene, α- and γ–terpinene, safranal and linalool are main components of volatile cumin oil. There are many different methods of obtaining essential oils. Major of the methods are Supercritical fluid extraction (SCFE), Hydrodistillation (HD), Steam distillation (SD), Superheated water extraction (SWE), Soxhlet extraction (SE), Combination of organic solvent and steam distillation (OS-SD) and Microwave extraction (MWE) (Sahana et al., 2011). Table 3 shows the ratio of components obtained from cumin essential oil according to the OS-SE method.

Table:3 Contents of Cumin Oil Obtained by OS-SD Method (Combination of organic solvent and steam distillation) (Sahana et al., 2011).

No	**Compounds**	**%**
1	Terpene hydrocarbons	30.53
2	Aldehydes/ketones	48.01
3	Alcohols	10,86
4	Oxygenated compunds	0,29

Cold press cumin seed oil is a rich source of fatty acids and lipid-soluble bioactive compounds. It contains significant levels of petroselinic acid and natural antioxidants. Oleoresin from the seeds is usually applied in crackers, meat, sauces and sausages. The distinct and strong aroma of the seeds are responsible for its use as spices as well as other medicinal uses (Allaq et al., 2020).

Agriculture of cumin

According to the latest statistics, 91% of cumin production in the world is carried out by four countries: India, Syria, Turkey and the United Arab Emirates. India is the leader with its 70% share in total cumin production. (8). The shares of other countries in production are: Syria 13%, Turkey 5% and UAE 3%. Cumin production and consumption has an important place in Iran. There is a rapid increase in cumin production area and cumin yield in India. Turkey is also among the important cumin exporting countries (Table 4). The production of Turkish cumin according to European standards increases the quality.

Table 4: Cumin planted area and yield statistics by years in India and Turkey (Turkstat, 2021 and DASD, 2021)

Year	India		Turkey	
	Area Thousand ha	**Yield Kg/ha**	**Area Thousand ha**	**Yield Kg/ha**
2006	409,00	432,00	18,30	500,00
2007	429,00	402,00	18,40	480,00
2008	429,00	402,00	19,00	760,00
2009	377,00	415,00	17,10	740,00
2010	508,00	619,00	20,00	660,00
2011	594,00	663,00	22,60	610,00
2012	594,00	663,00	24,70	690,00

2013	859,00	598,00	22,40	690,00
2014	890,00	546,00	27,00	630,00
2015	808,00	623,00	26,90	690,00
2016	781,00	641,00	26,70	720,00
2017	781,00	641,00	36,20	670,00
2018	996,00	714,00	36,17	670,00
2019	1028,00	682,00	32,18	630,00
2020	1276,00	715,00	21,21	660,00

Cumin varieties

Cumin varieties that adapt to different climatic conditions have been developed. Rajasthan and Gujarat are the cities where cumin is grown the most in India. RZ-19, RZ-209 and RZ-223 varieties were developed at Sri Karan Narendra College of Agriculture (RAU), Jobner through selection. Gurajat Cumin-1,2,3,4 varieties were devoloped by Spice Research Centre (SDAU), Jagudan.

Gujarat Cumin-1 variety was devoloped from local germplasm. The variety is tolerant to wilt disease. Gujarat Cumin-2 was developed through pure line selection. It matures in 100 days. Gujarat Cumin-3 was devoloped through exotic line selection. It is also resistant to cumin wilt. Gujarat Cumin-4 variety was devoloped through selection from Gujarat Cumin-3 and it is tolerant to Fusarium wilt.

There are Egebir-09 and Turkmen-09 cumin varieties registered by Transitional Zone Agricultural Research Institute by selection in Turkey.

Climate and sowing

Cumin is cultivated mostly in tropical and subtropical regions. For good growt and succesfully production 15-25 °C and dry air conditions are ideal for cumin planting time. Time of sowing is an important agro-technique for production, disease and pest incidence. Humidity in atmosphere during flowering and beginning seed stage is not good because cumin is prone to attack by several diseases. Cumin is also sensitive to frost damage during flowering and fruit setting. Cumin production areas are limited to areas with low humidity and where winters are not severe. The most suitable planting time for cumin in Turkey is between February 15 and March 15.

Cumin is planted in two ways: row planting and broadcast sowing. Cumin is traditionally planted as a broadcast, but row planting provides optimum habitat for plants and facilitates post-planting cultural operations like weed management. The use of mechanical feeders in seed drillers, requires a very precise fit between the size of the holes and thickness of the metering plate and the seeds, making it necessary to have plates with different characteristics for each seed lot. For these reasons, cumin seeds are usually discarded (Piri et al., 2019). Soaking cumin seeds in slow running water one day before planting is recommended to remove germination inhibitors. In cases where there is contamination with fungal diseases such as *Alternaria* and *Fusarium*, cumin seeds should be disinfected with fungicides. The high sowing density can increase the humidity in the canopy and allow the development of these diseases.

Before sowing cumin, the field should be prepared for planting by plowing 3-4 times. For a good germination, care should be taken to have sufficient moisture in the soil at the time of planting. Optimum row spacing should be between 15-25 cm, depending on planting time and precipitation. The optimum seed rate for this crop is 12 to 15 kg per hectare (Sharma et al., 1999). The sowing depth should not be more than 1,5 cm and the seeds should be covered with a thin layer of soil and the soil should be compacted with a suitable tool. Planting the seeds too deep delays germination.

Irrigation

Cumin is commonly grown as rainfed plant and watering is only aplied when excess water is available as supplementary irrigation. Sufficient and timely irrigation increases the quality and quantity of the product well. A light irrigation should be done immediately after sowing cumin seeds. The second watering should be done 8-10 days after planting. Seed emergence starts after the second irrigation. By following the weather conditions and the water demand of the plant, irrigations made at intervals of 20-30 days increase the yield significantly (Lal et al., 2014).

According to the researches, it has been stated that the weight of 1000 seeds of irrigated cumin is less than the weight of 1000 seeds of cumin grown by rain. This has been associated with more vegetative growth and less nutrient delivery to the seeds (Kafi et al., 2006).

Plant nutrition and fertilizers

The necessary fertilizers and their amounts vary according to the amount of mineral and organic matter in the soil. Soil analysis should be done to determine the fertility of the soil and the necessary fertilization program should be made. For cumin 30 kg N, 60 kg P and 30 kg K per hectare is recommended with 15-20 tons per hectare manure.

Weed management

Just like in other plants, weed is one of the important factors affecting the yield for cumin. Cumin is not a good competitor to weeds. While weeds share the nutrients of cumin, they increase the humidity and prepare suitable condition for diseases. In order to provide a suitable environment for the development of cumin, the first weed cleaning should be done 30-40 days after planting. After the first weeding, one or two more hoeing and weeding is recommended. *Chenopodium album*, *Sinapis arvensis*, *Cynodon dactylon*, *Asphodellus tenifolius*, *Plantago pumila*, *Chenopodium murale, Melilotus indica* are the common weeds in cumin fields. Plantago is the most severe weed. If it is not removed from the field in time, it is inevitable that Plantago seeds will mix with cumin seeds at harvest. Weed control and struggle are also carried out by spraying before and after planting. Oxadiazon, benthiocarb, fluchloralin and oxadiargyl are recommeded for weed control in cumin fields.

Plant protection

Cumin is succeptiple to frost especially inital flowering and seed formation stage. Agricultural frost events due to sudden temperature drops during the cumin growing period cause damage to cumin. Necessary precautions should be taken according to the signs of frost in the air and the agricultural frost warnings of the meteorology. Irrigation and creating smoke in some way helps to reduce frost damage. Application of 0.1% H_2SO_4 spray has been found effective to protect the crop against incidence of frost (3).

Major diseases of cumin are blight, wilt and powdery mildew and the diseases are caused heavy losses in yield and quality of seeds. Plant protection measures should be applied carefully and in a planned manner in order to minimize yield loss due to diseases. Using disease-free seeds, removing sick plant residues from planting areas and crop rotation are the main cultural measures that can be taken against diseases.

Blight is a disease caused by *Alternaria burnsii* and is an important fungal disease restricting cumin production in many countries. Little information is known about morphologic, phenotypic and phylogenetic characteristics of *Alternaria burnsii* (Bayraktar et al., 2017). The symptoms of the disease are usually noticeable during the flowering period and the whitish necrotic areas seen at the tips of the young leaves spread to other parts of the plants over time, causing the plant to burn (Bayraktar et al., 2017). Fungicides such as iprodione, captain and prochloraz applied to the seeds in appropriate doses before planting are recommended for chemical control of the disease. Dithane-containing fungicides, which are applied to the leaves at regular intervals, can reduce yield loss.

Cumin wilt caused by *Fusarium oxysporum* f. sp. *cumini* (Foc) is one of the most destructive diseases (Kanani and Shukla, 2020). This disease infects cumin at all stages but especially it appears in field when the crops are one month old. Crop rotation is very effective for control this disease. Trichoderma applied to seeds reduces the incidence of the disease. Solarization applied to the production plots is also one of the disease control methods.

Powdery mildew is caused by *Erysiphae polygoni* and is usually appears in late stage of the crop. In severe infection cumin leaves show greyish-white apperance. Warm and humid weather conditions are very favorable for the spread of this disease. In chemical control against powdery mildew, Bavistin is used twice, with powdered sulfur and sulfex. Two times sprays of Karathane can also reduce the infection and increase the cumin yield.

Major pests causing damage to cumin are cotton aphid, green peach aphid, onion thrips, brown mite and luceren caterpillars. In order to avoid pests, planting time should be chosen carefully, developmental stages of pests should be known and early control should be done. Chemical pesticides suitable for pest groups should be applied on time, correctly and in appropriate doses.

Harvesting

Cumin reaches harvest maturity 90-120 days after planting, depending on the variety and environmental conditions. Physiological maturity stage (not complete drying of plants, complete yellowing of plants) is the most suitable stage for harvest. In traditional methods, cumin is harvested by hand and harvested cumin plants are bundled in the field. Cumin seeds are separated from their stems with suitable tools. In recent years, cumin harvesting can be done with combines adapted to cumin.

Cumin for health

Cumin seeds have medicinal properties and are used as astringent, carminative, stimulant. Cumin herbs are beneficial to the digestive disorders like morning sickness, biliousness, indigestion, diarrhea. The spice is valuable in easing sleeplesness.

Kızıl and Sogut (2002) found that the low concentrations of esseantial oils of coriander and cumin revealed effectively antibacterial effects against some Gram (+) and Gram (-) bacteria in their study.

Antimicrobial activity has been reported from aqueous extract and essential oils of cumin. Cuminaldehyde is the major component of cumin for antimicrobial property. Cumin seed oil decreased creation of biofilm by *Klebsiella pneumoniae* (an important virulence factor), and also increased the activity of ciprofloxacin against multidrug resistant *K. Pneumoniae* (Derakhshan et al., 2010) Limonen, eugenol, pinenes and some other minor components have been found in cumin essential oil and suggested as the active antimicrobial agents.

Cumin essential oil has antioxidant properties due to the monoterpene alcohols it contains (De Martino et al., 2009). Cumin can be used as a potential source of natural antioxidants in foods.

Cumin is used as an antiseptic in the treatment of the cuts associated with hemorrhage. Cumin may be a stimulant and furthermore as a noble herbal medicine for biological progression ailments, stimulate the discharge of enzymes from the duct gland which might facilitate absorption of nutrients, increase the liver’s capacity to detoxification, anti-carcinogenic property, cut back the chance of abdomen and liver tumor and additionally boost the immune system (Rajput et al., 2021; Tanvar and Goyal, 2021).

Antioxidant activities of the essential oils had positive correlation with their phenolic contents that increased at stages of inter-mediate and premature. In conclusion, the antioxidant activity of cumin essential oil was considered a useful antioxidative compound in the food industries (Moghaddam et al., 2015).

Cumin contains a significant amount of iron (approximately 66,00 mg/100 g), which is five times the requirement of iron per day for an adult. Developing adolescents, lactating women, children and pregnant ladies require more quantity of iron.

Cumin trade

Major cumin exporting countries are India, United Arab Emirates, Turkey, Syria, Ethiopia, Iran. India is the largest cumin exporter country in world. According to statistics in 2018 India exported about 187,000 tonnes cumin around the world with a net value of about US$438 million (DASD, 2019). India's three major markets being Vietnam, Bangladesh and USA. Although the United Arab Emirates does not have a significant share in cumin production, it ranks second in cumin export.

Major cumin importing countries are Vietnam, Bangladesh, United States, United Arab Emirates, Egypt, Nepal. According to 2018 data, the total cumin import value was US$415 million and with US$115 million, Vietnam became the country with the highest cumin import.

CONCLUSION

Cumin is one of the most known and widely used medicinal and aromatic plants in the world. While adding flavor to meals and drinks with its different and delicious aroma, it increases the nutritional value of foods with the important compounds it contains. The high level of iron mineral in its seeds is an indication that it can be used for anemia. The health-beneficial compounds contained in cumin essential oil are important in the medicinal use of this plant. Cumin, which can be used to increase the shelf life of foodstuffs, is an important natural antioxidant.

Cumin can be grown in areas with water shortage and can be recommended to generate more income per unit area than other plants grown without water. There are not many high-yielding and disease-resistant commercial varieties of cumin. More research should be done to develop high-yielding and high-quality cumin varieties with new techniques.

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CHAPTER 11

THE IMPORTANCE AND GENERAL CHARACTERISTICS OF CORIANDER (*Coriandrum sativum* L.): A REVIEW

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INTRODUCTION

The Umbelliferae (Apiaceae) family grows in regions of the world with mostly northern temperate climates and has more than 3000 species and about 300-400 genera (Deniz ve ark., 2018), which are common in the Mediterranean region in general (Megaloudi, 2005). Many plants in this family (fennel- *Foeniculum vulgare*, anise-*Pimpinella anisum*, dill-*Anethum graveolens*, cumin-*Cuminum cyminum*, etc.) are in the class of medicinal and aromatic plants (Keskin, 2015). Coriander (*Coriandrum sativum* L.) is one of the precious plants belonging to this family (Kalkan, 2015; Çelik & Ayran, 2020). Coriander farming has evolved from ancient times to the present day. Its leaves and fruits are mostly used in making spices and medicines (Arslan ve ark., 1994; Gökduman & Telci, 2018). Coriander is mentioned in many languages in different ways (coriander, dhania, dhanya, kuzbara, cilantro, etc.) (Shavandi et al., 2012). Coriander entered Turkish from Persian (Yalçın, 2016). In Turkey, coriander is also called with local names (aşotu, kuzbere, kinzi, kişnit, etc.) depending on the region where it is grown (Baytop, 1994; Arslan ve ark., 2015; Gürbüz, 2010; Konak, 2018).

As a result of the researches, the remains found in 2000 BC show that the cultivation of coriander has been done since those times and it was used for the flavoring of medicines, spices and beverages (Nadeem et al., 2013). The fruits of this plant were placed in the tombs of the pharaohs, which was expressed as the "spice of happiness" by the

Egyptians with the thought of having aphrodisiac effects (Shavandi et al., 2012).

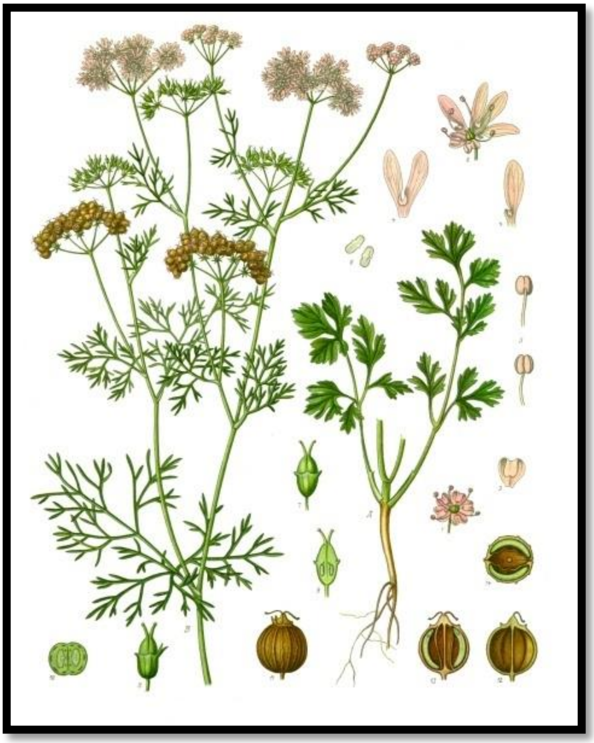

Figure 1. Coriander (*Coriandrum sativum* L.)

(https://en.wikipedia.org/wiki/Coriander)

Coriander (*Coriandrum sativum* L.) is a herbaceous annual, medicinal and aromatic plant with an erect, pile root structure (Şarer, 2004; İzgi, 2017; Deniz ve ark., 2018). It has a branching structure from the upper parts of which the plant height can be about 30-70 cm. Parts of the plant (leaf, fruit, stem) and essential oils are evaluated by many sectors (medicine, food, cosmetics, perfumery, etc.). Different varieties, including summer and winter, have been developed and sold to the domestic market and foreign countries (Arslan ve ark., 2015; Altun, 2020).

Coriander prefers neutral or slightly alkaline soils with high lime content, sandy-loam, light texture. It can be planted in a well-prepared seed bed at a depth of 2-3 cm with 30 cm rows and 1.5-2 kg of seeds per decare between March and April. It is possible to produce from seedlings as well as from seed. The coriander plant, which starts to mature approximately 90-120 days after planting, is harvested after the middle of the summer when the stems begin to turn Brown (Baydar, 2013; Gürbüz, 2010). It has small, pinkish-white flowers. Its seeds, which are close to the spherical form, are brown in color (sometimes in light-ocher tones or green, gray colors) and are about 3-5 mm in size (Asgarpanah & Kazemivash, 2012). According to the general classification, *Coriandrum sativum* L. var. *macrocarpum*; The seeds smaller than 3 mm and weighing less than a thousand grains are *Coriandrum sativum* L. var. *microcarpum* DC. is indicated as (Diederichsen, 1996; Gürbüz, 2010). Coriander fruits are yellow or brown in color, spherical, fragrant, 2-7 mm in diameter and a thousand-seed weight varies between 5-18 g (Arslan & Gürbüz, 1994; Baydar, 2013). According to the researches where planting was done in different row spacings, 0.5 kg seeds were applied per decare at 40 cm row spacing, 215.5 umbrellas were formed per plant, the number of seeds per umbrella was 39.5, and the essential oil ratio was 0.533% (Arabacı & Bayram, 2005). The coriander plant, which is carefully harvested in order to prevent seed losses, is then evaluated in product processing steps such as cleaning, separation and drying.

While mechanization practices are used in the cultivation of coriander in the world, human labor is used rather than mechanization because it is done in small areas in Turkey. On the other hand, when the moisture content of the seeds is below 30%, harvesting with the help of combine harvesters prevents possible seed losses (20-25%). In addition, the advance speed of the combine, the rotation speed of the drummer and its characteristics (fingered or jamb), the length of the concave, the height of the stubble on the field surface affect the harvest quality (Sessiz ve ark., 2006).

While 0.03-2.60% essential oil is obtained from coriander (*Coriandrum sativum* L.) fruits, linalool ratios can vary between 50-70%(Telci ve ark., 2006(a); Telci ve ark., 2006 (b)). Due to the essential oil yield and chemical structure, the leaves and fruit of the plant may have different sensory properties (Mandal & Mandal, 2015). The main components of coriander herb are volatile flavonoids and isocoumarins. In addition to these, it also contains vitamin A, B2 (riboflavin), vitamins C (Paarakh, 2009; Sharma et al., 2010; Asgarpanah & Kazemivash, 2012). In its fruit, essential oils and fatty acids come to the fore. The contents of fresh (0.03% to 2.6%) and dried (9.9% to 27.7%) fruits vary. It may also contain crude protein (11.5% to 21.3%), crude fiber (28.4 to 29.1%), ash (4.9% to 6%) (Deniz ve ark., 2018; İsmailoğlu & Özkan, 2021). Studies on its leaves are limited. Essential oil, flavonoids, phenolic acids and prophenols, nonan, C9-16 alkenes, C7-17 alkenols, C10-12 primary alkenols, oxalic acid, vitamin C, carotene, calcium, capric acid are some components found in the leaves (Sahib et al., 2013). The content of coriander varies depending on the environment in which it is grown, irrigation status and climatic characteristics, and storage conditions after harvest (Nadeem et al., 2013).

Studies have shown that coriander has antimicrobial, antioxidant, anthelmintic, diuretic, anticonvulsant, anticancer, anxiolytic, anti-inflammatory, cholesterol-lowering, antihypertensive, hepatoprotective effects, as well as memory enhancing and proactive effects against heavy metal toxicity (Ramadan et al, 2008; Sreelatha et. al., 2009; Wu et al, 2010; Aissaoui et al., 2011; Rondon et al., 2011; Mani et al., 2011; Rajeshwari et al., 2012; Momin et al., 2012; Sahib et al., 2013; Mohammed et al., 2014; Velaga et al., 2014; Deniz ve ark., 2018).

Coriander is used as a raw material by many sectors such as medicine, food, spice and cosmetics due to its rich content, smell and usage possibilities (Bayram ve ark., 2010; Nadeem et al., 2013). On the contrary, when combined with its current benefits, the fresh and dry forms of this plant are met with increasing interest by the sectors (Matasyoh et al., 2009).

CONCLUSION

Since coriander (*Coriandrum sativum* L.) is cultivated in Turkey in the form of collection from nature and production on small lands, the amount of product obtained is much lower than it should be. In order to prevent this situation, it is necessary to cultivate this plant in larger areas first. It is possible to reach more products with less labor and input (seed, fertilizer, fuel, etc.) by using mechanization opportunities in the period from the seed bed to the harvest of the plant. In addition to these, coriander is a medicinal and aromatic plant that has commercial importance. However, further increase of this potential depends on increasing the quality of the plant to be grown. With the researches to be done, it is possible to determine the needs of this plant and to make a profit by encouraging the producers to grow this product.

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CHAPTER 12

USE OF MEDICINAL AND AROMATIC PLANTS IN DAIRY PRODUCTS

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1. Introduction

Milk is an important drink among all food groups as a food with high nutritional value with its water, carbohydrates, fats, proteins, vitamins, and minerals required for our metabolism. However, as a difficult product to store, milk has met with many preservation methods since ancient times. These methods have opened an important aspect for the development of new products for the milk and dairy products industry and allowed the milk to be stored for a longer time. In addition to yogurt, cheese, butter, kefir, ayran, and ice cream, milk powder, dried and condensed milk production contributed to the increase in the diversity of milk and dairy products.

On the other hand, while medicinal and aromatic plants, which have been known for centuries with their different functional properties, are included in many productions in the food industry, their use with milk and dairy products is also very common. Milk and dairy products have become important carrier matrices for medicinal and aromatic plants preferred for antimicrobial, antioxidant, or aromatic purposes in Turkey and the world.

In recent years, due to the increase in health problems and diseases and the avoidance of treatments with synthetic components, the orientation to herbal sources in treatments is increasing day by day. Medicines used in treating many diseases are generally compounds obtained from natural sources, and plants are among the most used materials. There are many different forms of use of medicinal and aromatic plants, which have an extensive usage area, and used as a whole, fresh and dry, such as leaves, roots, flowers, seeds, bark, tubers, or aerial parts, which are also called herbaceous parts, their crushed or ground forms, and their extracts prepared in different ways (Akarca et al., 2015; Toker et al., 2015). They are the richest biological resources for modern medicines, traditional medicines, food additives, nutraceuticals, chemical units of synthetic medicines, and pharmacological intermediates. Aromatic plants are the source of taste, fragrance, cosmetics, and chemical terpenes. Medicinal and aromatic plants are extracted by various methods, from simple methods to the most advanced techniques in developing countries and developed countries, and they are transformed into valuable biological resources. Industrial evaluation of medicinal and aromatic plants starts with the extraction of active ingredients using various techniques. Common methods used for this purpose; maceration, brewing, leaching, shearing, Soxhlet extraction, extraction with organic solvents, extraction with microwave aid, supercritical fluid extraction, ultrasonic extraction, and extraction with hydrofluorocarbon solvents. Hydrodistillation and aqueous maceration are the most commonly applied methods for aromatic plants. Much newer techniques are solid phase microextraction, protoplast extraction, micro distillation, thermomicro distillation, and molecular distillation (Türk, 2010; Türk and Giray, 2020). The most widely used medicinal and aromatic plants are thyme, mint, rosemary, laurel, basil, sage, poppy, garlic, while plants such as cumin, cinnamon, licorice, anise, ginger, vanilla, fennel, and sumac are also used in the food sector which enables new approaches for especially milk and dairy products

One of the plant species with the broadest distribution globally is the thyme plant, which is a member of the *Lamiaceae* family, which contains about 3000 species belonging to 200 genera (Heywood, 1978). The *Lamiaceae* family attracts attention with both its health-supporting use and its species with high essential oil content. It is known that five important genera belong to the thyme plant. These genera are listed as Thymus, Origanum, Satureja, Tymbra, and Coridothymus for the thyme plant, which is especially preferred for the essential oils in its compositions. The number of species included in the Thymus is 220 worldwide, and 39 species (58 taxa) exist in Turkey, 43 species included in the genus Origanum worldwide, and 23 species (27 taxa) exist in Turkey, 30 species in the genus Satureja included worldwide, 13 species (14 taxa) exist in Turkey, about 12 species of the genus Thymbra included worldwide, two species (4 taxa) exist in Turkey. Only one species belonging to the genus Coridothymus is included worldwide, and this species is also found in Turkey (Bozdemir, 2019). Thyme is cultivated for many reasons as a spice, brewing tea, consuming oil, or for many purposes in landscape applications. Volatile components called thymol and carvacrol in their composition attract attention with their antimicrobial effects and health-supporting properties.

The homeland of mint (*Mentha*), another member of the *Lamiaceae* family, is the Mediterranean coast. Species with high menthol content are widely cultivated around the world due to their valuable essential oil. In terms of essential oils, mint plant whose primary component is menthol contains limonene (1.0-5.0%), cineole (3.5-14.0%), menthone (14.0-32.0%), menthofuran (1.0-9.0%), isomentone (1.5-10.0%), menthyl acetate (2.8%). -10.0%), isopulegol (0.2%), menthol (55.0%), pulegone (4.0%), and carvone (max. 1.0%) (Balakrishnan, 2015).

Rosemary (*Rosmarinus officinalis* L.) is a member of the *Lamiaceae* family with a strong and pungent aroma. The essential oil composition in its composition changes depending on many factors such as the soil in which the plant grows, environmental conditions, and climate. In a study extracted by hydrodistillation, it was reported that the main components in its composition were 14.9% a-pinene, 7.43%, 1,8-cineol, and 14.9% linalool (Gachkar et al., 2007). Volatile components in their composition are preferred in many sectors, including the food industry, due to their antioxidant and antimicrobial properties as well as their pungent aroma.

Laurel (*Laurus nobilis* L.) leaf, which has an important place among medicinal and aromatic plants, is preferred for its essential oils besides its use as a spice. As with all medicinal and aromatic plants, the composition's variety and amount of essential oil may vary depending on many factors. 1,8-cineol, sabinene, α-terpinyl acetate, α-pinene, β-pinene have an important place in the essential oil composition. It is known that around 90% of the world's laurel leaf production is done in Turkey (Gölükçü et al., 2019).

Basil (*Ocimum basilicum* L.), one of the most widely used essential oils in the world, is preferred more as a spice in the Lamiaceae family as well as its essential oils. The main components of basil, which vary according to its cultivated conditions, and which contain essential oil in the range of 0.25-1.79%, are defined as linalool, methyl kavicol, eugenol, linalool, methyl cinnamate, camphor, and citraline (Katar et al., 2021).

Sage (*Salvia*) is an important medicinal, aromatic plant that has been widely used since ancient times. About 900 species belong to the genus Salvia worldwide. In addition to the aromatic phenolic components of sage, whose leaves and essential oil can be used, its antiseptic and antimicrobial properties are also used in traditional use. For *S. Officinalis* L., α-thuion (18-43%), β-thuyon (3-8.5%), camphor (4.5-24.5%,) 1,8-cineol (5.5-13%) are in its essential oil, parallel to the increase in drying temperature, α-thujon and 1 ,8-cineol ratios decrease, camphor and borneol ratios increase.

While vegetable oil is produced from the seeds of Poppy (*Papaver somniferum* L.), which is one of the most important plants in the world, it is also used as an additive in the production of confectionery and bakery products in the food industry. It is known that the essential oils found in poppy flowers obtained by the hydrodistillation method are n-nonadecan, heneicosan, n-pentacosan, n-heptacosan, 1-heptacosanol, palmitic acid, and 1-nonadecanol (Dilek et al., 2018). There are much scientific data on the antimicrobial and antioxidant capacity of the plant, which has blue and white varieties.

The garlic (*Allium sativum* L.) plant, known as the most effective antibiotic with its rich composition, has strong antifungal, antibacterial, and antiviral properties. Besides being consumed directly as food, it has an important place in the food industry with its aroma and anti-agent properties.

Cumin (*Cuminum cyminum* L.) is a plant variety that is widely used as a spice. The active compound of cumin, which is efficient in terms of essential oil, is known as cumin aldehyde. Known as a necessary spice for marinating meat and meat products in Turkey, cumin is indispensable for special flavored cheeses in some countries like Norway and the Netherlands (Varlı et al., 2020).

2. Functional Properties of Medicinal and Aromatic Plants

Plant-derived raw materials are increasingly used in the food industry due to their odor and taste features, health-supporting functions, and anti-agent properties. In addition to plants that share their unique aroma with food, herbal raw materials that increase their functional properties with essential oils obtained by different methods are also preferred in the food industry, particularly in the production of milk and dairy products.

The term phytotherapy, which means treatment with medicinal plants, was first used by the French physician Henri Leclerc. The phrase "Every problem has a herbal remedy, the point is to find it," said by a naturalist who lived approximately 2000 years ago, is still acceptable today. Whether a plant is beneficial to human health or not has been experienced by observing as a result of its use. In other words, the fact that it is good for some ailments after consumption has given the view that plants a useful for the problem in question (Baytop, 1999; Özbek, 2010). Compounds that can be utilized by the human body occur in plant metabolism. Primary and secondary metabolites, which are natural products produced by plants, are basic products that are important for the industry directly or indirectly (Faydaoğlu and Driveoğlu, 2011; Arslan et al., 2015). It is possible to examine the functional properties of medicinal and aromatic plants under four main titles. We can list these properties as enrichment (taste-aroma), bioactive component content, antimicrobial and antioxidant capacity.

2.1. Enrichment (Flavor)

No matter how beautiful and healthy a food product is, it is difficult to prefer it when it is poor in taste. While the consumer defines the five basic tastes (sweet, salty, sour, bitter, and umami) in the mouth, the nose works much harder than the tongue and distinguishes different odors. The sense perceived by the nose for a product is called smell for people who have the ability to distinguish tens of thousands of odors, and people's ability to distinguish odors decreases in the process from infancy to adulthood. When the same product is taken into the mouth, the tongue defines the sense of taste, while the nose defines the product's aroma. When the product is in the mouth, the sense taken with the nose, tongue, whole mouth, and throat is called flavor. The taste of the food is one of the most important factors for being chosen by the consumer.

The history of using herbal raw materials for flavor purposes in foods goes back to ancient times. The first written document on this subject is found in Mesopotamia. It is known that dill, cardamom, thyme, sesame, and saffron are mentioned in the cuneiform library in Babylon. The documents containing the benefits of herbal raw materials, spices, and their recipes were bequeathed to the future by the Babylonian kings. Although transportation is easy today for spices, which were an important trade source of the time, the trade wars in the past should not be forgotten. We can say that many spices that we frequently prefer today find wide use in world cuisines. For example, while the use of anise in meals and cumin in bread is very popular, mint is preferred in meat sauces. While fennel is an indispensable part of pungent sauces with vinegar, garlic has been recognized as a raw material consumed by people living in rural areas. In other words, the consumption of spices has been the expression of wealth and richness (Mete, 2017). Different herbal sources have been the raw materials that give the original flavor of our various dishes in our kitchen for many years. Spices, whose value increased in the table of the nobility in medieval Europe, were one of the important trade products of the time. The Spice road stretching from India to Europe remained open for years as the only gateway for this important trade, but only the wealthy people had the opportunity to enter through this gate and meet with spices. The historical Spice route has lost its importance over time by discovering new ways to access spice-producing monopoly countries. As for today, we see that every country has a large number of spice production under the soil and climatic conditions they have due to their geographical location.

Medicinal and aromatic plants have been consumed as food and/or spice for centuries. In the Turkish Food Codex Spices Communiqué of the Ministry of Agriculture and Forestry, spices are defined as the products of various plants used to give color, taste, smell, and flavor to foods, and obtained by whole and/or crumbling and/or grinding of the dried "seed, bud, fruit, flower, bark, root, stem, rhizome, tuber, leaf, stem, onion. When viewed within the scope of this definition, it is possible to say that spices such as mint, thyme, sage, linden, basil, cumin, cardamom, black cumin, laurel, and rosemary are the most preferred medicinal and aromatic plants to enrich the flavor of foods. Spices come to the fore in discovering new flavors in world cuisines, especially with the increase of the fusion cuisine perspective, which is a method that brings together the traditions, production methods, and raw materials of different cuisines. New herbal raw materials are blended with more and more different production methods and take their place in kitchens under fusion kitchen. With the fusion cuisine approach, which is also called the meeting of bitter and sweet, salty and sour on the same plate, unique tastes are revealed by blending the unique herbal flavors of each region and country. Undoubtedly, the share of spices that come to mind first for herbal raw materials is quite high in this blend of flavors.

There are many advantages in the use of herbal resources for enrichment in foods. Each country can choose the herbal resources specific to the growing region in its climatic conditions. It is very important that there is no need for high technology in the processing stage for easy-to-produce plant raw materials. Another advantage can be defined as the fact that the material used in terms of taste provides support with different effects and properties (antioxidant, antimicrobial effect) and the aroma it gives to the food. Medicinal, aromatic plants are also used as food additives and colorants. Turmeric and saffron (yellow), safflower (red and yellow), pomegranate (red-purple), tomato and paprika (red), marigold (yellow-orange) are preferred as natural colorants in the food industry.

2.2. Bioactive ingredient content

Although bioactive components are not essential for the growth and development of living things, they are defined as secondary metabolites that positively support cellular activities. It is stated that there are more than 25000 bioactive components in a typical diet (Hergenç, 2015). Bioactive components of plant origin are defined as phytochemicals. Although the term bioactive ingredient does not date back to ancient times, the World Health Organization (WHO) estimates that approximately 80% of the world's population has preferred herbal products for health problems for many years. In developed countries, about 25% of the drugs are herbal-based drugs. The most frequently used health-supporting herbal resources around the world are actually legacies from the past. While garlic is preferred for blood pressure and cholesterol, licorice root, linden, hibiscus, and cloves are important herbs in colds, coughs, and digestive problems. For diabetes, bitter melon, mahaleb, myrtle, cinnamon are used, while herbal raw materials such as anise, centaury, lemon balm, and chamomile are used against stress, anxiety, depression.

The traditional use of many substances and products in many countries for many years indicates that they are reliable ingredients without the need for written information in this sense. In recent years, many studies on the medicinal effects of spices and wild herbs, apart from their aroma-providing functions, have proven health-supporting effects due to bioactive components in their compositions. In addition to the content of bioactive components, many studies show the antimicrobial effects of herbal extracts on different types of microbiological organisms, including pathogens that cause food poisoning, and emphasize their antioxidant capacity (Dağdelen, 2010; Köse, 2015).

2.3. Antioxidant capacity

One of the most important storage problems for foods high in fat is oxidation. Rancidity, which is also defined as a bitter taste, occurs in oxidized oils. This situation, known as rancidity in oils, causes changes in the food's color, flavor, texture, and nutritional value. To prevent this undesirable situation, medicinal and aromatic plants are often preferred.

Medicinal and aromatic plants are raw materials of great importance as natural antioxidant sources. In recent years, when the demand for a more natural, healthier life has increased, medicinal and aromatic plants with many antioxidant components became important for consumers. Antioxidants are known as systems that destroy the negative effects of free radicals. Free radicals, which are compounds with high activity, can occur during vital activities or under the influence of endogenous sources such as respiration, enzyme reactions, autooxidation reactions, and various environmental sources such as cigarette smoke, air pollution, UV, ionizing radiation, and xenobiotics. Free radicals play an important role in forming many degenerative disorders, diseases such as cancer and similar diseases, cardiovascular diseases, and Alzheimer's.

Plants have developed protection systems by developing varying antioxidants against the damage of active oxygen forms that cause various stresses. In this way, plants provide the repair of cell and genetic materials with the help of antioxidant enzymes, radical scavenging compounds, and other synthesized components. Plants are defined as the main source of natural antioxidant compounds. Many studies have studied the antioxidant compounds in fruits and vegetables, spices, herbal teas, and oilseeds. It is stated that the antioxidant effects in question arise from phenolic compounds and especially from the flavonoid structure (Diri, 2006).

Naturally sourced antioxidants are phenolic compounds, nitrogenous compounds, organic acids, and carotenoids found in plants. In addition, amino acids such as cysteine, methionine, histidine, tryptophan, and lysine, and thioredoxin protein, which is rich in sulfur, also show antioxidant properties. Synthetic antioxidants are used to prevent the deterioration of foods and to extend their shelf life. Today, BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), PG (propyl gallate), and TBHQ (t-butylhydroquinone) are known as the most widely used synthetic antioxidants. However, studies are showing that synthetic antioxidants and the by-products they create can cause various diseases. For this reason, studies on finding new antioxidant substances that can replace synthetic antioxidants from natural sources have gained importance, and researches in this field are increasing (Öztürk, 2008).

Antioxidants, which reduce the risk of developing many diseases such as cancer and cardiovascular diseases that pose a significant risk in terms of human health or which show positive effects, are a subject that attracts much attention, and many researches have been carried out today. Excessive amounts of free radicals, which are formed due to various metabolic reactions in the body and are highly reactive due to having one or more unpaired electrons, can cause damage to many tissues, organs, and systems. In addition, oxidation of lipids may occur in the processing, storage, and other technological stages of foodstuffs. Therefore, an additive is needed to increase the durability of these products. Natural antioxidants are considered more preferable to synthetic butylated hydroxytoluene and butylated hydroxyanisole compounds due to the suspicion that they are carcinogenic (Türk, 2010).

While the antioxidant substances in the composition of the plants have a protective effect until they are consumed in the foodstuff, they maintain the same function when taken into the body with food. In this respect, it is a common practice to evaluate different foods by determining their antioxidant activity (Dağdelen, 2010). It is known that hundreds of natural and synthetic compounds have antioxidant properties. Plants, animal products, enzymes, and some microorganisms are among the essential natural antioxidant sources, and it is stated in the literature that such natural substances are more effective than synthetic antioxidants (Turhan and Üstün, 2006). Because natural antioxidants are additives that people have consumed or mixed with foods for hundreds of years, they are seen as safe by consumers (Bera et al., 2006). Besides the aroma that they give the food that they were added, It is a well-known practice today that spices and plants extend the shelf life of the food, thanks to its antioxidative effect, and by preventing oxidative rancidity with its antioxidative effect, and by preventing microbial spoilage with its bacteriostatic effect.

One of the biggest problems that occur during the preservation and storage of foods is lipid oxidation, which causes rancidity in oils, deterioration in color, taste, aroma, texture, and consistency, and a decrease in nutritional quality in other foods containing fat. The use of antioxidants is necessary for the food industry to prevent or reduce lipid oxidation, prevent the formation of toxic oxidation products, maintain nutritional quality, and extend the shelf life of food. However, many researchers point out that synthetic antioxidants such as BHA and BHT, which have been used in food processing for a long time, have carcinogenic effects in living organisms (Cerit, 2008). While the increase in human welfare has led to diversity in nutrition, it has also led to serious expectations for preventing food-borne diseases. Therefore, human beings want both to eat in the best way and protect their health simultaneously. For this purpose, some synthetic additives have been used in food production for a long time. However, it is not known exactly whether they are safe or not (Kavuncuoglu, 2012; Ağıroğlu andDriveoğlu, 2013). Due to the increasing concerns over the safety of synthetic antioxidants, there has been intense interest in the food industry to obtain natural antioxidants from various plant materials. This situation has led to the increasing use of medicinal and aromatic plants, which have great potential as a natural antioxidant source, to prevent oxidation, especially in fatty foods such as meat, dairy, and bakery products (Arslan and Kırca, 2006).

2.4. Antimicrobial capacity

The desire of people to keep the food edible for a longer time necessitated the use of various antimicrobials in the production of food. Antimicrobial substances, which constitute an important class of food additives, are added to foods to delay the deterioration of foods and prevent the development of microorganisms that can be reproduced in foods. Antimicrobial substances show their effects by either killing microorganisms or preventing their development (Guven, 2008). Due to the consumer's question marks against synthetic preservatives and the legal restrictions against these preservatives, the sector has entered into new searches regarding long shelf life in food products and the protection of food from microbial spoilage. Today, due to the use of a large number of additives to protect foods, the potentially toxic substances of these substances, and the limitations imposed on this issue, the interest in preservation methods in the food industry, primarily in which natural origin antimicrobial components are used, has increased day by day. In particular, various materials obtained from herbal sources are preferred because they provide natural antimicrobial effects. Antimicrobial substances obtained from plant sources can be used to prevent the development of pathogenic microorganisms, yeasts, and molds in foods, and in this way, the quality of the products can be preserved for a long time.

Until today, many studies have been conducted on medicinal plants, which are a rich source of antimicrobial agents. Since they are used as raw materials in many industries such as medicine, food, perfume, and cosmetics, natural plants and their essential oils have been the subject of much researches, especially since 1940 due to their antimicrobial effects, and important results have been obtained thanks to these researches (Faydaoğlu and Süroğlu, 2013). It is a well-known practice today that medicinal and aromatic plants extend the shelf life of food. Besides the aroma they add to the food, they prevent oxidative bitterness with its antioxidative effect and microbial spoilage with its bacteriostatic effect. Many plants are used for their antimicrobial properties due to the secondary metabolism compounds they synthesize, and the essential oils obtained from these plants are in the class of natural preservatives that can be used safely in foods. Antimicrobial substances characterized by essential oils also have value as spices, and these substances are considered safe to use. Essential oils generally carry the characteristic aroma of plants and can be obtained from plants by the distillation method. Even if they are used in minimal amounts, they bring the plant's aroma from which they are obtained to the product they are applied to. Antimicrobial activity properties vary depending on the plant species, concentration, composition, type, and load of the target microorganism, the food composition, processing and storage conditions. Gram-negative bacteria are more resistant to the antimicrobial properties of essential oils than gram-positive bacteria (Bakkali et al., 2008).

The antimicrobial properties of plants and herbal sources depend on the aldehydes, organic acids, and phenolic compounds in their composition. Allspice, almond, laurel, black pepper, caraway, cinnamon, clove, coriander, cumin, garlic, grapefruit, lemon, mandarin, onion, orange, thyme, rosehip, sage, and marjoram are plants that essential oils are obtained from, and they have an antimicrobial effect (Anonymous, 2018). Some of these plants, which are known to have an effect against microorganisms, and their essential oils are also used to prevent mold development. The lipophilic properties of these plants that cause antimicrobial activity are due to terpenoids (isoprenoids), monoterpenes and sesquiterpenes, low molecular weight aliphatic hydrocarbons, acids, alcohols, aldehydes, acyclic esters, or lactones (Djilani and Dicko, 2012).

In a study on essential oils of cinnamon, cloves, allspice, rosemary, black pepper, marjoram, garlic, and cumin, it was determined that clove, cinnamon, allspice, and rosemary were the most effective on Gram (+) and Gram (–) bacteria (Faydaoğlu and Driveroğlu, 2013). At the same time, antifungal and antimicrobial activity are caused by phenolic compounds such as thymol, eugenol, carvacrol, which are found in high concentrations in plants and essential oils, as well as components such as linalool, sabinene, menthol, myrcene, and camphene (Puvača, 2018). It has been found that phenolic compounds such as tea catechins, oleuropein, ferulic acid, ellagic acid, and coumaric acid inhibit the growth of some pathogenic bacteria (*Staphylococcus aureus*, *Salmonella enteritidis*, and *Listeria monocytogenes*) and molds (Bin et al., 2011). In a study, they stated that resistance was lost by destroying the plasmids containing the resistance genes by using thyme, pomegranate, clove, and lemon balm extracts in bacteria belonging to *S. aureus* and Shigella species, which were found to be resistant only to Ampicillin and/or Chloramphenicol and/or Tetracycline antibiotics. Jirovetz et al. (2003), in their study on the antifungal activity of dill (*Anethum graveolens* L.), showed that essential oils of dill seeds have high activity against Aspergillus niger mold and *Saccharomyces cerevisiae* and *Candida albicans* yeasts.

Rosemary is an intensely aromatic herb with antioxidant and antimicrobial properties. There are phenolic components such as carnosic acid, rosmarinic acid, carnosol, rosmarol, epirosmarol, which show antimicrobial properties in the structure of rosemary. It has been reported that the essential oils extracted from rosemary contain bioactive components such as α-pinene, 1,8-cineol, camphor, and borneol, which also show antimicrobial activity (Demirtaş et al., 2011; Çiftçi et al., 2013). The antibacterial, antifungal, and antiviral effect of garlic, which has been used as a remedy for the disease for centuries, has been reported. The antimicrobial property of garlic was first identified by Louis Pasteur in 1858. Antifungal, antibacterial, and antiviral effects of garlic have been found in numerous studies that were conducted later. It is the allicin compound isolated from diallyl thiosulphinade, which gives the garlic its typical odor and taste, showing antimicrobial properties. The amount of allicin in garlic is between 0.2-0.4%. Another compound with antimicrobial properties other than allicin is allogen.

Allicin is not formed when the garlic clove is whole, and when it is crushed, it is created quickly by the effect of allinase enzyme. In the studies, it has been determined that the effect of garlic on bacteria is due to the interaction of allicin with -SH groups, and it has been suggested that it is through lipid synthesis blockade by inhibiting acetyl CoA synthetase. Its mode of action on fungi is through inhibition of protein and nucleic acid synthesis and blockade in lipid synthesis. A study examining the antimicrobial effects of 1/10 extracts of different Allium species in water, ethanol, and ether using 68 microorganisms and five reference strains determined that garlic was more effective than other Allium species. In addition, the aqueous extract of Garlic showed an inhibitory effect against 30 strains of Mycobacterium at doses of 1.34 - 3.35 mg/ml. It was determined that an average dose of 1.67 mg/ml showed an inhibitory effect against M.

tuberculosis (Evren et al., 2006). It has been shown that the use of essential oils from black pepper, clove, geranium, nutmeg, and two species of thyme (*Origanum vulgare* L., *Thymus vulgaris* L.) has significant counteracting effects against pathogens even at low levels (Dorman and Deans, 2000). A study found that garlic, onion, cinnamon, thyme, wild marjoram, black pepper, clove, and allspice oils prevented Clostridium botulinum from forming spores (Ismail and Pierson, 1990).

The plant itself, oil/essential oil, or extract form are used in studies on medicinal and aromatic plants in dairy products. Most studies aim to increase the shelf life of products by adding plants with antimicrobial and antifungal activity to dairy products in different forms. As an innovative approach in cheese varieties, certain aromatic plants to prevent the development of undesirable microorganisms in cheese and protect consumers from the risk of molds forming mycotoxins are gaining popularity. In addition, these aromatic herbs and spices can be more effective than commercially used ones used in flavoring and antimicrobials in the development and flavor in products and the storage of products (Cuervas-Mons et al., 2013). Essential oils such as thyme, rosemary, cumin, pepper, and sage, which show antimicrobial activity against pathogens and spoilage microorganisms that contaminate cheese, have been used to protect the cheese from ancient times to the present (Macwan et al., 2016). Mahgoub et al. (2013) investigated the effect of adding 0.1% and 0.2% (w/w) black seed oil to Domiati cheese on the inhibition of foodborne pathogens

(*Staphylococcus aureus, Salmonella enteritidis, Escherichia coli*, and *Listeria monocytogenes*). As a result of this study, it was determined that 0.2% black cumin oil added to the cheese showed the maximum effective antimicrobial potential on pathogens during storage and improved the physicochemical and sensory properties of the cheese. Hassanien et al. (2013) found that adding 0.1 or 0.2% black cumin seed oil to cheese has significant inhibitory effects against certain pathogenic bacteria (*Escherichia coli* ATCC 8739, *Listeria monocytogenes* Scott A, *Salmonella enteritidis* PT4 and *Staphylococcus aureus* ATCC 6538). Bahrad et al. (2009) determined that cinnamon yogurt containing probiotic bacteria inhibited the growth of Helicobacter pylori in vitro. Elbagory et al.(2019) found that pomegranate peel extract and Moringa tea leaf extract improved yogurt's antibacterial, functional, and nutritive properties, and with a 2% concentration of both pomegranate peels and Moringa tea leaves inhibits its development of *E.coli* O111:H2 (EHEC O111:H2) during the storage period. According to the studies, it has been determined that the shelf life of Labneh cheese, which has a short storage period, is extended by adding 0.2 ppm of thyme, marjoram, and sage essential oils (Al. Otaibi and El. Demerdash, 2008).

Today, medicinal plants, which are the natural source of compounds used against many diseases, contain various chemicals that have significant biological effects on humans. The therapeutic properties and antimicrobial effects of plants are due to the chemical compounds expressed as secondary metabolites. In the modern sense, 25% of the active ingredients of drugs produced pharmacologically are obtained from plants. Another superior aspect of herbal medicines is that research on new antimicrobial substances has accelerated in recent years due to the high cost of producing new generation antibiotics and the increase in resistance against many types of microorganisms that cause infectious disease agents and hospital infections (Çopuroğlu, 2013).

It has been reported that herbal products stimulate the digestive system of animals, destroy pathogenic microflora, or increase the concentration of microbial population in the digestive system, which leads to better digestion and absorption of nutrients, and significantly improving feed consumption, feed efficiency, and carcass quality (Yadkoori et al., 2015). Herbal products are broad-spectrum antimicrobial agents. It directly or indirectly affects the biochemical processes of cells and disrupts their physicochemical integrity. Terpenes, which are especially hydrophobic, interact with the cell wall and damage the cell wall integrity. The hydrophobic property of terpenes, their interaction with the lipids in the cell wall causes them to aggregate together and increase the membrane's permeability. Naturally, the deterioration of the physicochemical structure will cause proton movement and electron flow in the cell, thus transporting disruptions and coagulation of the cell contents (Burt, 2004; Silva and Fernandes, 2010).

In the literature, the concept of "Hurdle Technology" (barrier technology) has been defined to prevent microorganisms from spoiling food or causing disease. In this technology, more than one inhibitory factor against microorganisms is used at low doses and one after the other. The sector has entered into new searches regarding the long shelf life in food products and food protection from microbial spoilage (Farag et al., 1989). Plant extracts, which are used as flavoring and spice agents, have been used therapeutically in foods and beverages for centuries, and the antimicrobial activity of garlic, cinnamon, and cloves has been studied since the end of the last century (Elgayyar et al., 2001).

Antimicrobial activity of spices and essential oils is shown by looking at the type, concentration, and composition of the spice or derivative, the type, and concentration of the target microorganism, composition of the substrate, the production and storage conditions of the food. Many volatile compounds exhibit significant antimicrobial activity when tested. This effect can be increased even more (Nostro et al., 2000, Sadç 2003, Recio and Rios 2005, Hohman et al., 2006).

It is known that natural antimicrobial plants that can be used in the food industry are extremely safe compared to many antimicrobials. The extracts obtained by the appropriate method from these also show antimicrobial effects besides food preservation and aroma-flavor component. When added to ready-to-eat food products, medicinal and aromatic plants and essential oils increase food storage time with its antimicrobial effect. Essential oils with antimicrobial effect against bacteria and molds belong to marjoram, thyme, sage, rosemary, clove, black cumin, garlic, and onion. Oils that inhibit yeast and molds should be especially rich in phenols, aldehydes, and alcohols (Bruni et al., 2003; Nair et al., 2005; Benefic and Driveroglu, 2013).

3. Use of Medicinal and Aromatic Plants in Milk and Dairy Products

Food fortification is expressed as the addition of components that are naturally found or not found in the food to foods in greater amounts to correct or prevent nutrient deficiency in the society or a risk group (Coşkun, 2012). Fruit, vegetable, and plant sources with different functional properties can be used to enrich foods. Traditional medicinal plants are used for obesity and weight control in many countries, and it is known that herbs and spices in nutrition contain many phytochemicals with medicinal properties and are used in alternative medicine (Brahma and Narzary, 2015; Jaradat et al., 2017).

Medicinal and aromatic plants, which have a wide range of uses, are also widely used in the food industry. The fact that these plants have functional properties such as antioxidants and antimicrobials has been effective in increasing the usage area in the food industry. In addition, the aromatic properties of these plant products are also significant in the use of these plant products. Medicinal and aromatic plants, which have a wide area of use, are used as a whole, fresh and dry, and there are many different forms of use, such as leaves, roots, flowers, seeds, bark, tubers, or aerial parts, which are also called herbaceous parts, their fragmented or ground forms, and their extracts prepared in different ways (Toker et al., 2015; Temel et al., 2018). In studies on the use of spices in dairy products, the spice itself, its oil/essential oil, or its extract form were used. Milk is an easily perishable food with 87% water, 4.7% lactose, 3.4% nitrogenous substances, 3.7% oil, and 0.75% mineral substance content. The application of various herbs in various forms (i.e., powder, essential oils, etc.) in several dairy products have been tried successfully. Different dairy products combined with herbs are discussed later in the chapter.

3.1. Drinking Milk

The use of plant-based products in the production of milk and dairy products can be for many purposes. In addition to being preferred for its health-supporting effect and antimicrobial and antioxidant capacity, R&D studies aiming to add flavor also bring new dairy industry products to the consumer. Drinking milk is very important for the consumer with its rich nutritional value and unique taste. Therefore, it is important to be storable for a longer time for drinking milk that is sterilized or pasteurized according to the processing technology and put on the market. For this reason, drinking milk has also been the subject of scientific studies, albeit relatively less than other dairy products. The main objective of the studies is to implement practices that will extend the storage period of drinking milk.

In one of the studies conducted for this purpose, the change in the shelf life of pasteurized milk was observed by adding cinnamon at different rates to drinking milk. The study aimed to extend the shelf life of pasteurized milk, which has a higher nutritional value than UHT milk. Research findings showed that plain milk was preferred on the first day of storage, but pasteurized milk with 0.2% cinnamon added was preferred as the storage continued. The study reported that with 0.2%, 0.5%, and 1% cinnamon added, pasteurized milk was stored at 4ºC for 25 days. It was stated that total aerobic mesophilic, lactic acid, and *Lactococcus* bacteria, yeast, and mold counts were lower in cinnamon added milk than plain pasteurized milk. This study emphasized that herbal raw materials in drinking milk for enrichment gained consumer appreciation from the sensory point of view, while the antimicrobial effect of cinnamon was also emphasized (Akarca et al., 2015).

3.2. Cheese

In the Agricultural Economics and Policy Development Institute's Milk and Dairy Products Situation Forecast Report for 2021, it has been reported that there is an increase in the production and consumption of milk and dairy products such as raw milk, milk powder, cheese, butter. Despite the negative impact of COVID 19 on the milk and dairy products supply chain, it is estimated that milk and dairy products production will increase worldwide. When we look at Turkey, it is seen that there is an increase in the amount of milk and dairy products depending on the amount of milk production. It was especially emphasized that the said increase was seen in drinking milk, cheese, skimmed milk powder, and butter. Especially cheese is an important product that allows enrichment with herbal resources among milk and dairy products. It is reported that there are around 4000 cheese varieties with different components in terms of taste in the world, but because some of them are similar varieties thus, fewer varieties are known. One of the most important parts of this wide product range is the plant raw materials included in cheese production.

Many different seasonings for flavor purposes are preferred for the search for new product development in cheeses or for prolonging the storage period of the product. Capers, black cumin, ginger, zahter, cardamom, cinnamon, anise, thyme, rosemary, mint, and basil are the most common used plant raw materials in cheese production. The purpose of using spices in cheese production may be to enrich the product in terms of flavor, benefit from the antimicrobial/antioxidant effect of spices or essential oils, or promote health-promoting effects. It is stated that the sensory quality of white cheeses produced increases by adding plant raw materials such as dill, parsley, thyme, chives, black cumin, and basil (Paksoy, 2016; Deveci, 2016).

It is known that more than 60 plant species belonging to 9 different families are used in the production of Van herby cheese, which is a traditional cheese produced in Turkey. The unique aroma of this cheese, which is loved and consumed by the local people, comes from the plant raw materials grown in the region. Species heavily added in herbed cheese has been defined as plants such as *Ferula* sp. (Black), *Allium* sp. (Sirmo), *Chaerophyllum* sp. (Mendo), *Heracleaum* sp. (Sov), *Thymus* sp. (Thyme), *Prangos* sp. (Heliz), *Zizophora* sp. (Catır) (Tunçtürk and Tunçtürk, 2020).

Another way of using plant raw materials in cheese production is the packaging process that uses the anti-agent effects of essential oils. Edible films and coatings are defined as thin membrane layers that allow moisture, oxygen, and fluid movements that the consumer can eat with food. Edible film and coating applications among dairy products are mostly encountered in cheese production. It is possible to see edible film applications enriched with plant sources in cheeses such as cheddar cheese, curd cheese, and cottage cheese. It is known that essential oils, which have strong antimicrobial effects due to the phenolic substances in their composition, are used effectively in edible film and coating systems. Many active ingredients such as carvacrol, cinnamaldehyde, eugenol, p-cymene, thymol and menthol, and essential oils in their composition are considered within the scope of flavoring substances that are legal to be used in foods by the EU because they do not pose a risk to consumer health. One of the studies on this subject is an edible film-coated production trial containing myrtle essential oil to provide longer storage in cheddar cheese. In the study conducted by Saygılı in 2015, although it was stated that the edible film-coated samples containing myrtle essential oil contained an excessive level of foreign taste and odor in terms of sensory, the antimicrobial effect of the myrtle plant was found to be high. In the study, 2% myrtle plant essential oil showed high antimicrobial activity against *E. coli* O157:H7 *S. aureus* and *C. albicans* in artificially contaminated cheddar cheese samples.

3.3. Fermented Dairy Products

Fermented dairy products are dairy products produced as a result of the fermentation of milk by suitable microorganisms and lowering the pH value in a way that causes or does not cause coagulation, and that contains microorganisms in sufficient numbers, live and actively. Although there are many reasons why milk is fermented, the main goal is to extend its shelf life. Furthermore, in response to consumers' search for new taste experiences, countless traditional fermented milk products have been revived and globalized over the past two decades. In addition to the many nutritional effects of fermented milk products, new dairy products have begun to positively affect health. The interest in these products, called functional dairy products, is increasing rapidly day by day. In terms of their health effects, functional dairy products affect many ailments such as cancer, coronary heart disease, osteoporosis, and food allergy. The most common use method to add functional properties to fermented milk products is to enrich the content by using different additives. In this context, studies in which some fermented milk products are enriched with medicinal and aromatic plants are briefly summarized below;

In a study on spicy probiotic yogurt, yogurt and probiotic yogurts with cardamom, cinnamon, and coconut oleoresin added were produced. It was determined that the probiotic viability of spice oleoresin in yogurts was not affected, and the antioxidant capacity of the products was preserved during four weeks of storage (Illupapalayam et al., 2014). ChingYun et al. (2009) added extracts of some plants grown in China to yogurt, and pH, acidity, lactic acid bacteria, sensory properties, acid and bile resistance of yogurts were investigated during the fermentation and storage period. They determined that plain yogurt was preferred more in terms of sensory.

Amirdivani and Baba (2011) investigated the effects of peppermint (Mentha piperita), dill (Anethum graveolens), basil (Ocimum basilicum) on yogurt formation, proteolysis, and inhibition of the ACE enzyme. They determined that the pH levels of yogurts to which plants were added decreased faster, o-phthalaldehyde (OPA) peptides with higher antioxidant activity increased, and they had higher anti-ACE activity. Yogurt containing mint showed the highest ACE inhibition activity during the storage period. They stated that consumers could prefer these yogurts due to their functional properties.

Sarabi-Jamab and Niazmand (2009) investigated the effects of *Mentha piperita* L. and *Ziziphora clinopodioides* essential oils on the growth of *Lactobacillus acidophilus*, which is frequently used in the production of probiotic yogurts. Although there was no significant difference in the product between the plant concentrations used, they determined that the number of starter cultures decreased significantly during storage. Marhamatizadeh et al. (2011) investigated the effect of dried mint on the growth of *Bifidobacterium bifidum* and *L. acidophilus* in probiotic milk and yogurt. They explained that increasing mint concentration had a positive effect on the development of probiotic bacteria.

Hasneen et al. (2020) added ground forms of turmeric, sage, or marjoram to yogurt and water extracts at zero (control) and 1%, 2%, or 3% levels. The addition of turmeric, marjoram, or sage stimulated acid production and the growth of starter bacteria. *Streptococcus* *thermophilus* count was always higher than *Lactobacillus delbrueckii* subsp. *bulgaricus* . As a result, it was concluded that fortifying nonfat yogurts with 1-2% level of the mentioned herbs can meet the intended health benefits.

Chowdhury et al. (2008) used pre-treated leaves of various plants, including tulsi (*Ocimum sanctum* L.), pudina *(Mentha arvensis* L.), and coriander (*Coriandrum sativum* L.) in the production of probiotic yogurts. They observed that the presence of plants in the yogurt did not affect the probiotic population, and there was no significant difference in total titratable acidity and pH during storage. However, compared to the control yogurt without any plant, plant-added yogurts had higher β-D-galactosidase enzymatic activity, while tulsi-added yogurt had maximum β-D-galactosidase activity.

Many studies show that adding aloe vera gel to yogurt improves yogurt's functional properties and therapeutic values. Govindammal et al. (2017) reported that the addition of 15% aloe vera gel to yogurt increases the overall acceptability according to the sensory evaluation results of the products in question. Compared to plain yogurt, the addition of aloe vera gel increased protein, fiber content, phytonutrients (such as steroids, anthraquinones, saponins, and phlorotannins) and showed an improvement in vitamin C. It has also been observed that the texture of yogurt has been improved.

In another study, cinnamon fortified yogurt was high in phenolic acids, flavanols, and cinnamaldehyde, and cinnamon fortified yogurt increased total phenolic content by 34.7%. In vitro digestion of cinnamon-fortified yogurt resulted in the release of phenolic compounds from milk proteins, with the higher recovery of phenolic compounds in cinnamon-fortified yogurt at the end of digestion. It was also concluded that adding cinnamon to yogurt significantly increased free radical scavenging behavior, improved gastrointestinal stability, and could increase the bioavailability of dietary polyphenols (Halal and Tagliazucchi, 2018).

Azizkhani and Parsaeimehr (2018) stated that the addition of essential oils obtained from plants such as mint, basil, and zataria to probiotic yogurt increases antioxidant activity, antiradical activity, and consumer acceptability. Similarly, yogurt made with Rosmarinus officinalis oil (0.14; 0.21; 0.29; and 0.36 g/L) was found to have improved flavor and texture in addition to microbiological and physicochemical properties. Srivastava et al. (2015) observed that plants with high antioxidant properties such as ginger and beetroot, beneficial for human health, were added to yogurt, and ginger or beetroot extract (2%) changed the antioxidant properties of herbal yogurt. The highest antioxidant properties were found in goat milk yogurt with ginger root/stem addition and with beetroot extract.

Foda et al. (2007) added 0.0%, 0.1%, 0.25%, 0.50%, 0.75% and 1.0%(w/v) turmeric (Curcuma longa) powder to set type yogurt and evaluated the chemical, rheological and sensory properties of the product. They concluded that using turmeric in yogurt is a good idea, but using a smaller amount of turmeric is more acceptable and resulted rheologically better. Marhamatizadeh et al. (2011)

investigated the effect of dried mint on the growth of B. *bifidum* and *L. acidophilus* in probiotic milk and yogurt. They explained that increasing mint concentration had a positive effect on the growth of probiotic bacteria. Ghalem and Zouaoui (2013) added *Rosmarinus officinalis* L. oil to the yogurt at the rates of 0.14; 0.21; 0.29, and 0.36 g/L and stored for 21 days. As a result of the sensory evaluation, the panelists gave the maximum score in terms of taste, aroma, and texture to herbal yogurt with 0.14 g/L essential oil added. In addition, the addition *of R. officinalis* essential oil improves the quality of yogurt by decreasing the pH values and dry matter while it increases titratable acidity, proteins, ash, and fat content. In general, the storage time did not have any negative effect on the Physico-chemical properties of yogurt.

Tomar et al. (2021) added ethanol extracts of three different plants (*Mentha piperita* L., *Ocimum basilicum* L., and *Hibiscus sabdariffa* L.) to mixed type yogurts at different rates (0.1%, 0.3%, and 0.5%). It was concluded that adding plant extracts had a positive effect on yogurt's sensory and functional properties. Gurkan et al. (2019) have produced four different kinds of yogurt by adding water extract and powder forms [1.0% and 0.4% (w/w)] of purple basil to milk. Antioxidant capacity, color and total phenolic contents, physicochemical and rheological properties of yogurt samples were measured during the 21-day storage period. No adverse changes were observed in the yogurt samples' titratable acidity, pH, and hardness parameters. While the addition of basil powder or water extract did not significantly affect the general chemical properties of yogurt, the use of basil powder positively changed the rheological behavior of the yogurt gel and contributed positively to the antioxidant activity.

Al-Nawawy et al. (1998) emphasized that *Streptococcus thermophilus* and *L. bulgaricus* bacteria decreased with the addition of thyme oil in Labneh and yogurt, to which thyme essential oil was added. Kum et al. (2013) prepared yogurt concentrate fortified with crushed mint leaves at the rates of 2%, 4%, and 6%. They found that adding a 2% mint level to yogurt was optimal in all senses. In addition, it has been suggested that the shelf life of yogurt is ten days at 5˚C and that mint-flavored yogurt can be used in hamburgers, sandwiches, and other bakery products. Labneh is generally known as a concentrated yogurt variety that is very popular in the Middle East. Labneh (23.0% TS) containing 0.2 ppm of thyme, marjoram, and sage essential oils each had an extended shelf life (21 days over control) at 5°C, while yeast and mold growth was observed from day 14 of storage on control Labneh (without essential oil) when stored at 5°C. Labneh (23.70% TS) containing 0.3% cinnamon essential oil had a longer shelf life (i.e., more than eight days) when stored at 6°C compared to the control product (Thabe et al., 2014).

Tarakci et al. (2011) added some herbs (purslane, dill, parsley, cress, coriander, arugula, mint) to Labneh as fresh and stored at 7-8°C for 30 days. It was found that the addition of plants caused a decrease in *L** and *a** values in color analysis. pH decreased, different mineral contents were determined, no significant change was observed in appearance, color, texture in terms of sensory evaluation, but a decrease in flavor was observed. Labneh samples containing mint and parsley were preferred over the others, and it was emphasized that more studies should be done to provide better physicochemical and sensory properties in the final product. Roushdy and El-Saadany (2007) added garlic powder, rosemary, and thyme to yogurt and Labneh in their study. Therefore, it can be said that by using these plants, products with improved functional properties can be produced, Labneh with garlic powder is preferred, and that garlic powder has positive effects on the shelf life.

Potoroko et al. (2014) investigated the preparation of a functional kefir beverage enriched with alfalfa extract. After the alfalfa extract was added to the milk, it was fermented at approximately 20°C for 10-12 hours. Alfalfa extract, which contains organic and inorganic compounds, amino acids, mono sugars, phenolic compounds, and trace elements specific to plant materials, as well as humic and other biologically active substances that are not commonly found in plant extracts, affects the fermentation rate, intensifying lactose breakdown and proteolytic reactions,and making kefir drink dietetic.

Skorkina et al. (2015) created a new formulation using hawthorn puree and stevia syrup in bio kefir production. Hawthorn puree contains substances that expand blood vessels, increase heart and oxygen absorption, heart muscle, and arrhythmia relieving properties. According to the research, the acidity of bio kefir containing natural additives increased during shelf life and remained within normal ranges. Sarabi-Jamab and Niazmand (2009) investigated the effects of *Mentha piperita* L. and *Ziziphora clinopodioides* essential oils on the development of *L. acidophilus*. Although there was no significant difference in the product between the plant concentrations used, they determined that starter cultures decreased significantly during storage.

Gabriel- Dănut et al. (2009) developed a new probiotic product called 'Rosalact'. This product is produced from pasteurized milk. This product is enriched with some plant extracts (rosehip, licorice root) and produced using the probiotic ABT-5 culture. They investigated that licorice extract contains carbohydrates, and as a result of the analysis, it is determined that it contains mono and disaccharides, polysaccharides, organic acids, essential oils, triterpenoids resins, steroids (β-sitosterol), phenol carboxylic acids and their derivatives, coumarins, tannins, higher aliphatic hydrocarbons and alcohols, high oil Iacids and alkaloids.

In another study, licorice extract and sea buckthorn berries were used to enrich milk-based beverages. Plant extracts were mixed with milk and fermented at 42°C for 5 hours using ABY-3 culture (*B. lactis*, *S. thermophilus*, *L. acidophilus*, and *L. bulgaricus*). As a result, the final product is enriched with increased vitamin B1, B2, C, E, K, P, and flavonoids, folic acid, carotenoids, betaine, choline, coumarins, and glucose, fructose, and phospholipids, macroelements, and microelements. In addition, the product had a long shelf life (Ehsani et al., 2018). Kozłowska et al. (2015) investigated the effect of phenolic compounds of rosemary, hyssop, nettle, cumin, and lemon balm extracts on the growth of *L. acidophilus* and *L. delbrueckii* bacteria. Rosemary extract has been shown to suppress the growth and activity of bacteria. Lemon balm extract has the maximum amount of antioxidant substances that extend the shelf life of the product. Therefore, the authors did not recommend using rosemary as a functional additive for lactobacillus-containing beverages. Alternatively, they reported that it could be added to the final product after fermentation.

Dahi and Lassi are traditional fermented milk products widely consumed in some countries such as India. Many studies have found that supplementing lassi and genius drinks with aloe vera (Aloe barbadensis Miller) improves immune-protective properties, encourages the growth of probiotic bacteria, and increases health benefits. Similarly, enriched with ginger (2%), turmeric (1%), and carrot extracts (15%), lassi helps provide phytochemicals and other nutrients. The functional benefits of Lassi can be enhanced by the inclusion of probiotic microorganisms and antioxidant-rich plant juices, which are the body's primary defense system to neutralize free radicals and prevent damage.

Shrikhand is a semi-soft, sweet-sour, full-fat dairy product prepared using lactic fermented curd, and there are studies in which plants and extracts are used without significant changes in their sensory quality. Ashwagandha powder was added at a rate of 0% to 0.7% by weight of chaka (concentrated yogurt obtained by partially draining the whey from yogurt), and 40% cane sugar was used to produce shrikhand.

Shrikhand prepared using 0.5% ashwagandha powder had superior organoleptic properties than the experimental shrikhand containing 0.3% and 0.7% powder and control shrikhand (without herbs). Herbal Shrikhand exhibited acceptable properties for up to 52 days when stored in cold weather conditions.

3.4. Cream – Butter

In recent years, with the increasing interest in medicinal and aromatic plants and the active substances obtained from them, the perception that the essential oils of these plants or themselves can be added to dairy products such as butter and cream has created both in consumers and in the industry. Foods fortified with plants with natural antioxidant properties are a good alternative, especially for people with Cardio Vascular Disease (Hussain et al., 2015). Two large groups, namely terpenes and terpenoids in essential oils, and aromatic and aliphatic contents play a decisive role in the biological properties of these substances. In particular, the unique smell and taste of plants come from terpenes. While they have many different functions in plants and animals, they are also important as aroma components. Limonene and citral (both found in lemons), camphor, pinene (pine trees), eugenol (clove), anethole, thymol, geraniol (rose), and menthol are the most widely known terpenes. Most essential oils are generally recognized as Generally Recognized As Safe (GRAS) status by the Food and Drug Administration (FDA). However, the use of these substances in high amounts for preservative purposes is limited because they change the organoleptic properties of foods (Karatepe, 2010). Rosemary, sage, sumac, thyme, cloves, ginger, red pepper, and fennel plants with high antioxidative properties can be used in various foods (Karatepe, 2010). In their study, Ayar and Özcan (2001) used sage, rosemary, and thyme extracts to protect butter from oxidation during storage and determined that the best preservation was provided by using the sage extract. Sage (*Salvia officinalis* L.) and Rosemary (*Rosmarinus officinalis* L.) are the most commonly used medicinal plants to extend the shelf life of butter. These plants have much stronger antioxidant activity than synthetic antioxidants (Butylated Hydroxy Anisol [BHA], Butylated Hydroxy Toluene [BHT]) (Özcan, 2003; Estévez et al., 2007). Najgebauer et al. (2009) evaluated the storage stability of butter in a study in which they added 2% sage or rosemary as a dried herb to butter prepared from sour cream. They concluded that adding rosemary herb was more effective in delaying lipolysis in butter than in sage, but both fortified products increased oxidative stability through storage more than control butter. Farag et al. (1990) stated that adding thyme and cumin essential oils to butter prevents the deterioration of butter stored at room temperature and is more effective than BHT. A study on the antioxidant effects of thyme in butter determined that butter containing thyme had strong antioxidant effects resulting from the plant's thymol, carvacrol, and p-cemen content (Özkan et al., 2007). Medicinal and aromatic plants have antimicrobial activity not only against bacteria but also against yeasts. In a study investigating the effect of using spices to prevent the development of yeasts that spoil in butter, it was concluded that marjoram and black cumin could be used as antimicrobial agents against yeasts that spoil in butter (Sagdic et al., 2010). In studies carried out by adding medicinal and aromatic plants to butter or cream to be used in butter making, the plants themselves have been used in the form of essential oil or extract. As seen in the studies, the plants prevent oxidative deterioration, which is effective in the storage period of butter, with their phenolic compounds, prevents microbial-induced deterioration with their antimicrobial properties, and extends the product's shelf life.

3.5. Ice cream

Ice cream is a dairy product, which has a complex physicochemical system, and which can contain fruit, vegetable oil, and pulp, functional dietary fibers, probiotic microorganisms, and sweeteners in the mix, in addition to milk and skimmed milk dry matter, cream, sugar, stabilizer, emulsifier substances, and forms obtained by traditional and industrial methods (Arslaner and Salık, 2017). Ice cream is one of the most consumed dairy products globally but is often poor in natural polyphenols, antioxidants, and colors. For this reason, many studies are carried out to increase the nutritional values, rheological properties, and physical properties of ice cream by using health-beneficial ingredients such as herbs, plants, and spices. During the freezing stage, Gabi et al. (2017) added ginger to the mix in four different ways (dough, juice, sugar, and powder). It was determined that the addition of ginger juice and pulp decreased the dry matter, while sugar and powder increased it. The addition of different forms of ginger reduced the fat and protein content (except powder) and increased the ash and fiber content (except juice) of the resulting ice cream. Antioxidant activity and total phenols increased significantly when different forms of ginger were added. In addition, as a result of the use of ginger, the volume of ice cream decreased, and the melting resistance was increased.

Çınar (2015) on the ice cream produced by using lemon balm plant extract in different ratios, it was determined that the ice cream samples to which 3% lemon balm plant extract was added had a little negative effect on the physical and chemical analysis results and got the highest score in the sensory analysis. This study determined that lemon balm plant extract could be used as a natural additive in ice cream production. In a study by Javidi et al. (2016), it was determined that basil seed gum is used as a surface-active polysaccharide to improve the rheological properties in low-fat ice cream production used as both an emulsifier and a stabilizer. At the same time, the use of basil seeds in ice cream gave positive results in the sensory evaluations made by the panelists. Karaman and Karacier (2012) found that the phenolic contents of ice cream samples increased with the use of black tea or herbal teas in their study in which they added black tea, sage, linden, and chamomile tea to improve the functional, sensory, and rheological properties of ice cream. However, when evaluated sensorially, black tea and herbal tea additions other than chamomile were found to have lower scores than the control sample. Kumar et al. (2013) found that, as a result of sensory evaluation of ice creams to which Indian basil was added at different rates, basil added at 2 and 3% was more liked by the panelists.

The addition of medicinal and aromatic substances to ice creams is not only to improve their functional, physical, sensory, and antimicrobial properties but also natural colorants are preferred instead of synthetic colorants used in production. For example, the use of natural cartamidine, obtained from the yellow pigments of the leaves of the safflower plant, instead of synthetic dyes, in the production of ice cream increases the value of these products. (Kaptan and Sivri, 2018). On the other hand, Manoharan et al. (2012) examined the acceptable ratio of curcumin to be added to ice cream as a natural colorant and found that the best curcumin powder level was 0.5%. Although the strength of aroma components in medicinal and aromatic plants differs for each plant, more studies are needed to determine the ratios used in milk desserts such as ice cream.

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CHAPTER 13

ETHNOBOTONICAL ASPECTS OF SOME MEDİCAL SPECIES IN DÜZCE AND ITS VICINITY

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1. Introduction

All animals, plants and humans in the nature have been outcomes of a balanced system. In mythology, plants were regarded as the most valuable gift that gods bestowed to man. In this sense, all plants were in the service of human being, whose relation with the plants thereby began from the time of man's existence (Gezgin, 2006). According to archaeological findings from the earlier ages, people primarily benefited from the plants to obtain food and recover health problems (Koçyiğit, 2005). So, treatment with plants was a healing method as old as human history. The knowledge, experiences, works and beliefs passed from generation to generation throughout ages have therefore led the formation of this asset (Bağcı ve ark. 2006). In 21st century, many unnatural artificial products, besides medicines have entered in our daily lives or will enter soon. (Bayram ve ark. 2010). Innovations, and social and political changes brought by technological developments in early 20th century caused to rapidly decline the use of plants as medicine. As well as mass production of the synthetic drugs in pharmaceutical industry has been also effective on this reduction (Bayram ve ark. 2010).

The developed countries were mainly oriented to plant resources in the treatments. A substantial portion of medicines used was of natural origin. The use rate of natural medicines was reported to be 60% in developed countries whereas it was around 4% in developing countries. Besides, approximately 80% of the world population were also reported to be using traditional medicine and medicinal plants (Toksoy ve ark.2010).

The ecological and biological diversities in Turkey, formed by the combination of features from three old continents such as Europe, Africa and Asia, left behind the other places on 40o N longitude in the region. In Turkey, three biogeographical regions, Mediterranean, Europe-Siberia and Iran-Turan have been observed as being demonstrations of large climatic and topographical ranges. Each region has its own endemic species and natural ecosystems (Tan, 2010). Thus, Turkey' flora harbored many plant ingredients which constitute the entries of medicines, chemicals, additives and cosmetics in the developed countries. In terms of diversity, 8,988 plants were natural and 2,991 species were endemic (Bayram ve ark, 2010,Tan,2010). Turkey hosts 75% of plant species distributed in the Continental Europe, about one third of which are endemic (Özhatay ve ark. 1997).

According to 2021 TUIK data, the total area of cereals and other herbal products is 231 451 337 data, while this area was determined as 35 587 493 data in fruit, beverage, medicinal and aromatic plants.. In medical and aromatic plant agriculture, the perfumery, pharmaceutical and spice plants were prioritized. In Duzce, Sakarya, Kocaeli, Yalova and Bolu, the harvest areas of cereals and other herbal products were 1 250 424 data while the areas of medical and aromatic plants were limited to 362072 data (TÜİK, 2021).

This work was attempted to investigate the plant species used by local people in Duzce province and its vicinities. In this sense, providing knowledge about regional names, health effects and other use proposes of local plants, which are indispensable materials for pharmaceutical industry and also used as foods, will become valuable resources for scientific community in future studies.

2. Materials And Methods

This study was conducted in 2021, plant species that used by local people for foods, medicines and various other purposes were investigated. The collected plants were identified from Turkish Flora (Anonim, 2021). During field studies, information about plants' local names and their use purposes was provided by agricultural engineers, Mustafa İlyasoğlu and Emrah Ozan Gülkan from Duzce Provincial Directorate of Agriculture, by agricultural engineers, Aydın Acar, Hakan Çetin and Abdullah Şener from Duzce Branch of Agricultural Engineers, by herbalist Eren Keskin in Duzce Province, by Yasemin Karslıoğlu, Ercan Sak and Rahmi Aydın from Çilimli district of Duzce Agriculture Industry, and by Halime Zengin (Beyköy-Duzce center), Yusuf Med (Beyköy district) Ali Uçan (Konuralp district), Ozan Altundal (Kaynaşlı district), Selçuk Baycan (Cumayeri district) and Şafak Çavuş (Gölyaka district) from local community. The identified plant materials were also searched from other relevant resources (Akçicek ve Vural, 2003; Bağcı, 2000; Duran, 1998; Işık ve ark. 1959; İlçim ve Varol, 1996; Koçyiğit, 2005; Tan, 2010; Yıldırımlı, 1994; Yıldırımlı, 1995; Yıldırımlı, 1991). Below the letters of the alphabet are the scientific, family and local names of the plants studied and information about the health effects or purposes of their use.

3. Results

Althea officinalis L. (Malvaceae) (Gülhatmi): Its flower tea removes phlegm, relieves respiratory diseases and abdominal/intestinal colds, and eliminates complaints from colds and coughs.

Arbutus unedo (Ericaceae) **(Dağ çileği, kocayemiş):** It has constipating and germicidal effects. Germicidal feature is particularly effective in urinary tract infections. Its fruits are also diuretic. 20 g dry leaves are boiled in 1 L of water and consumed three cups a day. It is mainly consumed as fresh fruit in Duzce, besides its jam is also made.

Beta vulgaris var. Cicla (Amaranthaceae) **(Pazı):** It protects from diabetes and cancer, and strengthens bones. In Duzce, it is consumed as sautéed and has no special medical use.

Brassica oleraceae L. (Brassicaceae) **(Kara lahana):** It regulates the proper functioning of nervous system, and reduces the effects and occurrence of Alzheimer's and other degenerative nervous system diseases. It is mainly cooked as meal and soup in Duzce.

***Brassica oleraceae L. Capitata (Brassicaceae*) (Lahana):** Its fresh/raw consumption is useful for eyes. It has germicidal and wound healing effects, and reduces blood sugar. Externally, softened cabbage leaves are wrapped on the wounds. Besides, leaves are also softened by iron and put on the region with rheumatic pain. Leaves are replaced by fresh ones at every 10-12 hours. In addition, its juice passed through cheesecloth has wormreducing effects.

Carpobrotus edulis (Aizoaceae) (Kazayağı): It removes the intestinal worms, by benumbing, from body. It is used against skin irritations and pits. It also improves immune system. In Duzce, it is used as immune system supporter, besides it is cooked as meal and served as burek.

Capsella bursa-pastoris (L.) Medik. (Brassicaceae) (Çoban çantası): It lowers blood sugar, and stops teeth and nose bleedings if it is brewed and consumed like tea. A spoon a day from its boiled water removes kidney stones. In nose bleeding, it stops if the juice is applied in a few drops into nose. It is used especially for hemorrhoids in Duzce.

Castanea L. (Fagaceae) (Kestane): It eliminates physical and mental fatigue, and provides energy. It is also indispensable for winter evenings in Duzce.

Cephalaria duzceensis (Lythraceae) (Düzce Pelemir otu): Besides medical use, extracted oil is used as raw material for linseed oil.

Centaurea yaltirikii (Lythraceae) (Peygamber çiçeği): It is also known as “mavi kantoron” in Duzce. It increases appetite, facilitates digestion, reduces rheumatic complaints, gives comfort and refreshment, has analgesic, anti-inflammatory and diuretic effects, helps remove kidney sands and eliminate toxic substances, and it is also useful for eye and Nikris disease.

Cirsium arvense (L.) Scop. subsp. vestitum (Wimmer & Grab.) Petrak., Compositae (Asteraceae), (Devedikeni): It has urine boosting, fever reducing and appetizing effects if it is brewed like tea and consumed before meals. Its fruits are sold under the name of thistle seeds in herbal stores. In Duzce and its vicinities, it is used as bile enhancer and against liver diseases; its powder is mixed with honey or fruits.

(Cnicus benedictus (Asteraceae), (Şevketi bostan): It is an edible wild plant that is collected by cutting the above-ground parts, thoroughly peeled and cleared of its thorns, then its rosette leaves and roots are cooked and consumed as a vegetable. In alternative medicine, it is used as an antipyretic, strengthening, appetite increaser, diarrhea suppressant, diuretic, liver cleanser, cell regenerator, healing wounds and relieving digestive problems. Trials were made in Düzce, and it has been harvested for 2 years.

Crocus biflorus (Iridaceae) (İki çiçekli safran): It improves appetite, strengthens memory, gums and body, relieves nerve weakness, increases uterine movements, eliminates itchiness and acne on skin, increases sexual desire with stimulant effect, helps get rid of sands as prepared paste with honey, has sedative and soothing effects, and is also useful for cough, bronchitis and asthma, and effective in reducing menstrual pain.

Corydalis wendelboi (Fumariaceae) (Dağ horozu ibiği): If it is boiled, sweetened with honey and served before meals, it is useful for hemorrhoids, and stomach and liver fever, and also cleans intestines and stomach.

Corylus L. (Betulaceae) (Fındık): It eliminates mental and physical fatigue, and gives vigority. The nuts consumed in healing periods enable the wounds to be closed faster and the body to recover more quickly. Hazelnut oil plays a major role in treatment of kidney disorders. It helps to remove stones and sand in kidneys much faster and painlessly, and aids to protect heart and vascular health. However, patients with high blood pressure are not recommended to consume too much nuts. In Duzce, its production and consumption are very high.

Cynara cardunculus (Asteraceae) (Yabani enginar-kenger): It strengthens stomach and nerves, expels intestinal worms, prevents gingivitis, and is also useful for tooth pain and effective against indigestion. Home-made medicines are obtained using plant roots and leaves. In Duzce, it is mostly used against fatty liver by boiling plant leaves.

Cynodon dactylon (L.) Pers., Poaceae (Gramineae) (Ayrık otu): It helps remove stones, sand and inflammation in bladder and kidneys if plant roots are boiled and added with lemon. Besides, juice of boiled plant is used to stop coughing. It is also useful for rheumatic diseases.

Delphinium fissum (Ranunculaceae) (Anadolu hazeranı): It is also called as “Bitotu” in the region. Today, its internal use is abandoned since it is too poisonous. Earlier was known to be sedative in diseases such as tetanus, rabies and epilepsy. It is not thereby used medically in Duzce.

Diospyros kaki (Ebenaceae) (Trabzon hurması-Cennet hurması): It has diuretic effect. In winter months, it is used as phlegm remover. It heals cough, flu, cold and stomach ailments like ulcer and gastritis. Both fresh and dry fruits are consumed in Duzce.

Ficus carica L. (Moraceae) (İncir): If dried figs are boiled or taken as syrup, it has laxative effect. Its milk is used externally to treat warts. By daily application, warts disappear over time. Mash from fresh leaves is used externally ripening and piercing the abscess. Dried fig water softens the chest and expectorates the phlegm.

Hordeum vulgare (Poaceae) (Arpa): Barley juice is used as natural medicine in treatment of eczema, scabies, fungus, various itchy and skin diseases, muscle sores, pulmonary tuberculosis, urinary burns, kidney sores and many other diseases.

Juglans regia L. (Juglandaceae) (Ceviz): Dry leaves are boiled with some water and consumed. This regulates blood sugar and bathing with this water also relaxes muscles. Fresh and dried leaves are added to warm bath water to make the skin beautify. It increases appetite, gives strength and cleans blood. In Duzce and its vicinities, it is especially given to children in order to improve brain development. It is also used as cholesterol lowering agent by consuming fruits, along with its soaking water, in the morning.

Lactuca sativa (Asteraceae) (Marul): Lettuce has almost same health effects like other cultivars. Because it is an effective iron deposit, it strengthens the body against anemia and hair loss caused by iron deficiency. Besides, iron also helps protect blood and vascular health.

Lamium garganicum L. Lamiaceae (Labiatae) (Ballıbaba): As blooming started, plants are collected and dried in the shade. It is useful for constipation, wounds and cold. In particular, its brewed tea is used against bed-wetting problems in the elderly.

Lathyrus undulatus (Lythraceae) (Nazende-yabani bezelye): It reduces stomach cancer risk, strengthens immune system, regulates blood sugar, facilitates digestion, and is also useful for digestive system. It is an endemic species, however there is no medical use in Duzce.

Lavandula angustifolia (Lamiaceae) (Lavender): It has a relaxing effect on the nervous system. It is an antiseptic that can be applied directly to the skin to heal wounds and burns. The oil obtained is antispasmodic, aromatic, carminative, gallbladder, diuretic, sedative, sedative, stimulant, stomachache reliever and tonic. It is a very effective restorative. It is good for headache. It can be added to bath water. It is a powerful antidote to snake venom. For the first time this year, it was harvested in Düzce as a result of the trials.

Lonicera caucasica (Caprifoliaceae) (Doğu Kafkas hanımelisi): Its tea is useful for colds, bronchitis and shortness of breath. Consumption of boiled leaves, shells or dried flowers stops coughing, and is good for stomach discomfort and kidney swellings.

Lythrum anatolicum (Lythraceae) (Anadolu aklar otu): It has blood clotting and astringent effects. It is used as mash prepared from plant leaves.

Malus sylvestris Mill. (Rosaceae) (Elma): Healing cold-caused cough and throat irritations, whole apple is cooked to soften on the stove, and its hot shells are peeled off and eaten. Apple juice is useful for diarrhea. Besides, apple cooked in the cinders is also consumed for goiter.

Malva sylvestris L. Malvaceae (Ebegümeci): Its flowers stop coughing. Mash prepared from fresh leaves -in cheesecloth- is applied on the skin to relieve the pain of abscesses and sores. Its leaves are consumed as fresh vegetable and also cooked. In Duzce, it is mostly used in treatments of stomach diseases. Its tea is useful for cold and bronchitis, stops coughs, and prevents nausea and vomiting.

Mentha aquatica L., Lamiaceae (Labiatae) (Toros nanesi): Its juice from boiled leaves is used for nausea, gas releasing in stomach and nerve soothing. It prevents cheesemaking if it is put on the fresh milk. It is chewed with Peganum harmala (üzerlik) getting rid of hiccups. If some mint is boiled with lemon and consumed like tea, it is useful for stomach burn and sour. In Duzce and its vicinities, it is most commonly used for dental inflammation and against colds.

Muscari auchieri (Asparagaceae) (Dağ sümbülü-kedi nanesi): It is used for stress, insomnia, regla cramps and intestinal discomforts.

Nicotiana tabacum (Solanaceae) (Virjinia tütünü): Nicotine causes different stimuli in human brain, thereby its effects are diverse and complex. It increases bowel and stomach movements, and gastric emptying, consequently it triggers diarrhea. It was widely cultivated until beginning of 2000s in Duzce but today it is not grown anymore. There is no medical use because it is so damaging than usefulness.

Ocimum basilicum L. Lamiaceae, (Labiatae) (Reyhan otu): Its seeds are used to stop coughs, and are also useful for indigestion and dizziness. It is not used medically in Duzce but used as spice in salads and soups.

Ononls spinosa L. (Leguminosae) (Yandak kökü-Kayışkıran kökü): It is used as urine enhancer and stone remover. Externally, it is also used in treatments of eczema and similar skin diseases due to its antiseptic and wound healing effects. In Duzce, it is mostly used internally in treatments of stomach and intestinal wounds by drinking 2-3 cups a day.

Oryza L. (Poaceae) (Kasaba Pirinci): It is a high energy source. Rice bran oil can be used as massage oil because it bears skin softening effect. In Duzce, it is an indispensable dish for meals.

Petroselinum crispum (Mill.) A.W.Hill., Apiaceae, (Umbelliferae) (Maydanoz): Mash of plant leaves is applied on the inflamed wounds. It is chewed to swallow getting rid of onion and garlic smell. In Duzce, its most widespread use is to drink juice from boiled leaves and stems at frequent intervals to reduce the kidney and bladder stone and sand.

Platanus occidentalis (Platanaceae) (Kavlan-çınar yaprağı): It is useful for joint calcification, rheumatic disorders, and waist and neck hernia. In Duzce, it is mostly consumed as tea to treat rheumatic disorders.

Portulaca oleracea (Portulacaceae) (Semizotu): It is good for constipation problems. It is particularly useful in diabetic patients. It aids in removal of kidney stones. In Duzce, it is highly consumed as sautéed or cooked as meal.

Raphanus sativus (Brassicaceae) (Turpotu): Its leaves are the best cure for iron deficiency. It is used for removing urine, increasing appetite, strengthening liver and gums, reducing stone and sand, softening chest, expelling phlegm, improving nervous system, insomnia, sexual power and semen, facilitating digestion, and is also useful for kidney and gall bladder inflammation and sand, rheumatic, sciatica and joint pains, asthma and shortness of breath, bronchitis, and mouth sores. It is usually consumed in salads.

Rosa canina (Rosaceae) (Kuşburnu-gül burnu): It supports immune system against colds and flu. In Duzce, its tea is used against bone losses and colds.

Rosmarinus officinalis (Lamiaceae) (Biberiye): It has more germicidal effect than antibacterial products on the skin because of its deep penetration property. It is a diuretic and removes menstrual blood. In Duzce, its tea is consumed for losing weight.

Rubus canescens DC. var. Canescens (Rosaceae) (Böğürtlen): Its juice from boiled roots is used to remove kidney and bladder sand, and also used for diabetes, hemorrhoids and urine removal. Mash prepared from smashed leaves is applied on eyes in the eye pains. In a belief by folk, if plant branches are hung on the door, no evil eye, magic and amulet can effect to that home community. Its cultured species started to be newly cultivated in Duzce and its vicinities, however its fresh consumption as fruit is at forefront rather than medical use.

Salvia officinalis (Laminaceae) (Sage): Today, it is mostly used internally and externally due to its tonic, potent, antiseptic (in throat and nose diseases) and stimulating effect. Age herb has been taken since 2019 by making trials in Düzce.

Sempervivum armenum (Crassulaceae) (Gelin parmağı): Its leaves are consumed raw. It is also useful for wounds externally. However, there is still no medical use in Duzce.

Seseli resinosum (Apiaceae) (Horoz Gözü): It is usually considered as stimulant and strengthener, and has also facilitating effect in digestion. It is also endemic to Duzce, however its use is not reported.

Sinapis alba (Brassicaceae) (Hardal): It is very good energy and magnesium source. It helps relieve hardening problems in muscles and respiration disorders, reduces joint pains and diabetic risk, removes phlegm and toxic agents, prevents tumor formation, pneumonia, cardiovascular disease development, asthma and spot baldness, alleviates pains in regla period, regulates metabolism, aids in body fat decrease, supports the activities of blood vessels, immune and digestive systems, and weight control, eliminates drowsiness and weakness, has treatment properties for skin diseases like psoriasis and contact dermatitis, relaxes nerves, protects skin and hair health, delays aging effects, regulates cholesterol, and functions as pain reliever. In Duzce, its seeds are mostly used for restless legs syndrome. Sorghum bicolor var.

Saccharatum (Poaceae) (Şeker darısı): It is known to be a high energy source, which is used in sugar production being alternative to the sugar beet. In Duzce, it is prepared as jam as well as its seeds are used as animal food.

Spinacia oleracea (Amaranthaceae) (Ispanak): It facilitates weight loss and is also useful for digestive system. Its abundant vitamin A content is a source of healing for many diseases, making significant contributions especially for vision improvement and eye health. It is effective in wide ranges from the protection of bones to the health of blood cells. It is highly used as a fry or burk.

Taraxacum officinale Weber, Compositae (Asteraceae) (Karahindiba): It has diuretic effect and increases breast milk. Teeth can be cleaned with the milk leaked from freshly broken sprouts. Its ground roots can be also added in coffee. In Duzce and its vicinities, it is used for fatty liver.

Tilia argentea Desf. ex DC. (Tiliaceae) (Ihlamur): Its tea softens chest, eliminates coughs and expectorates phlegm. It is useful for colds and flu. Its hot consumption sweats, relaxes and causes sleep.

Chewing barks is good for high blood pressure. In Duzce, it is widely used against colds.

Thlaspi Jaubertii (Brassicaceae) (Batı Karadeniz Akçiçeği): It facilitates digestion, eliminates constipation, softens chest and helps to stop coughs. It has emetic properties and is also used in rheumatic pains. However, there is no medical use in Duzce.

Thymus longicaulis C. Persl., Lamiaceae, (Labiatae) (Kekik): Its tea is useful for asthma, bronchitis, stomach discomforts, gum irritation and diarrhea. In coughing and upper respiratory tract inflammation, its tea should be consumed and gargling be done. Its tea also relieves the painful cramps in menstruation and regulates menstrual bleeding.

Trachystemon orientalis (Boraginaceae) (Hodan, Galdirek, Kaldırık, Odan otu, Kalduruk, Galdirik): It has diuretic effect and opens urinary tract. It is a good expectorant especially for smokers and also believed to be useful for throat-tonsillitis inflammation. In Duzce, it is widely cooked as meal and prepared as pickle.

Trifolium pratence (Fabaceae) (Kırmız yonca): Flower groups are used in treatment of respiratory organ diseases.

Triticum vulgare (Poaceae) (Buğday): Fiber foods are the basis of a healthy diet. Bran removed from wheat grain is usually consumed with foods like corn flakes. Cookies made from whole wheat flour support the proper intestinal movement and prevents constipation.

Urtica pilulifera L. (Urticaceae) (Isırgan): Its tea is good for stomach, intestine and kidney diseases. Young sprouts are eaten cooked like spinach. It regulates menstruation bleeds. It is also thought that consumption of its seeds is good for cancer diseases.

Vitis Labrusca L. İsabella (Vitaceae) (Kara üzüm- muhacir üzümü): It strengthens immune system, provides quick energy, promotes kidney and liver without damaging stomach, melts fats, makes body resistant to viruses, accelerates gut metabolism, shows the skin fresh and alive, and prevents inflammation in allergies and calcification. The cream, which is produced from grape by a private firm in Duzce, is used in delaying skin wrinkles. As well as, cyme vinegar is also produced from grape and helps to lose weight.

Zea mays L. Poaceae (Gramineae) (Mısır): Fresh corncobs have diuretic effect. Corn tassel tea helps to lose weight. It also helps the child and elderly who wet his/her bed.

4. Conclusion

The replacement of pharmaceutical treatments with medicinal plants not discussed. However, it is clear that plants have some advantages over synthetic drugs because they contain biologically active substances. These active substance are easily metabolized by human body, compared to synthetic materials, as they are products from the metabolism of a living organism (Bağcı ve ark. 2006). Thus, biological activities of those active substances in medicinal plants should be investigated. In addition, research on the subject takes more attention since the active substances extracted from herbal plants are cheaper than the ready-made drugs. However, unfortunately, studies have demonstrated that Turkey could not show enough improvement in the medicinal plant agriculture, despite the fact that it is an agricultural country. For this reason, plants of medical importance have been started to be researched in our country, especially by examining the plants in Düzce and its surroundings, but they could not be brought to the sector at a sufficient rate. In this study, the plants in

Düzce and its surroundings were examined, and their local names and various usage areas among the people were compiled. It is hoped that present work will pave the way for further ethnobotanical studies on the subject.

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CHAPTER 14

THE EFFECT OF SOWING DATES ON GROWTH AND YIELD PARAMETERS OF BLACK CUMIN (*Nigella sativa* L.) CULTIVARS IN KIRŞEHIR SEMI-ARID CONDITIONS

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INTRODUCTION

Black cumin (*Nigella sativa* L.) is native in South Europe, East Mediterranean, Middle East and Western Asia, and also annual herbaceous seed spice and medicinal crop belonging to the family Ranunculaceae. It is known that black cumin has been used since ancient times (Yimam, Nebiyu, Mohammed, & Getachew, 2015). The indicative of its use since ancient times black cumin seeds was discovered in Tutankhamun's tomb in the Valley of the Kings. It was used by Hippocrates (460-370 BC), who is considered the founder of modern medicine, to strengthen the liver and relieve digestive system complaints (Ermumcu & Şanlıer, 2017). It is also mentioned that the seeds of the plant were used by Hippocrates for snake and scorpion bites and skin rashes, head inflammations and colds (Majid, 2018). It is seen that the black cumin plant is also used in Ibn Sina's book called 'Canon medicinae'. In the book, it has been reported that this plant has a positive effect against lethargy and low resistance, stimulate the metabolism and to relieve asthenia, lethargy and accelerates metabolism (Ceylan, 1997). Nigella sativa has been called by many different names in different regions. The seeds and oil of nigella sativa, known as black seed, black cumin, have been used in folk medicine for a long time, especially by the people of the Middle and Far East. Most common uses for illness including asthma, hypertension, infections, dysentery, pain, and gastrointestinal problems etc. (Al-Rowais, 2002; Salem, 2005; Schleicher & Saleh, 1998).

Nigella sativa is a rather pilous annual flowering plant grows at 20-90 cm tall with finely divided leaves; the flowers are white, yellow, pink, pale blue, or pale purple colour, with 5-10 petals. The fruit of black cumin is a large and inflated capsule consists of 3-7 united follicles with each containing several seeds. (Goreja, 2003). N. sativa seeds are 2-3 mm long, 1.5-2 mm wide and 1 mm thick, with 3 surfaces, non-matte black. When the seeds are rubbed, they have a sharp smell and the weight of a thousand grains varies between 1.9-2.6 g. The diploid chromosome number is 2n=2x=12 and it has a high rate of cross-pollination. The biggest pollinator factor in pollination is insects, especially honeybees. Black cumin reproduces with itself and forms a fruit capsule which consists of many white trigonal seeds becomes black colour in maturity phase (Schleicher & Saleh, 1998; Telci, 1995).

Chemical composition of black cumin; varies according to the harvest season, variety, climate and growing region of the plant (Ermumcu & Şanlıer, 2017; Güllü & Gülcan, 2013; Heshmati & Namazi, 2015; Sultan et al., 2009). The N. sativa seeds, depending on the variety and grown region, contain a yellowish volatile oil (0.01%–0.5%), a fixed oil (20%–40%), proteins, saponin, terpenoids, quinones (such as thymoquinone, nigellone, and thymohydroquinone), minerals (such as iron, calcium, potassium, magnesium, zinc and copper (1.79%–3.44%)) and vitamins (vitamin A, B1, B2, B6 and C) thiamine, niacin, pyridoxine and folate (Güllü & Gülcan, 2013; Salem, 2005; Sultan et al., 2009). Black cumin seeds contain other ingredients, including nutritional components such as carbohydrates, fats, vitamins, mineral elements, and proteins, including eight of the nine essential amino acids (Ghosheh, Houdi, & Crooks, 1999; Salem, 2005). Nigella sativa can be used in various forms, as a powder, oil or extract in traditional treatment (Ermumcu & Şanlıer, 2017; Heshmati & Namazi, 2015; Salem, 2005).

Thymoquinone, which is one of the most important bioactive components of N. sativa and is responsible for its many biological effects, was first synthesised in 1959 and it was reported that thymoquinone exists as a volatile oil in a proportion of 18.4%–24.0% (Ali & Blunden, 2003; Yüncü, Şahin, Bayat, & İbrahim, 2013). Nigella sativa and its active component thymoquinone have positive effects on health, and their mechanism of action depends on the type of disease (Ermumcu & Şanlıer, 2017; Salem, 2005). The other use of N. sativa seeds is as seasoning for foodstuffs like bread, donut and pastry, especially widespread among Turkish people (Baydar, 2009; İlisulu, 1992). For this reason, the interest in black cumin cultivation is increasing in Turkey, especially in the Central Anatolian region. Although the consumption of black cumin is high in the world and in Turkey, it is made especially from regional populations in the cultivation of the plant, and the low number of registered varieties is an important research problem. There are also few studies with the populations of the plant in order to obtain high yield and quality products. However, the combined effects of growing factors on yield and oil rate have not been examined in Kırşehir (Turkey). The aim of present study was to evaluate the effect of sowing times of different black cumin cultivar's yield and yield parameters and some quality characters of the seeds such as oil content.

MATERIAL AND METHOD

This study, in which the appropriate sowing time and variety of black cumin (*Nigella sativa* L.) were determined, was carried out for 2 years in the 2019-2020 vegetation period in Kırşehir Ahi Evran University Faculty of Agriculture Research and Application Field. This experimental field in Kırşehir province is located at 39.15° Northern latitude and 34.11° Eastern longitude at 1014 meters above sea level.

Table 1. Soil properties of the experimental field at 0-30 and 30-60 cm depth

Soil parameter	0-30 cm depth	30-60 cm depth
Saturation (%)	55	55
pH	7.59	7.63
Soil EC (mmhos/cm)	0.52	0.56
$CaCO_3$ %	27.9	28.39
Phosphor (P_2O_5 kg/da)	2.14	2.29
Organic Matter (%)	1.81	1.64
Potassium (K_2O kg/da)	66.62	51.47
Total salt (%)	0.02	0.02

Experimental areas soil has a clay-loam structure, and it is poor in organic matter. It is alkaline character, calcareous and non-saline. The amount of phosphorus of soil is sufficient and rich in potassium content.

The meteorological data collected from Meteorological Service of Kırşehir which was 1.5 km away from the experimental area for two years period (Table 2).

Table 2. Meteorological data of the study area

	Total Precipitation (mm)			Mean Temperature (°C)			Relative Humidity (%)		
	2019	2020	1980-2020	2019	2020	1980-2020	2019	2020	1980-2020
January	42.2	42.0	44.3	0.8	1.2	-0.1	79.3	71.2	79.0
February	42.8	60.9	31.6	4.2	2.5	1.3	71.4	73.1	74.1
March	10.2	15.4	36.7	6.3	8.0	5.6	56.4	61.6	67.2
April	29.0	25.3	42.4	9.7	10.8	10.9	64.0	55.2	63.3
May	17.1	42.1	45.6	17.5	15.9	15.4	52.7	56.6	61.3
June	84.7	38.3	36.4	21.8	20.6	19.7	56.1	49.3	55.5
July	8.7	9.7	8.9	22.4	25.6	23.3	47.5	41.1	48.9
August	59.7		8.8	23.4	24.0	23.4	49.9	35.5	48.1
Septembe	21.3	7.9	14.5	19.2	22.8	19.1	49.0	43.2	51.6
October	1.1	9.1	30.4	16.0	17.1	13.1	52.8	45.7	62.7
Novembe	30.4	20.3	41.6	8.5	6.5	6.3	60.6	64.1	72.4
Decembe	61.9		47.1	3.9	6.8	2.0	80.8	62.0	79.0
Total/ Mean	409.1	271.0	388.2	12.8	13.5	11.7	60.0	54.9	63.6

While the total amount of precipitation was 409.1 mm in 2019, it was 271.0 mm in 2020. Considering the growing period of black cumin, it was 149.7 mm in 2019 and 130.8 mm in 2020. Even though there was a significant difference between years in total annual precipitation, there was no significant difference in black cumin growing period. Both 2019 and 2020 were warmer than long-term monthly average temperature and 2020 was warmer than 2019. Relative humidity values, however, ranged between 35.5% (August 2020) and 64.4%

(April 2019) and the mean relative humidity of 2020 growing period was dryer then 2019 and long term mean (Table 2).

Experimental materials: Çameli black cumin cultivar was obtained from Eskişehir Transitional Zone Agricultural Research Institute and Burdur black cumin population from Burdur farmer. This cultivar and population of black cumin were selected as it was widely produced in the country.

Treatment and experimental design: The experiment consisted of two kind of cultivars (Çameli and Burdur) and five levels of sowing dates (1^{st} and 15^{th} March, 1^{st} and 15^{th} April, and 1^{st} May). These sowing dates were chosen based on climate and soil conditions of Kırşehir. Treatments were laid out in Randomized Complete Split Block Design (RCBD) with three replications. Main plots were cultivars and subplots were sowing date.

All parcels fertilized phosphorus at 60 kg P2O5 ha as triple super phosphate at sowing time. Nitrogen fertilizer was applied in two parts, one half nitrogen fertilizer (50 kg/ha N) Urea (%46N) at first sowing time, and the rest of the nitrogen (50 kg/h N) was given in the form of ammonium nitrate (33%) during the stem elongation.

In the study, seeds were planted with the calculation of 10 kg per hectare. Hoeing was done for the purpose of controlling weeds when the plants had 3-4 leaves, and in case of new weed, weed control was carried out every 15 days. Harvesting was carried out by hand following at full maturity.

Data were recorded on some growth, yield and quality parameters including emergence, flowering and harvest date, plant height (cm), number of branches (branches/plant), number of capsules (capsules/plant), number of seeds in the capsule (seed/capsule), thousand seed weight (g), seed yield (kg/ha), harvest index (%), crude oil rate (%) and oil yield (kg/ha) were recorded on randomly selected twenty plants and plot basis depending on the traits to be measured.

Days to emergence: The number of days elapsed between date of sowing and date of 75% emergence in each plot was computed and expressed as average number of days to emergence.

Days to 50% flowering: The number of days elapsed from sowing to date of 50% flowering was computed and expressed as average number of days to flowering.

Plant height (cm): The distance from the soil level to the top of plant at physiological maturity stage from twenty randomly selected plants in each plot. The values measured in centimetres are expressed as mean values.

Number of branches per plant: The primary branches on main stem of randomly selected twenty plants were counted and averaged

Number of capsules per plant: On plant basis, number of capsules in the 20 randomly selected plants counted from each plot was determined and averaged.

Number of seeds per capsule: The number of seeds in 20 randomly selected capsules from each plot was counted on individual capsules basis and average was expressed as number of seeds per capsules.

1000 seed weight (g): It was calculated by counting 100 seeds from each plot four times and weighing them on a 0.001 sensitive balance and multiplying the average weight found by 10.

Seed yield per hectare (kg): Seeds separated from all plants in the harvest area of the plot were weighed, seed yields were determined, and these values were calculated as seed yields by converting them to hectare over the plot area.

Harvest index (%): Harvest index was calculated by dividing seed yield by the total biological yield. Means expressed in percentage.

Crude oil rate (%): Seed samples from each plot were milled and 5 g of sample was weighed for extraction and placed in cartridges. It was extracted with hexane for 4 hours in a Soxhlet extraction device and the dry weight was determined in the oven as a result of the extraction. Predetermined moisture rates, fat percentages of weight loss before and after extraction were determined. Except for the predetermined moisture rates, the % oil ratios of the weight losses before and after extraction were determined.

Oil yield (kg/ha): Oil yields per hectare were calculated by using plot yield and crude oil ratios.

The obtained data were subjected to variance analysis in MSTAT-C package program according to the split plots trial method in randomized blocks (Russell, 1986). The differences between the applications were evaluated by grouping according to Duncan (P<0.01) multiple comparison test (Düzgüneş, Kesici, Kavuncu, & Gürbüz, 1987).

RESULTS AND DISCUSSION

Growth components recorded during the two-years research and overall statistical analyses results showed that there were significant (p<0.01) effects of sowing date (Table 3).

Table 3. Analysis of variance and mean comparison of days to emergence, flowering, and maturity.

Source	DF	Emergence	Flowering	Maturity
Year (Y)	1	3.75ns	38.02ns	3.27ns
Replication	2	1.13ns	22.67ns	5.42ns
Cultivar (A)	1	18.15*	56.07*	11.27ns
Y*A	1	0.15ns	1.67ns	1.35ns
Error 1	1	1.5	5.27	3.13
Sowing date (B)	4	484.93**	1064.9**	3623.43**
Y*B	4	0.67ns	5.33ns	1.77ns
A*B	4	1.23ns	3.57ns	2.32ns
Y*A*B	4	0.57ns	1.33ns	3.10ns
Error	32	0.96	2.26	3.82
CV (%)		4.95	2,05	1,56
Year				
2019		20.07	69.8	126.5
2020		19.57	68.47	126.13
Cultivars				
Çameli		19.27 b	72.17 b	125.37
Burdur		20.37 a	74.10 a	124.53
Sowing Date				
SW1 (1st March)		28.75 a	85.83 a	145.67 a
SW 2 (15th March)		23.08 b	79.33 b	137.67 b
SW 3 (1st April)		19.42 c	71.17 c	124.50 c
SW 4 (15th April)		14.75 d	66.67 d	114.33 d
SW 5 (1st May)		13.08 e	62.67 e	102.50 e
LSD		1.09	2.17	2.82

*: significant at the 5% level, **: significant at the 1% level, ns: not significant. Means followed by the same letter(s) in a column are not significantly different.

DF= degrees of freedom; CV= coefficient of variation; LSD= least significant difference SW= Sowing date.

Significant variations were observed in emergence day of cultivars by sowing dates. Cultivar Çameli had early emergence period then Burdur genotype. According to the change in sowing date, the emergence period of black cumin changed between 13.08 and 28.75 days (Table 1). It is clear from the mean values of the data that crop sowed on 1st March took maximum days to emergence, while plots sown on 1st May took minimum days to emergence. In other words, while early sowing date resulted in late emergence, late sowing resulted in early emergence. High temperature during late sowing could be the possible reason for fewer days to emergence in case of 1st May sowing.

It was determined that emergence day differences were 5 days between the first sowing date and the second sowing date, 4 days between the 2nd sowing time and the 3rd sowing date, 5 days between the 3rd and 4th sowing dates, and lastly and minimum time difference (1 day) between the 4th and 5th sowing dates.

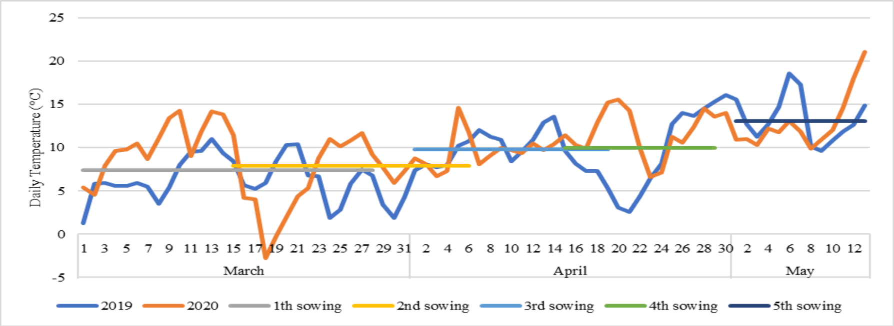

Figure 1. Daily temperature anomaly and emergence period of sowing dates.

The average air temperature is calculated from the date of sowing to the emergence and the emergence day of 1st sowing date (1st March) was 28 days with an average 7.4 °C/day, the 2nd sowing date (15 th March) was 23 days with an average 7.9 °C/days, the 3rd sowing date (1st April) was 19 days with an average 9.4 C/day, the 4th sowing date (15 th April) was 14 days with an average 10.0 °C/day and 5th sowing date (1st May) was 13 days with an average 13.1°C/day (Figure 1). Among all environmental factors, temperature has a very important role in seed germination and seedling growth (Steinmaus, Prather, & Holt, 2000). The germination process starts when seeds received a significant amount of heat. Below this temperature threshold that is known as the seed's base temperature (Elias, Copeland, McDonald, & Baalbaki, 2012) there can be no seed germination (Bewley, Bradford, Hilhorst, & Nonogaki, 2013). In germination period, base temperature of black cumin was considered as 5.5 °C (Ghamarnia, Miri, & Ghobadei, 2014). The number of days which daily mean temperature is 5.5 °C and below were calculated. Despite of the daily mean temperature differences between 1st and 2nd sowing period was 0.4 C, the emergence date was 5 days more than 2nd sowing. This differences related to the number of the base temperature days. The first sowing date (1st March) had 9 days, and second sowing date (15 th March) had 5 days below the base temperature of two years (2019 and 2020) mean.

Flowering day of black cumin cultivars significantly effected from sowing dates ($P<0.01$) and cultivars ($P<0.01$). Days to flowering decreases with delay in sowing. More days to flowering (85.83) were recorded in plot sown on 1th March while fewer days to flowering (62.67) were recorded in plot sown on 1th May (Table 3). Early sowed black cumin had more time for vegatative growth up to 57 days in March sowing, whereas, this period reduced to 49 days in mid april and may sowing.

Maturity period was significantly ($P<0.01$) effected from sowing date of black cumin. As with the emergence and flowering periods, the maturation period was shorter in late sowings. The longest maturity days (145,67) were recorded in plot sown on 1th March while the lowest maturity days (102,50) were recorded in plot sown on 1th May of research (Table 3). Early planted black cumin had more time after flowering for seed fiiling and maturity up to 60 days, whereas, this period reduced to 40 days after mid april and may sowing.

Plant height was significantly affected by cultivars ($P<0.05$) and sowing dates ($p<0.01$) (Table 4). Çameli cultivar was higher than Burdur genotype. Plant height drastically decreased from sowing date of 1st March to 1st May. Maximum plant height was 37.25 cm recorded in 1st March sowing parcels. The lowest plant height was 19.50 cm obtained in plots sown on 1st May. Plant height decreased with delayed sowing date was obtained and lowest plant height on last sowing date (1st May) during the both year. Acording to the analysed plant height data, the tallest plant was 37.25 cm sown on 1st March parcel which was 47.7, 37.6, 21.1 and 6.7 per cent higher than plant sown at 1st May, 15th and 1st April and 15th March respectively. The height of black cumin plant ranges from 30 to 80 cm (Baydar, 2009; Baytop, 1984). Plant height of black cumin in different ecological conditions and regions studies varied in a wide ranged and Toncer and Kizil (2004) found an upper range 64.9 to 71.5 cm, and Rahnavard, Sadeghi, and Ashrafi (2010) observed a lower range, up to 15.01 cm. The result was supported by Haq, Hossain, Haque, Das, and Huda (2015); Javadi (2008); Mehmet Fuat and Seyfi (2020); Rassam, Naddaf, and Sefidcon (2007) who reported that delay sowing significantly reduce the plant height.

Table 4. Analysis of variance and mean comparison of plant height, number of lateral branches, number of capsules per plant and seed per capsule.

Source	DF	PH	NLB	CPP
Year (Y)	1	33.75ns	0.82ns	2.38ns
Replication	2	44.5ns	1.57ns	1.35ns
Cultivar (A)	1	79.35*	0.15ns	0.69ns
Y*A	1	0.42ns	0.02ns	0.17ns
Error 1	1	7.53ns	1.13	2.18
Sowing Date (B)	4	672.38**	51.65**	164.92**
Y*B	4	1.04ns	0.48ns	1.46ns
A*B	4	2.14ns	0.4ns	0.66ns
Y*A*B	4	0.38ns	0.27ns	1.24ns
Error	32	4.93	0.85	1.95
CV (%)		7.73	19.27	19.85
Year				
2019		29.50	4.90	7.24
2020		28.00	4.67	6.84
Cultivars				
Çameli		29.90a	4.83	6.93
Burdur		27.60b	4.73	7.14
Sowing Date				
Sw1 (1st March)		37.25a	7.33a	11.49a
Sw2 (15th March)		34.75b	6.50a	10.34a
Sw3 (1st April)		29.00c	4.33b	6.08b
Sw4 (15th April)		23.25d	3.25c	3.91c
Sw5 (1st May)		19.50e	2.50c	3.36c
LSD (0.01)		2.31	1.03	1.55

*: significant at the 5% level, **: significant at the 1% level, ns: not significant. Means followed by the same letter(s) in a column are not significantly different.

DF= degrees of freedom; CV= coefficient of variation; LSD= least significant difference SW= Sowing date; PH = Plant height (cm); NPB = Number of lateral branches per plant; CPP = Capsule per plant.

Lateral branches per plant are an important yield contributing character and it was statistically (P<0.01) effected sowing date of black cumin. The highest lateral branch number was 7.33 in 1st March sown, which was statistically similar to 15th March (6.50) sown. Significantly the lowest lateral branch number was 2.50 that obtained from 1st May sown. Also 1st May was statistically similar with 15th April sown and the number of lateral branch in 15th April sown parcel was 3.25. Number of lateral braches decreased with delayed sowing date and the highest number of lateral branch was 7.33 pices at sown on 1st March parcel which was 65.9, 55.7, 40.9 and 11.4 per cent higher than plant sown at 1st May, 15th and 1st Apriland 15th March respectively (Table 4). Haq et al. (2015); Toncer and Kizil (2004); Tuncturk et al. (2011) reported number of branches 3 to 7 per plant and which was almost similar to finding. It might be depended on genetical as well as environment.

In the number of capsule per plant, the difference between the years (8.8-10.5 capsule plant-1) and cultivars were found not to be statistically significant (Table 4). On the other hand the difference between sowing date and number of capsule per plant was statisticallay significant (P<0.01). In the sowing date average, The highest number of capsules per plant was 11.48 in 1st March sown, which was statistically similar to 15th March (10.34) sown. The lowest value was obtained as 3.36 pieces in the 1st May sown parcel and it was statistically similar to 15 th April sown parcel (3.91) (Table 4). In different studies, researchers found that the number of capsule for black cumin were in the ranges of 2.1-14.6 (Nimet, Katar, & Baydar, 2015; Telci, 1995; Tunçtürk, Yilmaz, Erman, & Tunçtürk, 2005). Golparvar, Amin Hadipanah, and Salehi (2014) found an upper range 66 to 85 capcules per plant.

Significantly (P<0.01) differences were found among sowing date in number of seed per capsule (Table 5). The highest number of seed per capsule was 50.00 and it was obtained from 1st March sown parcels. Also 1st Marc, 15th March and 1st April sown were statistically similar and number seed per capsule were 50,00, 49,25 and 49,17 repectivelly.

Table 5. Analysis of variance and mean comparison of seed per capsule, thousand seed weight (g), seed yield (kg/ha).

Source	DF	SPC	TSW	SY
Year (Y)	1	2.27ns	0.01ns	12606.01ns
Replication	2	9.57ns	0.01ns	4948.97ns
Cultivar (A)	1	13.65ns	0.01ns	15629.66ns
Y*A	1	25.64ns	0.01ns	731.57ns
Error 1	1	8.63ns	0.01	8410.43
Sowing Date (B)	4	64.2**	0.08**	776503.28**
Y*B	4	5.22ns	0.01ns	310.52ns
A*B	4	4.8ns	0.01ns	6077.38ns
Y*A*B	4	0.87ns	0.01ns	238.84ns
Error	32	6.81	0.01	2988.24
CV (%)		5.13	1.48	8.78
Year				
2019		47.8	2.27	636.84
2020		48.17	2.3	607.85
Cultivars				
Çameli		47.53	2.3	638.49
Burdur		48.43	2.27	606.21
Sowing Date				
Sw1 (1st March)		50.00a	2.36a	912.82a
Sw2 (15th March)		49.25ab	2.37a	853.40a
Sw3 (1st April)		49.17ab	2.29b	580.13b

Sw4 (15th April)	46.75bc	2.24c	429.76c
Sw5 (1st May)	44.75c	2.17d	335.63d
Lsd (0.01)	2.75	0.04	61.11

*: significant at the 5% level, **: significant at the 1% level, ns: not significant. Means followed by the same letter(s) in a column are not significantly different. DF= degrees of freedom; CV= coefficient of variation; LSD= least significant difference SW= Sowing date; SPC = Seed per capsule; TSW = Thousand seed weight (g); SY = Seed yield (kg/ha).

The lowest number of seed per capsule was determained from 1st May sown parcels and this result significantly similar wit 15 April sown (44.75 and 46.25 respectivelly) (Table 5). In fact, the number of seeds per pods is the reservoir capacity of the plant. Photosynthetic material and ultimately biomass increases related to ecological and genetical conditions was effect capsul number and seed number per capsule.

Data regarding thousand seed weight are presented in Table 5. Thousand seed weight is an important yield contributing character and it was significantly effected by sowing date change. Thousand seed weight was significantly decreased with delay in sowing date. Heavier weight (2.37g) of thousand seed was produced in plots sown on 15th March however, thousand seed weight produced in 1st March was statistically at par with each other. Minimum thousand seed weight was 2.17g and it was obtained last sowing date of 1st May parcels. The result was similar to findings of Haq et al. (2015); Shah (2007); Tuncturk et al. (2011); Yimam et al. (2015).

Data pertaining seed yield are reported in Table 5. Seed production of black cumin were significantly affected by the effect of sowing dates. Seed yield was found maximum in early sown plots. Maximum seed yield was 912.82 kg ha^{-1}in early sown plots on 1st

March whereas lowest seed yield was 335.63 kg ha-1 in late sown plots on 1st May. With delayed sowing, significant losses are experienced in seed yield. While a 6.5% seed yield loses was observed between March 1 sowing and March 15 sowing, this decrase rate up to %36.4 between March 1 sowing and April 1 sowing. Even more important losses was obtained from 15th April and 1st May sowing compared to 1 March sowing seed yield , and this decrease rate is up to 52.9% and 63.2% respectively. Similar finding was supported by Haq et al. (2015); Rahnavard et al. (2010); Sardooyi, Shirzadi, and Naghavi (2011) who reported that, delayed sowing couse to decrease at seed yield.

Table 6. Analysis of variance and mean comparison of fixed oil rate (%), oil yield(kg/ha) and harvest index (%).

Source	DF	FOR	OY	HI
Year (Y)	1	1.44ns	1030.2ns	1.98ns
Replication	2	0.77ns	736.35ns	0.17ns
Cultivar (A)	1	3.04ns	3488.13ns	31.02*
Y*A	1	0.23ns	202.84ns	3.69ns
Error 1	1	0.53	1166.25	3.27
Sowing Date (B)	4	21.02**	128728.23**	23.76**
Y*B	4	2.06ns	204.17ns	0.37ns
A*B	4	0.09ns	977.16ns	0.85ns
Y*A*B	4	0.15ns	53.18ns	0.99ns
Error	32	0.33	404.16	4.52
CV (%)		1.55	8.56	1.88
Year				
2019		36.95	239	28.4
2020		37.7	230.71	28.03
Cultivars				
Çameli		37.55	242.48	28.94a
Burdur		37.1	227.23	27.49b
Sowing Date				
Sw1 (1st March)		38.89a	355.02a	26.65c
Sw2 (15th March)		38.43a	327.93b	27.25bc
Sw3 (1st April)		37.13b	215.30c	27.80b
Sw4 (15th April)		36.44c	156.25d	29.56a

Sw5 (1st May)	35.74d	119.77e	29.82a
LSD (0.01)	0.64	22.47	0.71

*: significant at the 5% level, **: significant at the 1% level, ns: not significant. Means followed by the same letter(s) in a column are not significantly different. DF= degrees of freedom; CV= coefficient of variation; LSD= least significant difference SW= Sowing date; FOR = Fixed oil rate (%); OY= Oil yield (kg/ha); HI= Harvest index (%)

The fixed oil rate of black cumin seeds are given in Table 6. In the research, sowing date changes effect on fixed oil rate was found significant. No significant differences between the years and cultivars were found. The fixed oil rate of the cultivars were found to be very close to each other with 37.55% from Çameli cultivar and 37.10% from Burdur genotype (Table 6). The highest fixed oil rate was 38,89% and it was obtained from 1st March sown parcels. Also 1st Marc and15th March sown were statistically similar and fixed oil rate of 15th March sown parcel was 38.43%. The lowest fixed oil rate was obrained from 1st May sown parsel with 35.74%. Delayed sowing date resulted decrease in fixed oil rate of black cumin. Many researchers determined that the fixed oil of black cumin vary between 30.4% and 37.7% (Matthaus & Özcan, 2011; Sener, Kusmenoglu, Mutlugil, & Bingol, 1985) and this results also partially similar our findings. Kulan, Turan, Gülmezoğlu, Kara, and Aytaç (2012) found an upper range 38.91%-40.58% and Üstun, Kent, Cekin, and Civelekoglu (1990) observed a lower range oil contents of black cumin seeds collected from the Kutahya, Denizli and Konya provinces were 24.4%, 29.5%, and 29.7%, respectively.

The oil yield is obtained by multiplying the seed yield with the oil ratio. Therefore, seed yield and oil rate change are significantly effective on oil yield count (Table 6). Oil yield decreased by 7.6% between the 1st sowing date and the 2nd sowing date. This decrease rate was increased every 15-day delaytion in sowing date. Delaying in sowing date (3rd, 4th and 5th) was compared with the first sowing period, the oil yield decreased by 39.4%, 56.0% and 66.3% repectivelly. This decrease rate higher than seed yield decrease in postponed sowing. Yilmaz, Biyik, and Dökülen (2020) reported that 27 black cumin genotypes in Tokat-Niksar conditions oil yield varied was ranged 316-557 kg/ha. Many researchers determined that the fixed oil yield of black cumin vary between 320.2 and 527.3 kg/ha (Tavas, Katar, & Aytaç, 2014; Telci, 1995) and this results also partially similar our findings.

Harvest index was found to be significantly influenced by the sowing date ($p<0.01$) and cultivars ($P<0.05$) (Table 6). The highest harvest index (28.94%) was obtained from Çameli cultivar. The highest harvest index (28.82%) was determained at last sowing date (1st May) however, harvest index obtained in 15th Apirl was statistically at par with each other. The lowest harvest index was 26.65% from 1st March sowing parcel. Delayed sowing was resulted higher harvest index rate. This means that the seed weight has decreased more than whole plant weight. It also indicates that there is not enough time and suitable conditions for the development of the seed.

CONCLUSION

A field study was conducted at Central Anatolian region of Turkey in Kırşehir province with the objective of determining the effect of cultivars and sowing dates on growth, yield and yield components of Black Cumin in 2019 and 2020. Treatment combinations of cultivar (Çameli cultivar and Burdur genotype) and 5 levels of sowing dates (1st,15th March, 1st,15th April and 1st May) arranged in RCBD with three replications. Results revealed that more than cutivars, sowing date changes significantly ($p<0.01$) effected on growth and yield parameters.

Statistical differences between cultivars were observed in the parameters of day to emergence and flowering, plant height and harvest index. Çameli cultivar had earlier emergence and flowering date, higher plant height and harvest index. Sowing date had a statistically significant effect on all parameters examined. As the sowing date was delayed, earlier emergence, flowering and maturation and higher harvest index were observed. Early sowings had higher plant height, number of branches, number of capsules, number of grains per capsule, 1000 seed weight, seed yield, fixed oil ratio and oil yield. According to these results, early planting provides suitable conditions for plant development as well as sufficient time for growth and development. Sowing black cumin in the earliest period, when the risk of frost is lower in rainfed agricultural areas, provides more benefit to growth and yield from the rainy and cool period.

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CHAPTER 15

FERTILIZATION OF MEDICINAL AND AROMATIC PLANTS

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INTRODUCTION

Medicinal and aromatic plants; They are plants that have many uses such as food, medicine, cosmetics and spices and are known to have been used for similar purposes since the beginning of human history (Demirezer, 2010). When it comes to medicinal and aromatic plants, it covers a very large area in terms of both plants, active substances and consumption areas. In this respect, although there is no standardized grouping today, they can generally be grouped according to their families, the active substances they contain, their consumption and use, the organs used and their pharmacological effects. However, the most commonly used grouping is based on active ingredients (Ceylan, 1995). There are 50.000–75.000 plant species used in traditional and modern medicine worldwide (Schippmann et al., 2006). Around 2000 medicinal and aromatic plant species and products are in used in Europe (Kathe et al., 2003). Medicinal properties can be obtained from the following plant parts: leaves, bulbs, essential oil, fatty acid, flowers, fruit, gum, stem, roots, rhizome, seed, tuber and wood. Plant secondary metabolites are thought to be responsible for the antimicrobial, antioxidant, anti-inflammatory and insecticidal activities of plant extracts (Kumar et al. 2005). Medicinal and aromatic plants called medicine, shell, leaves, flowers, dried roots, root-stem, tuber, woody structure, bark, seeds and herbs are referred to as drugs (Anonymous, 2005).

Peppermint (*Mentha piperita* L.) belongs to the Labiatae family and is widely distributed crop~~s~~ around the world. It is commonly used both in folk medicine and in the pharmaceutical, cosmetic, food, and animal feed industries. Peppermint is one of the oldest medicinal plants (Petrovska, 2012). The medical uses of peppermint appear in the forms of peppermint tea and peppermint oil (McKay, and Blumberg, 2006).

Mentha species of Lamiaceae family are well-known and commonly used annual species worldwide (Trevisan et al. 2017). In general, important Mentha species include peppermint (*Mentha piperita* L.), menthol mint (Mentha arvensis L.) and spearmint (*Mentha spicata* L.) (Kumar et al. 2011). Mentha piperita is generally defined as peppermint, which is involved in numerous products manufactured in various industries (aroma and fragrance products, cosmetics, aroma therapy and phyto-medics) (Mahendran and Rahman, 2020). Peppermint (*Mentha xpiperita* L.), belonging to the Lamiaceae family, is one of the most important aromatic and medicinal herbs. The essential oil obtained from the leaves is a valuable source of pharmaceutically and cosmetically important compounds such as menthol and menthone (Gupta et al. 2017). Lemon balm, locally known as *Melissa officinalis* L. is a perennial herbicous plant and belongs to Lamiaceae family (Ceylan et al. 1994). It is naturally grow in Mediterranean flora and is a significant essential oil plant. The plant is widely collected especially in Northern and Western regions of Turkey (Sarı and Ceylan, 2002). Lemon balm is a medicinal plant with various antibacterial, antiviral and antifungal impacts (Leung and Foster, 2003; Dukic et a., 2004; Silva et al., 205).

The Ocimum genus belonging to the Lamiaceae family is characterized by a great variability of both morphology and chemotypes (Lawrence, 1988; Marotti et al. 1996). Among all the species, *Ocimum basilicum* L. (basil or sweet basil) has the most economic significance and is cultivated and utilized throughout the world (Marotti et al. 1996). Sweet basil is used in traditional medicines, in cosmetic industry, as culinary herb and as insect repellent (Prakasa Rao et al., 2007; Nazim et al., 2009). Chamomile (*Matricaria chamomilla* L.), which belongs to the Asteraceae family, is a well-known medicinal plant and the fifth highest selling herb in the world. Medicinal value of this plant depends on the active substances, mainly accumulated in the flowers (Singh et al. 2011; Shams et al., 2012).

Chamomile, a well-known old time drug, is known by an array of names, such as Baboonig, Babuna, Babuna camornile, Babunj, German chamomile, Hungarian chamomile, Roman chamomile, English chamomile, Camomilla, Flos chamomile, Single chamomile, sweet false chamomile, pinheads, and scented mayweed, suggesting its widespread use (Leung and Foster, 2003; Franke, 2005).

Nutrient availability has a key role in improving biomass productivity and qualitative properties of essential oil in medicinal and aromatic plants (Machiani et al., 2019). Nutrient availability in soils is related to physical and chemical soil attributes. Soil reaction (pH) and parent material are the major factors moderating the content and availability of mineral elements in the soil. In soils with high pH reaction and high content of lime, availability of most mineral elements decreases (Catizone et al. 1986). Most crops have shown significant interactions between nutrients and water, in that water deficiency are often claimed to influence plant's use of nutrients negatively. As a consequence, in the arid and semi-arid areas of the world, more fertilizer is used when water for irrigation is available, and under rainfed Mediterranean conditions, fertilizer recommendations are tuned to the average rainfall incidence (Sivakumar and Huda 1984). The so-called three elements of fertility, namely nitrogen (N), phosphor (P) and potassium (K) are taken into account, since they are usually the most used in agricultural practice. Different ratios of compound NPK fertilizers were used and there is a significant increase in dry matter yield with increasing the ratio of nutrients (Sheykholeslami et al. 2015). Nitrogen (N), phosphorus (P), and potassium (K), the so-called three fertility elements, are taken into account because they are often the most used in agricultural practice (Carrubba, 2015). This is especially true for nitrogen, that in most cases is top-dressed in 2 or 3 fractions, allowing plants to extract it from soil in concordance with their needs along the growth cycle. Otherwise, P and K, claimed to have a scarce mobility throughout soil profile, are usually supplied before transplant (at the time of soil preparation) and distributed deeply enough to be absorbed by the roots during their elongation. Of course, in decision-making concerning fertilization, factors related to environment, plant genotype, goals of cultivation, and farm, must be kept into account. (Arnon, 1992). One of the main cultural practices that play an important role in the growth, development and yield is the application of fertilizers (Dzida et al., 2018). It is well known that fertilizers are applied to cultivate medicinal and aromatic plants. Fertilizers have a positive effect on the fresh and dry herb yield and essential oil content (Ipsilandis et al., 2020; Lima et al., 2020). However, fertilizers can have positive and negative impacts on phenolic compounds in plants (Amarowicz et al., 2020; Portilla et al., 2020). According to Kazimierczak et al. (2021), the phenol content in plants depends on the type of fertilizer applied. Two different kinds of fertilizers are often used in the cultivation of medicinal and aromatic plants, organic and mineral fertilizers. Organic fertilizers are mostly recommended for the cultivation of medicinal plants (Sodré et al., 2012). These contain all the micro and macronutrients essential for plants and have a positive effect on microorganisms, the structure of the soil, and soil water availability (Hirzel et al., 2018). Mineral fertilizers are used in the cultivation of medicinal plants in some areas. They are cheap and contain substantially higher amounts of macronutrients that are readily available to plants (Timsina, 2018). Nitrogen (N) and potassium (K) play key roles in plant metabolism and have effects on the synthesis and accumulation of nutrients and secondary metabolites. Nitrogen is an important yield enhancing primary nutrient and is necessary for building amino acids, structural elements of proteins as well as pyrimidin and purin bases, nucleotides and nucleic acids. Potassium is an alkaline cation, which balances charges of organic and inorganic anions, and activates more than 50 enzymes (Nurzynska-Wierdak et al., 2011).

Application of NPK fertilizer at optimum levels play a key role in growth and development of most physiological processes in the plant as described by Lambers et al. (2008). Nitrogen has an essential role in plants as constituent of proteins, amino acids, nucleic acids, chlorophyll and growth hormones as reported by Russel (1988). The lack of nitrogen used by plants caused depressed of protein synthesis and as a result the plant growth is affected. Phosphorus plays specific roles in the conservation and transfer energy in plants. Also Phosphorus is involved in root development processing (Yagodin, 1982). Potassium is known to be linked with carbohydrates metabolism, sugar translocation and cell division and development. Also, potassium increases the resistance of plants versus the drought, pests and diseases (Mengel and Kirkby, 1987).

Fertilization recommendations should be made according to soil analysis results, NPK requirement and the amount of elements removed by plants. Soil testing is always recommended, and the opportunity to add fertilizers should be carefully evaluated based on the goals of farmers. Please see Table 1 for fertilizers recommendations for medicinal plants based on soil analysis results (Boroomand and Grouh, 2012).

1. FERTILIZER RECOMMENDATION FOR PEPPERMINT

Based on peppermint optimum yield values of previous studies (peppermint fresh herb yields of between 670-1350 kg da^{-1}), plant nutrient requirements were determined as 28 kg da^{-1} N, 20 kg da^{-1}

P_2O_5 and 28 kg da^{-1} K_2O and applied accordingly (Mitchell and Farris., 1996; Scavroni et al., 2005). In organic farming, N is given as 17 kg da^{-1}. For Phosphorus and potassium, as stated above, soil analysis, target yield, N, P, K content of the inputs and amounts of plant nutrients uptake by basil (100 kg ha^{-1} N, 40 kg ha^{-1} P_2O_5, 120 kg ha^{-1} K_2O) are taken into account (Erşahin, 2006).

Mineral nutrients are essential for plant growth and production of essential oils in Mentha (Stanev and Zheljazkov 2004). The published results reveal that mint requires approximately 180 kg N $ha^{-1}$to support optimum growth. Phosphorus removed with harvest ranges from 40 to 80 kg P_2O_5 ha^{-1}, and remove over 275 Kg K_2O ha^{-1}(Brown et al. 2003).

2. FERTILIZER RECOMMENDATION FOR LEMON BALM

In calculation of fertilizer amounts, soil analyses and plant nutrient uptakes for targeted yields were taken into consideration. Calculations were made for optimum lemon balm yield (green herb yield of 1500-4000 kg da^{-1}) and recommended nutrients were calculated respectively as 17 kg/da N, 14 kg/da P_2O_5 and 14 kg/da K_2O (Blank et al. 2006). Fertilization with 90-120 kg/ha N, 13-18 kg P and 66-83 kg/ha K assured highest yields of lemon balm in Poland (Kordana et al. 1997). In Hungary, after manuring 60 kg/ha N, 10-13 kg/ha P and 58-66 kg/ha K are advised for the practice (Bernáth, 2000). A large scale experiment in Germany, Bomme and Nast (1998), reported that 1000 kg fresh shoot of lemon balm extract 4.9 kg/ha N, 1.4 kg/ha P_2O_5, 7.6 kg/ha K_2O and 0.9 kg/ha from the soil.

3. FERTILIZER RECOMMENDATION FOR BASIL

In calculation of fertilizer amounts, soil analyses and plant nutrient uptakes for targeted yields were taken into consideration. Calculations were made for optimum *Ocimum basilicum* L (green herb yield of 421-3197 kg da^{-1}) and recommended nutrients were calculated respectively as 10 kg/da N, 4 kg/da P_2O_5 and 12 kg/da K_2O (Runham, 1998; Erşahin, 2006; Blank et al. 2006).

An important factor affecting the quantity and quality of the harvested basil yield is to find the optimum level of fertilization. The level and the amount of fertilization naturally depend on the soil (Hiltunen and Holm, 1999). Similar results were achieved in a Hungarian study. On a sandy soil of low humus and nutrient content, the best fresh and dry herb yield (40 t/ha and 7.3 t/ha, respectively) from two harvests were achieved with medium doses of NPK elements (120;100;100 kg/ha). The essential oil yield was highest (40.5 kg/ha) at this fertilization level as well. No beneficial effects of higher doses were found. Increasing N-doses gave a considerable rise both in the fresh and dry yield of sweet basil (Wahab and Hornok, 1982). Halva and Puukka (1987) reported application of NPK 40–16–68 kg/ha as optimum basic fertilization. In addition basil received a benefit from the N-top dressing 80 kg/ha. Due to the cold weather, the fresh yields were quite low. Additionally, in cool and moist conditions the N-top dressing increased the susceptibility to fungus diseases (Pythium sp., Fusarium sp., Sclerotinia sclerotionun). The heavier fertilized the crop-stand, the more infected plants there were in both experimental years (Halva, 1987). According to the results of Tesi et al. (1995) Genovese" sweet basil, the application of different ratios of N, P_2O_5, and K_2O showed that a ratio of 1:1:2 gave the best growth result. According to Hornok (1992) the Hungarian fertilization advice includes three applications: basic fertilization in the autumn N=40–60 kg/ha, P=60–80 kg/ha and K=120–140 kg/ha are recommended. In India, in the practical cultivation, NPK=20–40–40 kg/ha basic fertilization is recommended before the soil preparation. 40 kg/ha nitrogen fertilization is applied as top dressing in two equal doses (Srivastava, 1980). In Egypt 35–40 t/ha organic manure and 35 kg/ha P are applied as basic fertilization. As top dressing, 35 kg/ha nitrogen is applied two times, four and seven weeks after sowing/planting. In addition 35 kg/ha N is applied after each harvest (Hiltunen, and Holm, 1999).

4. FERTILIZER RECOMMENDATION FOR CHAMOMILE

In calculation of fertilizer amounts, soil analyses and plant nutrient uptakes for targeted yields were taken into consideration. Calculations were made for optimum *Matricaria chamomilla* L.yield (green herb yield of 950–2640 kg da^{-1}) and recommended nutrients were calculated respectively as 10 kg da^{-1} N, 5 kg da^{-1} P_2O_5,15 kg da^{-1} K_2O (Erşahin, 2006; Grejtovský et al., 2006; Grejtovský and Pirc, 2000).

Asteraceae family, Ahmad et al. (2011) showed that application of NPK rates at 15:10:10 g m^{-2} caused the maximum values of plant height, flowers length flowers fresh weight and flowers diameter for marigold plant. The similar results were in family Asteraceae by Ahmed et al. (2017) and Ayemi et al. (2017) who found that NPK fertilization improved growth characteristics and essential oil of yarrow, chrysanthemum and gerbera plants, respectively.

A few studies have been conducted on the effect of N fertilization to the yield and the essential oil of chamomile. It was found that the increase in N-fertilization results to higher flower yield and the indicated optimum N fertilization level for the yield of chamomile was 60 kg ha^{-1} (Johri et al., 1992). Singh et al., (2011) observed that application N in the form of ammonium sulphate at 40 kg ha^{-1} significantly increased the yield of fresh flowers.

Table 1: NPK recommendations based on soil analysis results for medicinal plants

Available NPK levels in soil	Level	Response to NPK fertilization
Total N (%)	< 0.2 (% O.C < 1)	High
	0.2 – 0.5 (% O.C = 1-2)	Medium
	> 0.5 (% O.C > 2)	Low
Available P (mg kg^{-1})	< 10	High
	10 – 15	Medium
	> 15	Low
Available K (mg kg-1)	< 50	Very high
	50 – 100	High
	100 – 200	Medium
	> 200	Low

O.C; Organic Carbon

Table 2: Fertilizer amounts required by some selected medicinal and aromatic plants (Data from Karamanos 2000; Beyaert 2006; Basso 2009; Carrubba, 2015).

Species	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Matricaria chamomilla L. (German chamomile)	30-50 to 80 (in spring)	30-50	20
Melissa officinalis L. (Lemon balm)			
1st year	0 to 70, in 2 splits	70 to 100-120	100-120
2nd year and following	70 to 100-130 to 250, in 2-3 splits	0	0
Mentha spp. (Mints) Japanese mint (*Mentha arvensis* L.)	150-160	40-50	30-40
Peppermint (*M. x piperita*) L.	100-120 to 150-200	50-80 to 100-120	50 to 150-200
Ocimum basilicum L. (Basil)	40	40	40

Nitrogen is one of the most important nutrients needed by plants for growth. Information on the role of nitrogen in plant physiology is plentiful in literature. Nitrogen is involved in many physiological processes in plants including growth and photosynthesis. Consequently, nitrogenous fertilizers are among the most used fertilizers in the world. Nevertheless, excessive use of N can have negative economic and the environmental implications. Intensive N fertilization can lead to toxic N levels in plant tissues and herbivores. Thus, there are calls for implementation of better nitrogen use efficiency (NUE) (Masclaux-Daubresse et al. 2010).

Nitrogen is one of the most important nutrients needed by plants; it is an important element for the formation amino acids, it is essential for plant cell division, it is directly involved in photosynthesis, it is an important component of vitamins and it aids in the production of carbohydrates. Physiologically, N is mostly available to plants in the forms of ammonium and nitrate and preference for one of the two forms to be taken up by plants tend to be influenced by the plant species and soil conditions, including pH and soil temperatures (Masclaux-Daubresse et al. 2010; Boczulak et al. 2014).

Generally speaking, the primary effect of N fertilization is to promote plant development. Literature shows many examples of this: herbage yield was found to increase with increased N applications in Scotch spearmint (Mentha gracilis Sole) (Kothari and Singh 1995), peppermint (Piccaglia et al. 1993), basil (*Ocimum basilicum* L.) (Rangappa and Bhardwaj 1998), and many others. The relationship between root and shoot dry matter accumulation per year and the N fertilization rate often takes the shape of a quadratic curve (Beyaert 2006). As a matter of fact, N is the element that exerts the greatest and most evident effect on crops, in this explaining the farmers' tendency to spread high, and sometimes excessive, doses (Arnon 1992; Neeteson et al. 1999). In the field practice, as P and K are scarcely mobile along soil's profile, they are generally applied to perennials with the first soil works, allowing roots to find them as long as they grow (Arnon 1992). Very often, a local distribution of these elements at sowing time ("band" fertilization) is suggested (Kothari et al. 1987). Phosphor was proven to have a positive influence on development of generative organs and stimulation of flowering (Radanovic´ et al. 2004). Moderate P supplies led to significant increment of plant height, number of branches, fresh and dry weights (Naguib 2011). In this last species, the peak in phosphor demand was observed at the seed formation stage, i.e. later than that detected for nitrogen (Karamanos 2000). Potassium is claimed to exert a positive effect on roots development and elongation, that is useful for several Medicinal and Aromatic Plants a (Radanovic´ et al. 2004; Basso 2009). Nevertheless, many evidences exist that a balanced ratio between nutrients may be more important in determining several yield traits, than the absolute quantities of the elements themselves. In chamazulene-yielding species (chamomile), when N:K ratio is too low (unbalanced towards K), flowers are bigger but oil quality is reduced due to an increase in bisabololoxide; otherwise, proportionally high N and low K lead to a high content in bisabolole (Catizone et al. 1986). Similarly, the mutual interference of nutrients is probably the reason why P fertilization was found to have the maximum effect when P was applied with N, as seen e.g. in lemon balm (*Melissa officinalis* L.) (Sharafzadeh et al. 2011).

There are at least three factors that may modify the response of plant. They are: (1) a change in dry matter production; (2) a change in the proportions of organs; (3) a modification in the accumulation level (Bernath 1992).

CONCLUSION

Fertilizing medicinal and aromatic plants is important. Fertilization programs should be prepared according to soil and plant analysis, especially taking into account soil, plant and climate characteristics. Since fertilization is made with organic and chemical fertilizers, these fertilizers have a very important role in agricultural production systems.

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CHAPTER 16

DROUGHT-MEDIATED CHANGES IN GROWTH, PHYSIOLOGY AND BIOCHEMISTRY OF MEDICINAL PLANTS

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1.Introduction

Drought

Drought is one of the most important threats to plant production all over the world, it is a physiological form of water deficiency, in which the available water for plants is insufficient and adversely affects plant metabolism. Due to the increase in population, the expansion of agriculture, energy and industrial sectors, the demand for water is increasing (Saeidnejad et al., 2013). Demand for water will also grow to meet the needs of a growing population. However, the increase in demand for water is faster than population growth. For example, while the world population has tripled in the last century, the demand for water resources has increased sevenfold. While the total water consumption in the world was 1,000 billion m^3 in 1940, this amount doubled in 1960; In 1990, it was 4.130 billion m^3 (Yildiz, 2007). Drought is expected to increase further as a result of expected climate changes. Arid conditions prevent plant growth, disrupt plant-water relations, reduce water use efficiency and adversely affect physiological processes in the plant. Drought stress in plants results from disruption of water flow in the xylem. Obstruction of water flow leads to a reduce in cell turgor pressure. Decreased turgor influences mitosis, cell elongation and expansion. Consequently, growth and development are also significantly impressed and plant production decreases.

Plants respond to many morphological (narrow leaf area, short stem length, defoliation, waxiness, effective rooting), physiological (transpiration, water use efficiency, osmotic adjustment, stomatal size and activity) and biochemical responses (proline, polyamine, trehalose accumulation, increased nitrate reductase activity, storage of carbohydrates) (Elena et al., 2019).

In drought conditions, stomata close and CO_2 uptake is significantly reduced. Due to the decrease in CO_2 fixation, an excess of $NADPH_2$ occurs. The synthesis of reduced components such as isoprenoids, phenols or alkaloids takes place in the plant (Kleinwächter and Selmar, 2015). It is also known that the ability of a plant to cope with abiotic stress is mainly related to its changing biochemical content and produces various secondary metabolites (SM) (Zhu et al., 2009). One of the most basic responses of the plant to arid conditions is the increase in the amount of abscisic acid (ABA) (Bano et al., 2012). When plants are subject to drought stress, stomatal changes, scavenging of reactive oxygen species (ROS), metabolic changes are observed and photosynthesis is affected. Dehydrins include heat shock proteins (HSPs), late embryogenesis-abundant proteins (LEA) (Lipiec et al., 2013), osmolytes such as proline, trehalose and sugars (Ilhan et al., 2015), protective proteins such as glycine and betaine (Wang et al., 2010). In arid conditions, some signaling molecules such as polyamines (Rangan et al., 2014) and inositol (Sengupta et al., 2008) and hormones such as ABA (Saradhi et al., 2000), ethylene and methyl jasmonate (Bartels and Sunkar, 2005) are synthesized.

Drought stress causes dehydration, closure of stomata and limited gas exchange in the plant followed by inhibition of metabolism and photosynthesis and finally death in the plant (Jaleel et al., 2008 a).

In *Cassia angustifolia* plants exposed to drought yield decreased while proline and glutathione reductase activity increased (Khammari et al., 2012).

Drought stress in various ways leads to a decrease in the yield of medicinal and aromatic plants. The first is that photosynthetically active radiation reduces canopy absorption, limiting leaf area, transient leaf wilting and curling under severe stress conditions and premature leaf senescence. Second, the efficiency of photosynthetically active radiation absorbed by the plant to produce new dry matter is reduced. Third, drought stress reduces the harvest index of medicinal and aromatic plants (Sharafzadeh and Mahdi Zare, 2011).

Due to drought, researchers will have to improve new varieties for medicinal plants in the coming years, using new genomic approaches such as classical breeding or molecular marker assisted breeding, transgenic or genome technologies. In order to achieve success under stress conditions, plant perception mechanisms, signaling pathways, and genes responsible for stress tolerance need to be identified (Elena et al., 2019).

How does drought affect medicinal plants?

In *Melissa officinalis* L. water stress decreased the height, diameter, fresh and dry weight of the plants, while no significant difference was detected in root length, fresh and dry mass. Water stress decreased the flavonoid content of the plant, whereas the rosmarinic acid concentration increased (Radacsi et al., 2016).

In arid conditions biological yield, leaf yield, plant height, tiller number, stem diameter, stem yield, internode length, and essential oil (EO) yield decreased in *Melissa officinalis* L. (Farahani et al., 2009). Under severe water stress conditions, plant height, number of secondary branches, dry and fresh weight, root mass, root length and thymol percentage decreased while proline content increased in *Thymus vulgaris* (Babaee et al., 2010).

Water stress reduced the growth of *Hypericum brasiliense* Choisy (Nacif de Abreu and Mazzafera, 2005) and *Bupleurum chinense* DC (Zhu et al., 2009).

Salt stress adversely affected the germination of seeds of *Ocimum basilicum*, *Eruca sativa*, *Petroselinum hortense*, *Chamomilla recutita*, *Origanum majorana* and *Thymus maroccanus* (Miceli et al., 2003; Ramin, 2005; Ali et al., 2007; Belaqziz et al., 2009).

According to Moradi et al. (2014) emphasized that *Thymus serpyllum* is more tolerant to arid conditions than *Thymus daenensis*, *T. kotchyanous*, *T. vulgaris*, *T. serpyllum*, *T. capitata* and *T. zygis*, while *T. vulgaris* is the most sensitive species.

Drought-induced biomass increases are accepted as a criterion for tolerance to arid conditions (Purcell et al., 2000).

Although drought stress is generally accepted as the main factor responsible for serious yield losses in agriculture, this situation is different for spice and medicinal plants (Kleinwächter and Selmar, 2015).

Salvia officinalis L. exposed to drought increase the amount of salicylic acid and decrease the level of photosynthetic pigments and jasmonic acid (Abreu and Munne-Bosch, 2008).

In *Digitalis lanata* Ehrh plant exposed to drought stress, chlorophyll a and chlorophyll b contents remained unchanged, β-carotene content increased by 25%, and xanthophyll lutein, neoxanthine and violaxanthin contents decreased by 15-30% (Stuhlfauth et al., 1990). Fock et al. (1992), on the other hand, emphasized that conductivity, net photosynthesis rate and transpiration decreased, CO_2 uptake and photorespiration were less affected in the leaves of plants under water stress. The closure of stomata due to drought caused an increase in the amount of CO_2. In plants under severe stress, the rate of photosynthesis decreased by more than 70% and the photosystem quantum efficiency reduced. This prevented excessive reduction of photosynthetic electron transport chain of plants under stress conditions. Gray et al. (2003) reported that the chicoric acid content in the roots was higher during the first flowering period of *Echinacea purpurea* L. Moench grown in arid conditions. In addition, it was determined that the total alkamide content in the roots was not affected by the stress conditions, the total amount of phenolic acid increased by 67% and the dry weight of the roots increased by 70%.

Penstenton barbatus tolerated arid conditions with an increase in root/shoot ratio and a decrease in stomatal conductivity. *Lavandula angustifolia* and *Penstemon* × *mexicali* tolerate moderately dry conditions while rapid deaths occur in severe droughts. Shoot dry weight decreased by 50-84% in *Gaillardia aristata* and by 47-99% in *Leucanthemum superbum* (Zollinger et al., 2006).

In arid conditions, the osmotic pressure of plants increases, PEP carboxylase activity and oil biosynthesis are induced (Singh et al., 1997).

Daily dew application to *Melissa officinalis* plants under water stress improved photosynthesis rate and leaf pigment content. While the chlorophyll content decreased in dry conditions, α-tocopherol increased (Munne-Bosch and Alegre, 1999). Drought tolerance of *Hippophae rhamnoides* is highly correlated with antioxidant capacity, water use efficiency and leaf nutrient content (Yang et al., 2010).

According to Korkmaz et al. (2015) emphasized that there were significant decreases in shoot dry weight, leaf area, chlorophyll content, leaf water content, gas exchange characteristics and PSII activity but membrane permeability and lipid peroxidation increased in pepper seedlings in dry conditions. In other study, Said-Al Ahl et al. (2009) emphasized that water stress causes a decrease in photosynthesis in thyme and chamomile plants.

As the water content in the soil decreases, the height, stem diameter, leaf number, leaf area, leaf area index, plant yield and leaf chlorophyll content decrease and the amount of anthocyanin and proline increases in *Ocimum basilicum* plant (Moeini Alishah et al., 2006).

In plants exposed to drought stress higher amounts of secondary metabolite are produced while biomass decreases. This applies to alkaloids, cyanogenic glucosides or glucosinolates as well as phenols and terpenes (Selmar, 2008). Similarly, drought stress increases the percentage of EO, but causes a decrease in shoot biomass and therefore EO content (Aliabadi et al., 2009). de Abreu and Mazzafera (2005) emphasized that SM were more common in *Hypericum brasiliense* Choisy grown in arid conditions. The amount of betulinic acid in dry conditions gave similar results to the control conditions.

Hypericum brasiliense plant exposed to drought stress increased the concentration of dihydroxy-xanthone (300%) and betulinic acid (60%) (de Abreu and Mazzafera, 2005). Also for *Camellia sinensis*, significantly higher epicatechins were observed in plants under water stress (Hernaendez et al., 2006). Drought increased the amount of SM in *Rehmannia glutinosa* (Gaertn.) DC plant (Chung et al., 2006).

Total flavonoid and rosmarinic acid content were not affected in *Melissa officinalis* L. and *Thymus vulgaris* L. grown under different water stress conditions. *Melissa officinalis* L. plants on the other hand gave lower biomass weight at low water stress (Nemeth-Zambori et al., 2016). Fresh and dry weights of *Ocimum basilicum L.* and *Ocimum americanum L.* plants were negatively affected by water stress. Under water stress the amount of EO of plants, the main components of EO, proline and total carbohydrate content increased while the content of N, P, K and protein decreased (Khalid, 2006). In arid conditions, it was determined that the antioxidant activity of *Cuminum cyminum* L. seeds was high (Rebey et al., 2012).

On the other hand, Ozturk et al. (2004) reported that the EO ratio of *Melissa officinalis L.* was positively affected by increasing water stress. Arid conditions improved the EO content from 0.12% to 0.16%. In *Mentha piperita* L. water deficit caused a significant decrease in growth, EO yield and percentage (Khorasaninejad et al., 2011). Carnosic acid (CA) content was detected in *Rosmarinus officinalis* and *Salvia officinalis* species exposed to drought, but not in *Melissa officinalis* (Munne-Bosch and Alegre, 2003). Ascorbic acid level increased in chloroplasts. Also, along with other low molecular weight antioxidants, carnosic acid was effective in preventing oxidative damage in the chloroplasts of plants exposed to water stress. Water stress led to a significant increase in cyanogenic glucosides in *Eucalyptus cladocalyx* (Woodrow et al., 2002).

In arid conditions the concentration of berberine, jatrorrhizin, and palmatin in *Phellodendron amurense* increased, plant growth was adversely affected and the alkaloid content was significantly reduced (Xia et al., 2007). Jordan et al. (2003) emphasized that in *Thymus hyemalis* Lange harvesting should be done in winter for EO extraction in low water application.

In dry conditions, superoxide dismutase (SOD), peroxidase (POD), catalase (CAT) activity and proline content were increased in *Capsicum annuum* L. Resistant cultivars showed higher antioxidant enzyme activity, but decreased lipid peroxidation. In addition, moisture content was preserved and osmolite accumulation occurred. Therefore, these plants provided better growth and yield (Anjum et al., 2012).

Moderate drought stress in *Melissa officinalis* L. has been observed to be beneficial for balsam EO (Abbaszadeh et al., 2009). According to Halil et al. (2010) reported significant morphological and biochemical changes in the bacillus plant in arid conditions. Antioxidant enzyme activity decreased in *Hippophae rhamnoides* grown under severe water stress (Liu et al., 2017), while POD decreased in *Calendula officinalis* L. while SOD and CAT activity increased (Sedghi et al., 2012). In another study, lower terpenoids were obtained in *Melissa officinalis* and *Nepeta cataria* in arid conditions (Manukyan, 2011). It was observed that the quality of *Silybum marianum* L. seeds increased due to increased silymarin accumulation with drought stress (Keshavarz Afshar et al., 2015). Drought stress enhanced production of rosmarinic acid (phenolics) of *Melissa officinalis* (Tóth et al., 2003). In *Glycyrrhiza uralensis*, exposure to drought significantly impacted synthesis of glycyrrhizic acid and liquiritin (Li et al., 2011).

Drought applied to the *Bunium persicum* during the stem elongation and flowering period decreased the yield and yield components of the plant. Due to the decreased seed yield, EO yield was also adversely affected. In drought stress, phenolic compounds accumulate due to changes in the phenylpropanoid pathway, and many of the key genes in this pathway are induced by drought stress (Jan et al., 2021). It has been reported that *Bunium persicum* shows high tolerance to drought (Saeidnejad et al., 2013).

In *Thymus citriodorus* plants exposed to drought geraniol and diisobutyl phthalate content increased while pseudophytol decreased. Thymol and carvacrol on the other hand increased only under severe drought stress (Tátrai et al., 2016). Similarly, under moderate irrigation conditions *Thymus zygis* subsp. gracilis dry matter production, EO yield and thymol content increased (Sotomayor et al., 2004).

Dry conditions contributed to the EO content of *Satureja hortensis* L. (Baher et al. (2002). In another study, similar results were observed for *Petroselinum crispum* (Mill.) (Petropoulos et al., 2008). In *Satureja hortensis*, arid conditions affected protein synthesis and degradation, affecting protein content and photosynthesis process, resulting in a decrease in sugar content (Yazdanpanah et al., 2011).

The accumulation of SM is highly dependent on environmental factors such as light, temperature, soil moisture, soil fertility and salinity (Jan et al., 2021). Due to drought, secondary metabolite production increases in the plant (Valizadeh and Mirzapour, 2021; Yadav et al., 2021). In dry conditions, phenolic compounds in *Trachyspermum ammi* (Azhar et al., 2011), flavonoids in *Glechoma longituba*, thymol, γ-terpinene and proline content in *Carum copticum*, rutin, quercetin, betulinic acid and artemisinin in *Hypericum brasiliense* and *Artemisia* increased (Verma and Shukla, 2015).

Drought increased the accumulation of codeine in *Papaver somniferum* (Szabó et al., 2003) and glycyrrhyzin in *Glycyrrhiza glabra* (Nasrollahi et al., 2014). Water deficit stress disrupts the balance between the production of reactive oxygen species (ROS) and antioxidant defense, thus leading to accumulation of ROS in proteins, membrane lipids and other cellular compounds, which creates oxidative stress. It also significantly inhibits stomatal functioning and photosynthesis. Arid conditions adversely affect the growth parameters associated with roots and above-ground parts, resulting in significant reductions in growth, yield and quality of plants. Although there are many researches on the influence of drought on growth, yield and quality of field crops, such studies on medicinal and aromatic plants are scarce (Moinuddin et al., 2012).

2.Conclusion

Drought triggers different morphological, physiological and biochemical responses in medicinal plants. Medicinal plants do not only respond to drought with a decrease in biomass, but also their chemical content, especially SM, are changed. Due to drought, signals are transmitted from roots to leaves via xylem vascular bundles and partial closure of stomata is observed. This causes a decrease in the CO_2 level in the cell. The amount of $NADPH^+$ and H^+ decreases, causing free radicals such as hydrogen peroxide and superoxide, and reactive oxygen species (ROS) to increase. As a result, the biosynthesis of reduced secondary compounds such as phenols, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, which affect the EO percentage and content of medicinal and aromatic plants, occurs in arid conditions to prevent cell membrane damage, protein denaturation and plant growth inhibition.

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ISBN: 978-625-8007-73-2