9.1.3. ***Pistacia lentiscus*** L., Sp. Pl., ed. 1, 1026 (1753); Boulos, Fl. Egypt 2:76 (2000).

Proximate Composition, Carbohydrates and Lipids

The nutritional value of *Pistacia lentiscus* amounted to 0.14 F.U. (fodder units)/kg. Ash analysis indicated minimum required amounts of P and Na, and adequate amounts of Ca, K, Mg, Mn, Fe, Cu, and Zn (Sottini and Geri, 1970). Analysis of seeds of *Pistacia lentiscus* collected from Greek islands showed average weight/100 seeds 3.0 g, moisture 15.5, oil, 31.2, protein 8.7, N-free extract 16.5, crude fiber 24.7 and ash 3.23%. The seed oil has free fatty acids 9.7 % and unsaponifiable matter 0.79% (Marcopoulos, 1965). The hexane extract of *Pistacia lentiscus* and *Pistacia lentiscus* var. *chia* collected from Turkey in February are 5.2124 and 5.8030% respectively (Kıvçk and Akay, 2005). The fully ripe seeds yield about 10% of a greenish coloured oil known as shinokokka. Because of its aromatic properties, the oil is suitable for the preparation of toilet soaps. The leaves, although poor in tannin, are used to a small extent for tanning purposes. The Chios variety of *Pistacia lentiscus* yields a gum known as mastichi from which the alcoholic beverage masticha is distilled. The gum is also used in the preparation of mastic chewing gum and for the preparation of mastichi paste (Anon, 1932).

Pistacia lentiscus long known to trade as a source of mastic resin, contains in its fruit an abundant quantity of fatty oils. The residue after oil expression as well as the fresh branches of the tree yield a tanning material. The de-tanned expressed residue can be used as animal feed (Poggi, 1942). In Cyprus, an edible oil (shinia oil, about 18%) was early extracted from the fruit (Scherubel, 1918).

Palmitic and stearic acids were early identified in the oil of the plant (Sernagiotto and Vita, 1915). This oil is reported abundant is Sardinia. The approximate composition is palmitic acid 24.82, stearic acid 11.63, oleic acid 47.62, linolic acid 6.25, glycerol 9.53 and unsaponifiable (photosterol and resins) 0.96% (Vodret, 1929).

The total lipid content and fatty acid composition of barks and leaves of the evergreen shrub, *Pistacia lentiscus*, and of small trees of the summer green species *Pistacia terebinthus* and *Pistacia vera* were investigated throughout the period of a year. The total lipid content in the bark of *Pistacia lentiscus* was high in early winter, decreasing during the main growth period and further during the summer drought period. The barks of the 2 summer green species showed a decrease of the lipid content before frondescence and again during the time of seed-ripening. The lipid content of leaves of *Pistacia lentiscus* increased during the early growth phase and was minimal at the time of the summer drought. In both summer green species, the lipid content increased from the beginning of leaf growth to summer and decreased in autumn during leaf senescence. The most important fatty acids were palmitic, stearic, oleic, linoleic, and linolenic, and in leaves of *Pistacia lentiscus* also myristic acid. Barks and leaves of *Pistacia lentiscus* showed an increase of oleic acid during the summer and an increase of linoleic and linolenic acid during the winter. In leaves of the summer green species linolenic acid increased up to leaf-senescence. There is no unequivocal influence of summer drought on the fatty acid pattern. In seeds, the content of oleic acid was lowest in *Pistacia lentiscus* and highest in *Pistacia vera*; for linoleic acid, the reverse was true (Diamantoglou and Meletiou-Christou, 1979). Changes in storage lipids, fatty acids, and carbohydrates in vegetative parts of *Pistacia lentiscus*, during one year, have been studied. With the beginning of the dry summer period, total sugars increased in leaves. In bark, sugars increased in the summer, decreased in the fall, and remained low in winter. Total lipid in leaves decreaed during the summer and increased during the winter. Fatty acid composition of leaves and bark was similar; however, leaves contained more myristic. During winter polyunsaturated fatty acids increased; saturated fatty acids increased during the hot period of summer (Diamantoglou and Meletiou-Christou, 1981).

The black fruits of *Pistacia lentiscus*, growing in Algeria, has the highest crude fat of 32.8%, followed by the red fruits with 11.7%. The acid value was highest in red fruits oil (24.0 mg KOH/g), followed by the black fruits oil. The relatively high iodine value in the oils indicates the presence of many unsaturated bonds. Three dominant fatty acids were found: palmitic C16:0 (16.3-19.5%), oleic C18:1 (55.3-64.9%), and linoleic C18:2 (17.6-28.4%). The oils contain an appreciable amount of unsaturated fatty acids (78.8-83.5%). Six fatty acids were identified in the oil (Table 24) (Charef *et al*., 2008). Palmitic acid, linoleic acid, 3-undecylphenol, 3-formyl-1,3-cyclohexadiene, 3-pentadecylphenol and 2,6,10,14,18,22-tetracosahexane were identified from the fatty oil of the fruit (Mekni, 2011).

The total lipid content, fatty acids and 4-desmethylsterols accumulation in developing fruit of *Pistacia lentiscus* (lentisc) growing wild in Tunisia, were studied. Low oil accumulation was observed during the first 35 days after the fruiting (DAF) date (from 1.83 to 2.57%). After that, two phases were distinguished (35th until the 60th and 105th to the 145th DAF), where the rate of oil accumulation increased significantly. At the last stage of maturation, the lentisc fruits had the highest percentage of lipid content, 42.54%. The changing profile of the fatty acids during maturation had been marked by an increase in oleic acid content (from 19.49 to 50.72%) paralleling a decrease in linoleic acid content (from 42.5 to 21.75%). At the 15th DAF, the alpha-linolenic acid was found with a maximum of 13.81%. At full maturity, the main fatty acids were oleic acid, followed by palmitic and linoleic acids.

Table 24. Fatty acid composition of *Pistacia lentiscus* oils*

Fatty acids	Black fruit	Red fruit	Triglycerides	
			Black fruit	Red Fruit
C16.0	19.5±0.2	16.3±0.3	22.1±0.4	16.8±0.6
C16.1	2.1±0.2	1.0±0.1	--	--
C18.0	1.7±0.1	0.7±0.1	--	--
C18.1	55.3±0.8	53.5±0.9	56.9±0.7	50.7±1.1
C18.2	21.4±0.3	28.5±0.4	21.0±0.9	32.5±1.1
SFA	21.2	17.0	22.1	16.8
USFA	78.8	83.0	77.9	83.2
U/S	3.7	4.8	3.5	4.9

SFA: saturated fatty acids, USFA: unsaturated fatty acids, U/S: unsaturated / saturated fatty acids.
* Charef *et al.* (2008)

Other fatty acids were present in trace proportions, such as palmitoleic, stearic, linolenic, gadoleic and arachidic acid. In all stages of ripening only four sterols were identified. β-Sitosterol was the major 4-desmethylsterol, followed by campesterol. Cholesterol and stigmasterol were detected in trace amounts. During the first stage of ripening, the amount of total sterols was about 5.19/100 g of oil. It decreased to 0.43/100 g in the last stage. Sitosterol and campestereol showed nearly the same profile during the ripening the fruit ripening which could be linked to the relation between these compounds during their biosynthesis (Trabelsi *et al*., 2012) The study of the physico-chemical and chemical properties of the oil of *Pistacia lentisicus* revealed that it is comparable with the olive oil (Mizi and Djedala, 2010). The properties and composition of the oil have been reported by others (Semagiotto and Vita, 1915; Cordella, 1953; Amelotti *et al*., 1967).

The chemical composition (total solid, total digestible tannin, non-tannic, non-digestible and carbohydrate substances) of *Pistacia lentiscus* and *Pistacia terebinthus* have been reported by Koco (1967). Medina Carnicer *et al*. (1979) determined the composition and ratios of mineral elements in *Pistacia lentiscus* (growing in Spain) samples of leaves and stems ≤ 3 mm in diameter collected during 5 periods of the year. The contents of (1.40-1.56% on a dray matter basis) and K (0.35-0.74% except in April when the amount was 0.027%) were generally sufficient to supply the requirements of the animals, whereas P (0.13-0.16%0 and Na (≤ 0.04%) contents were sufficient throughout the year, and Zn levels were inadequate except in February and June, when maximum of 11.5 and 33.6 ppm, respectively were attained. Ca, Mg, Fe, Mn and Cu contents were adequate. Mineral ratios were generally unbalanced.

The preliminary results from the compositional studies of some forest plants (in Italy), including *Pistacia lentiscus* confirmed that whole or some of these species are suitable for industrial exploitation. The more significant yield was β-carotene and vitamin C in *Pistacia lentiscus* (Vidrich *et al*., 1983). The seasonal variations of major nitrogenous components (total N, protein N, soluble N) in sclerophyllus leaves of 4 Mediterranean species including *Pistacia lentiscus* were studied (Diamantoglu and Kull, 1988).

Analysis of the arabino-galactan proteins isolated from chios mastic gum (*Pistacia lentiscus*) indicated the presence of highly glycosylated protein backbone. It was separated into three major populations (A, B and C) which were consistent with their respective negative charge content namely, uronic acid. The characterization of neutral sugars showed the existence of arabinose and galactose in different amounts of each group (Kottakis *et al.*, 2008).

Essential Oils

The essential oils of the mastic gum and different parts of the plant growing in different localities have been investigated. However, *Pistacia lentiscus*, growing in India, was among plants which have been reported not promising owing to the low percentage of oil (Bhoyar, 1959). The composition of the essential oil of the leaves (0.4-0.5%) of the plant growing in Egypt is shown in Table 21. Monoterpene hydrocarbons amount to 75% of the oil of which Δ^3-carene, limonene, myrecene and α-pinene are the major constituents. The oil contains 7.5% sesquiterpene hydrocarbons, β-bisabolene and β-bourbonene being the major ones. The same oil was found to contain 4% sesquiterpene alcohols (α- and γ-cadinol and spathulenol) and to be devoid of monoterpene alcohols (Aboutabl *et al*., 1990; De Pooter *et al.*, 1991). Up to 250 constituents were detected in the essential oils of mastic gum, leaves, and unripe and ripe fruits of *Pistacia lentiscus* from Spain. From the components, about 90 were identified, comprising over 95% of the oils. The gum oil contained 90% monoterpene hydrocarbons, and the leaf oil 50% monoterpene hydrocarbons, 20% oxygen-containing monoterpenes and 25% sesquiterpenes, whereas the fruit oils consisted of 90-96% monoterpene hydrocarbons and 2-3% sesquiterpenes. The main constituents of the gum oil were: 79% α-pinene and 3% β-myrcene; of the leaf oil: 11% α-pinene and 19% β-myrcene; of the unripe fruit oil: 22% α-pinene and 54% β-myrcene, and of the ripe fruit oil: 11% α-pinene and 72% β-myrcene. α-Terpineol and terpinen-4-ol (together 15%) were the dominant monoterpene alcohols in the leaf oil. Undecan-2-one)0.1-0.6%) seems to be an olfactively important constituent of the oils. Dimyrcene (4 isomers) occurred (0.5-4.4%) in all the oils (Boelens and Jimenez, 1991).

The essential oils of fresh leaves and semi-ripe fruits of *Pistacia lentiscus*, widely distributed on the mountains of Galilee (Palestine) Gilead, Carmel and Judea were similar in composition. The leaf oil was rich in α-terpineol (13.02%), ethyl hexadecanoate (10.36%), ethyl linolenate (11.30%) and some unidentified sesquiterpene alcohols (15.90%), while the fruit oil was found to be rich in terpinen-4-ol (13.07%), α-terpineol (13.62%) and some unidentified sesquiterpene alcohols (13.20%) (Table 25). The leaf and fruit oils differ substantially from mastic oils of other Mediterranean origins primarily by their very low monoterpene content (Fleisher and Fleisher, 1992).

Table 25. Composition of the leaf and fruit oils of *Pistacia lentiscus* from Carmel Mountain, Palestine*

Components	Leaf oil %	Fruit oil %	Components	Leaf oil %	Fruit oil %
1. α-Pinene	0.47	0.21	31. Ethyl decanoate	0.06	0.05
2. Camphene	0.07	0.03	32. Aromadendrene	0.06	T
3. β-Pinene	0.24	0.09	33. Isoamyl octanoate	0.17	0.06
4. Myrcene	0.06	0.24	34. α-Humulene	2.89	0.93
5. α-Phellandrene	T	0.06	35. α-Terpineol	13.02	13.62
6. α-Terpinene	0.02	0.04	36. Borneol	0.10	1.44
7. Limonene	2.74	2.33	37. a Muurolene**	0.18	0.16
8. 1,8-Cineole	0.04	0.25	38. α-Amorphene	2.74	0.17
9. γ-Terpinene	0.07	0.02	39. Piperitone	0.06	3.75
10. (*Z*)-β-Ocimene	T	0.05	40. Carvone	-	1.32
11. Ethyl hexanoate	0.06	T	41. δ-Cadinene	4.34	0.62
12. Isoamyl butyrate	1.12	0.58	42. Cumin alcohol	T	T
13. *p*-Cymene	0.11	0.33	43. (E)-Anethole	T	0.02
14. Terpinolene	0.06	0.07	44. *cis*-Carveol	-	0.33
15. Furfural	-	0.04	45. Calamenene	-	0.41
16. (*E*)-2-Hexenol	-	0.03	46. Isopiperitenone	-	2.21
17. Ethyl (*Z*)-3-hexenoate	0.07	-	47. Piperitenone	-	2.30
18. 2-Heptanol	0.05	T	48. Caryophyllene oxide	3.01	5.16
19. (*Z*)-3-Hexenol	3.05	0.31	49. Ethyl tetradecanoate	1.97	-
20. 2-Nonanone	1.71	0.14	50. Methyl eugenol	1.97	0.79
21. Ethyl octanoate	0.18	T	51. a Humulene oxide**	T	0.41
22. Isoamyl hexanoate	0.87	0.41	52. δ-Cadinol	3.56	3.89
23. α-Copaene	0.28	0.07	53. Methyl isoeugenol**	T	0.08
24. Linalool	0.09	0.06	54. Elemicin	0.23	-
25. *cis*-Pinene hydrate	0.03	0.02	55. Ethyl hexadecanoate	10.36	8.35
26. α-Fenchol	0.14	0.58	56. Ethyl linoleate	2.50	0.51
27. 2-Undecanone	4.75	2.16	57. Ethyl linolenate	11.30	0.32
28. β-Caryophyllene	2.30	5.10	58. Unidentified sesqui-terpene alcohols	15.90	13.20
29. Terpinen-4-ol	5.31	13.07			
30. Terpinen-1-ol	0.10	0.85			

** correct isomer not characterized, t = trace
* Fleisher and Fleisher (1992)

Differences in the composition of the essential oils obtained from gum samples were found in samples from different localities in Greece. The main components were α-pinene (64.43-80.38%) and myrcene (5-25.3%) (Katosiotis and Oikonomou, 1984). The essential oil from two qualities of mastic gum contain 62 constituents, 61 of which were identified. The main components were α-pinene (58.86-77.10%), camphene (0.75-1.04%), β-pinene (1.26-2.46%), myrcene (0.23-12.27%), linalool (0.45-3.71%), and β-caryophyllene (0.70-1.47%). These six components total > 90% of the oil. Some qualitative and quantitative differences were found between the two oils (Papageorgiou *et al*., 1991). The essential oil components of the mastic gum of *Pistacia atlantica* and *Pistacia lentiscus*, collected from Aegean coast belt in Turkey between August and September and the mastics from Chios Island of Greece, the unique producer of mastic have similar characteristics (Boztok and Cokuysal, 2007). Sixty-nine constituents were identified from the oils of mastic gum, leaves, and twigs of *Pistacia lentiscus* var. *chia*, gowing in Greece; α-pinene, myrcene, *trans*-caryophyllene, and germacrene D were the major components (Magiatis *et al*., 1999).

The chemical components from the leaves, and from ripe and unripe fruits of the plant (from Italy) essential oils were compared. In the acid and phenolic fractions of the oil, numerous fatty acids, phenolic compounds and terpenes were identified (Bonsignore *et al*., 1998a). Castola *et al*. (1996) analysed around 20 samples of essential oils of *Pistacia lentiscus* harvested in places in Corsica. The main compounds were α-pinene and terpine-4-ol, but in some cases, other terpenes can have high ratio. Seventy-eight components constitute > 96% of the leaf oil of the plant collected in Sicily. Sesquiterpene and monoterpene hydrocarbons comprise $\sim$ 81% of the volatile fraction; the most representative compounds are germacrene D 29.18, β-caryophyllene 10.49, and δ-cadinene 5.86%. The most representative aliphatic and aromatic oxygenated compounds are (*E*)-2-hexenal 1.89, 2,6-dimethyl-5-heptenal 2.50, 2-nonanone 1.31, and 2-undecanone 2.00%. Spanish oil has a greater content of monoterpene hydrocarbons than the Sicilian oil (Verzera *et al*., 2001). The chemical composition of the volatiles present in the fresh leaves and twigs of *Pistacia lentiscus*, growing in Sicily was determined by Lo Presti *et al*. (2008). The oil samples were obtained using traditional hydrodistillation (HD) and simultaneous distillation and extraction (SDE). The obtained results showed that more compounds were detected in the SDE extract (96 components) than in the HD extract (62 components). Several minor components contained in the HD product probably contribute significantly to its aromatic properties and could be useful for chemotaxonomic characterization (Table 26). *Pistacia lentiscus* leaf and twig oil could be employed as a flavor contributor or as food preservative. The oil was employed in the perfumery, food and pharmaceutical industries, as a flavouring in alcoholic beverages and chewing gums (Lo Presti *et al*., 2008).

The chemical composition of the essential oils obtained from the galls and aerial parts of the plant, growing in Spain were reported. Among the 58 constituents identified (representing 82.8% of the oil composition) sesquiterpene hydrocarbons dominated (*ca*. 47%), β-caryophyllene (13.1%), δ-cadinene (8.1%) and germacrene D (6.8%) being the major components. Although galls and oils of the aerial parts were similar from a qualitative viewpoint, the latter oil was somewhat more complex (73 components were identified, accounting for 85.4% of the oil) and the monoterpene hydrocarbons fraction (*ca*. 35%) was dominant in the oil, α-pinene (13.0%), β-caryophyllene (6.9%), limonene and β-phellandrene (5.4%); β-pinene (4.9%) and *p*-cymene (4.7%) being the main components (Table 27) (Fernandez *et al*., 2000). Vidrich *et al.* (2004) studied the chemical composition of the essential oils obtained from the leaves, branches and fruits of the plant from Tuscany (Italy). The leaf oil contained α-pinene (16.1-25.3%0, limonene (6.6-12.3%), terpinen-4-ol (7.6-12.7%) and germacrene D (9.6-14.3%) as major components. The branch oil contained α-pinene (34.4-46.2%), myrcene (6.3-11.6%) and limonene (8.1-13.0%), while the fruit oil contained α-pinene (7.5-11.2%), myrcene (68.2-71.0%) and limonene (9.6-19.7%) as major constituents. Little differences in composition were found between samples collected in different seasons and years, while epigenetic variations were observed for samples of oils

Table 26. Qualitative and quantitative profile of the volatile fraction of *Pistacia lentiscus* twig and leaf-derived essential oils**

Compounds	Leaf		Twig	
	SDE%	HD%	SDE%	HD%
Aliphatic compounds				
1. (2)-Hexenal*	0.79	-	-	-
2. (1*E*)-Hexenol*	0.37	-	-	-
3. Hexanol	0.37	-	-	-
4. 2-Nonanone	0.36	0.05	0.05	0.27
5. 2-Nonanol	0.26	0.01	0.18	0.05
6. Isopentyl-2-methyl butanoate	-	0.06	0.10	0.05
7. 3-Methyl butanoate	0.18	-	-	-
8. 2-Methyl butyl isovalerate	-	-	-	0.02
9. (3*Z)*-Hexenyl butyrate	0.10	-	-	0.05
10. Isopentyl hexanoate	-	0.29	0.15	0.08
11. Pentyl octanoate	0.13	-	0.20	-
12. 2-Undecanone	0.57	0.66	0.80	1.16
13. (2*E*,4*E)*-Decadienal	-	-	0.01	-
14. *n*-Dodecanal	0.04	-	2.28	0.10
15. *n*-Tetradecanal	-	-	0.15	0.03
16. Octadecenal	-	-	0.15	-
17. Hexadecenal	-	-	0.04	-
18. Ethyl palmitate	-	-	0.02	-
Total	3.17	1.07	4.58	1.81
Monoterpene hydrocarbons				
19. Tricyclene	0.35	0.01	1.06	0.02
20. α-Thujene	8.39	0.05	9.59	0.27
21. α-Pinene	18.35	0.58	17.79	3.86
22. Camphene	1.68	0.05	4.81	0.13
23. Sabinene	13.11	0.07	0.72	12.19
24. β-Pinene	1.56	0.27	3.69	0.80
25. Myrcene	9.04	0.07	13.59	1.83
26. α-Phellandrene	1.58	0.30	0.12	7.56
27. α-Terpinene	0.73	0.14	0.14	0.34
28. Limonene	8.35	0.48	7.62	3.19
29. β-Phellandrene	-	0.44	-	3.24
30. (*Z*)-β-Ocimene	0.29	0.01	-	0.01
31. (*E*)-β-Ocimene	0.98	0.03	-	0.03
32. γ-Terpinene	1.83	0.39	0.76	0.76
33. Terpinolene	0.38	0.16	0.19	0.47
Total	66.62	3.05	60.08	34.7
Oxygenated monoterpenes				
34. *cis*-Sabinene hydrate	0.06	-	-	-
35. Linalool	0.41	0.05	0.80	-
36. β-Thujone	-	-	0.11	-

Table 26. Qualitative and quantitative profile of the volatile fraction of *Pistacia lentiscus* twig and leaf-derived essential oils (cont.)

Compounds	Leaf		Twig	
	SDE%	HD%	SDE%	HD%
37. *trans-p*-Menth-2-en1-ol	0.14	0.01	-	0.02
38. α-Campholenal	-	-	0.25	-
39. *trans*-Pinocarveol	-	-	0.10	-
40. *(Z)*-β-Terpineol	0.12	-	-	-
41. Verbenol	-	-	0.10	-
42. Camphene hydrate	0.03	-	-	-
43. Pinocarvone	-	-	0.10	-
44. Terpinen-4-ol	3.21	0.54	0.80	0.55
45. *p*-Cymen-8-ol	-	-	0.11	-
46. α-Terpineol	0.57	0.16	0.27	0.05
47. Verbenone	-	-	0.17	-
48. *trans*-Piperitol	0.08	0.01	-	0.01
49. *trans*-Carveol	0.06	-	0.17	-
50. Nerol	0.08	-	0.80	-
51. Citronellol	0.05	-	0.80	-
52. *cis*-Carveol	-	-	0.10	-
53. Neral	0.14	-	0.10	-
54. Carvone	0.04	-	0.10	-
55. Linalyl acetate	-	-	0.50	-
56. Piperitone	-	-	0.01	-
57. Geranial	0.10	-	0.10	-
58. Perillaldehyde	-	-	0.10	-
59. Phellandral	-	-	0.01	-
60. Bornyl acetate	0.26	0.14	6.00	0.18
61. Carvacrol	0.03	-	0.10	-
62. Methyl geraneate	-	-	0.10	-
63. Neryl acetate	0.07	-	0.21	-
64. Benzyl isovalerate	0.04	-	0.10	-
65. Methyl eugenol	0.02	-	0.04	-
66. Methyl-*n*-methyl anthranylate	0.06	-	0.05	-
Total	5.75	0.97	12.4	0.81
Sesquiterpene hydrocarbons				
67. Bicycloelemene	0.02	-	0.10	0.01
68. *δ*-Elemene	-	0.09	0.10	0.02
69. α-Cubebene	0.06	0.28	0.09	0.12
70. α-Longipinene	0.02	0.10	0.02	0.06
71. α-Ylangene	0.02	-	-	0.02
72. α-Copaene	0.15	1.31	0.14	0.12
73. β-Bourbonene	0.08	0.18	-	0.04
74. β-Cubebene*	0.02	-	-	-
75. β-Elemene	0.77	0.25	0.10	1.41
76. (E*)*-Caryophyllene	3.11	14.68	2.28	4.66
77. β-Copaene	0.14	0.33	-	0.05

Table 26. Qualitative and quantitative profile of the volatile fraction of *Pistacia lentiscus* twig and leaf-derived essential oils (cont.)

Compounds	Leaf		Twig	
	SDE%	HD%	SDE%	HD%
78. β-Gurjunene	-	-	0.13	-
79. (*E*)-β-Farnesene	0.21	0.82	-	-
80. *trans*-Muurola-3,5-diene	-	-	-	0.56
81. α-Humulene	0.81	3.47	0.35	1.89
82. *allo*-Aromadendrene	0.30	1.13	0.19	0.69
83. 10-β-*(H)*-Cadina-1(6)4-diene	0.13	0.20	-	0.22
84. γ-Muurolene	0.78	3.60	0.39	1.85
85. Germacrene D*	5.30	18.61	4.35	16.77
86. (*E*)-Muurola-4(14)5-diene	0.18	1.34	-	-
87. Bicyclogermacrene	0.37	0.75	0.37	2.12
88. α-Muurolene	0.46	2.91	0.30	1.40
89. β-Bisabolene	0.34	1.58	0.19	0.23
90. β-Curcumene	-	0.34	-	0.23
91. γ-Cadinene	0.35	1.04	0.20	-
92. *δ*-Cadinene	1.75	11.13	1.23	4.36
93. (E)-γ-Bisabolene	-	1.53	-	0.16
94. *trans*-Cadina-1,4-diene	0.11	0.70	0.24	0.17
95. α-Cadinene*	0.06	-	0.10	-
96. α-*trans*-Bergamotene	-	0.71	-	-
97. Aromadendrene	-	-	0.10	-
Total	15.54	67.08	10.97	38.2
Oxygenated sesquiterpenes				
98. β-Acorenol	0.07	0.17	0.07	0.26
99. Cubebol	0.23	-	0.40	2.79
100. α-Elemol*	0.03	-	0.16	-
101. (*E*)-Nerolidol	-	-	0.07	-
102. Germacrene D-4-ol	0.12	0.33	-	2.23
103. Spathulenol	0.24	0.40	0.77	-
104. Gleenol	0.05	-	-	-
105. l-*epi*-Cubenol	0.21	1.88	-	0.44
106. *epi*-α-Muurolol*	0.72	5.79	0.48	1.02
107. α-Muurolol*	0.03	1.68	0.14	0.34
108. α-Cadinol	0.78	5.36	0.99	2.32
109. α-Bisabolol	0.26	-	0.51	1.35
Total	2.74	15.61	3.59	10.75
Diterpenes				
110. Dimyrcene isomer	-	-	0.05	
111. Dimyrcene isomer	-	-	0.52	0.16
112. Dimyrcene isomer	-	-	0.20	
Total			0.75	0.16
Miscellaneous				
113. *p*-Cymene	0.23	0.10	1.22	0.46

Table 26. Qualitative and quantitative profile of the volatile fraction of *Pistacia lentiscus* twig and leaf-derived essential oils (cont.)

Compounds	Leaf		Twig	
	SDE%	HD%	SDE%	HD%
114. Isopentyl benzoate	0.07	0.05	0.10	0.14
115. Elemicin	0.10	-	0.10	-
116. (3*Z*)-Hexenyl benzoate	0.03	-	0.15	-
117. Caryophyllene oxide	0.11	0.64	0.30	0.16
118. Humulene epoxide II	0.05	-	-	-
119. Unknown	0.15	-	0.45	2.84
120. Phytone	-	0.05	-	-
121. Malonyl oxide	-	-	0.40	-
122. *epi*-13-Manoyl oxide	-	-	0.07	-
Total	0.74	0.84	2.79	0.46
	94.6	88.6	95.1	90.4

* Compounds detected only in the Sicilian oil.

** Lo Presti *et al*. (2008)

from different sources (Vidrich *et al*, 2004) The main constituents of 105 samples of essential oil of individual plants of *Pistacia lentiscus* were myrcene, limonene, terpinen-4-ol, α-pinene, β-pinene, α-phellandrene, sabinene, *p*-cymene and γ-terpinene. The results were submitted to cluster analysis and discriminant analysis which allowed three groups of essential oils to be distinguished with respect to the content of terpinen-4-ol/α-pinene, limonene and myrcene (Castola *et al*., 2000). The composition and chemical variability of the essential oils of 17 samples of leaf oil of the plant, growing wild in Algeria were reported. Leaf oils were dominated by monoterpene hydrocarbons. α-Pinene (20.0-34.2%), myrcene (23.0-33.1%) or limonene (25.5-43.8%) were the major components. Statistical analysis of these results confirmed the chemical variability of the leaf oil of *Pistacia lentiscus* and showed a typical composition characterized by pre-eminence of sesquiterpene hydrocarbons (Mecherara-Idjeri *et al*., 2008a). α-Pinene, β-pinene, terpinen-4-ol and α-terpineol were the major components of the essential oils from the leaves and resins of the plant from Turkey (Table 28) (Duru *et al*., 2003). Approximately 95% of the components were identified in *Pistacia lentiscus* leaves from two Algerian populations; among which terpinen-4-ol (17.3-34.7%), α-terpineol (10.4-11.0%) and germacrene D (8.4-15.8%) were the major constituents (Benyoussef *et al*., 2005). The essential oils of aerial parts of *Pistacia lentiscus* from three regions of Algeria (Algiers, Tizi-Ouzou and Oran) were studied. Longifolene was predominant in the oils from Algiers(12.8%) and Tizi-Ouzou (16.4%), while α-pinene (19.0%) was the major constituent in the Oran oil. The other compounds of oils were present in important amounts; Algiers oil: γ-cadinene (6.2%), *trans*-β-terpineol (5.0%) and α-acorneol (4.6%); Tizi-Ouzou oil: *trans*-β-terpineol (15.6%), terpinen-4-ol (7.0%) and γ-muurolone (5.7%); Oran oil: *trans*-β-terpineol (13.1%), sabinene (12.6%) and β-pinene (6.5%) (Dob *et al*., 2006). The fruit oils from nine samples of *Pistacia lentiscus* growing wild in Algeria, collected from eight localities, ranged between 0.2 and 0.8%. The composition of the nine samples is shown in Tables 29 and 30. Monoterpene hydrocarbons were the main constituents of all samples (70.4-94.0%), α-pinene and myrcene being predominant. The concentration of these two compounds varied substantially from sample to sample. The most important sesquiterpenes detected in the fruit oil were β-caryophyllene (0.5-2.1%) and germacrene D (0.2-3.6%). Two groups can be easily distinguished: The six samples of the first group are characterized by appreciable (27.0 and

Table 27. Percentage composition of the essential oils of *Pistacia lentiscus* growing in Spain*

Compound[b]	Gall	Aerial parts
1. (*E*)-2-Hexenal	-	T
2. (*Z*)-3-Hexenol	t	T
3. Hexanol	-	T
4. Tricyclene	t	0.2
5. α-Pinene	4.4	13.0
6. Camphene	t	0.3
7. Sabinene	0.5	3.3
8. *β*-Pinene	1.7	4.9
9. Myrcene	0.3	0.8
10. α-Phellandrene	1.0	0.7
11. δ-3-Carene	t	0.1
12. 1.4-Cineole	-	T
13. α-Terpinene	0.2	T
14. *p*-Cymene	0.3	4.7
15. Limonene + β-Phellandrene	2.0	5.4
16. (*Z*)-β-Ocimene	t	T
17. (*E*)-β-Ocimene	t	T
18. Isoamyl butyrate	t	0.2
19. γ-Terpinene	0.4	0.2
20. Terpinolene + 2-Nonanone	0.7	1.0
21. Linalool + α-Campholenic aldehyde	0.1	0.5
22. Isoamyl isovalerate	-	0.3
23. Isoamyl valerate	0.2	T
24. *trans*-Pinocarveol	-	0.2
25. *p*-Menthatriene	-	0.3
26. Pinocarvone	-	0.1
27. Borneol	0.2	0.1
28. Carvotanacetone	t	0.1
29. Terpinen-4-ol	1.8	2.8
30. p-Cymen-8-ol	-	0.8
31. α- Terpineol	1.9	2.2
32. Myrtenal	0.2	0.3
33. *cis*-Sabinol	t	0.2
34. Verbenone	-	T
35. *cis*-Carveol	t	T
36. (*Z*)-3-Hexenyl 2-methylbutyate	-	0.1
37. (*Z*)-3-Hexenyl isovalerate	-	0.1
38. Cuminaldehyde	-	T
39. Carvone	-	T
40. Isoamyl hexanoate	0.1	0.4
41. Bornyl acetate	0.3	0.4
42. 2-Undecanone	0.9	1.6
43. 2,4,6-Trimethyl-benzaldehyde	2.7	0.7
44. α-Cubebene	0.3	0.2
45. 2,4,5-Trimethyl benzaldehyde	2.2	-
50. β-Caryophyllene	13.1	6.9
51. Isoamyl benzoate	0.5	0.5
52. Isoamyl octanoate	0.1	0.3
53. Geranyl acetone	0.2	0.2
54. α-Humulene	3.0	1.6
55. Aromadendrene	1.2	0.7
56. α-Amorphene	3.3	2.0
57. Gemacrene D	6.8	2.3
58. α-Muurolene	3.4	2.6
59. β-Bisabolene	0.6	0.4
60. γ-Cadinene	1.1	0.9
61. δ-Cadinene	8.1	4.1
62. Cadina-1,4-diene	0.7	0.1
63. Elemicin	-	0.1
64. (*Z*)-3-Hexenyl benzoate	0.2	0.1
65. Spathulenol	0.5	1.4
66. Caryophyllene oxide	1.3	3.7
67. 10-*epi*-γ-Eudesmol	3.5	-
68. T-Muurolol	3.8	3.6
69. α-Cadinol isomer	4.3	3.7
70. Bisabolol	0.6	0.9
71. Myristic acid	0.5	-
72. Benzyl benzoate	0.2	0.2
73. Unknown	0.6	0.2
74. Unknown	1.2	-
75. Unknown	1.2	-
76. Unknown	-	0.6
77. Unknown	0.4	1.2
78. Unknown	0.6	0.5
79. Unknown	1.2	0.9
80. Unknown	-	0.8

* Fernandez *et al.* (2000)

Table 28: Composition of essential oils of *Pistacia lentiscus* growing in Turkey*

Components	Leaf oil (%)	Resin oil (%)	Components	Leaf oil (%)	Resin oil (%)
1. Tricyclene	2.3	-	39. β-Bourbonene	tr	-
2. Styrene	1.2	-	40. *n*-Tetradecane	-	tr
3. α-Pinene	4.2	21.7	41. β-Caryophyllene	3.2	-
4. Camphene	1.0	0.4	42. α-Guaiene	-	0.5
5. β-Pinene	1.9	38.7	43. Aromadendrene	0.8	-
6. Oct-1-en-3-ol	-	tr	44. Geranyl acetone	1.1	-
7. α-Terpinene	0.6	-	45. Germacrene-D	0.7	1.8
8. *p*-Cymene	tr	tr	46. (*Z*)-Calamenene	0.8	tr
9. Limonene	10.6	3.8	47. (*E*)-Nerolidol	tr	-
10. *γ*-Terpinene	0.6	tr	48. Ledol	1.0	-
11. Terpinolene	-	tr	49. (*Z*)-3-Hex-l-enyl benzoate	6.7	-
12. *p*-Cymenene	0.7	-	50. β-Caryophyllene oxide	0.8	-
13. Linalool	2.0	-	51. Cedrol	0.8	-
14. *n*-Undecane	2.5	0.8	52. *n*-Hexadecane	-	tr
15. *n*-Nonanal	-	3.5	53. Cubenol	tr	-
16. 2-Hydroxymethyl benzoate	1.8	-	54. T-Cadinol	tr	-
17. Pinocarveol	0.8	0.6	55. δ-Cadinol	0.9	-
18. Isopinocarveol	1.6	-	56. 8-Cedren-13-ol	0.8	-
19. Pinocarvone	-	5.3	57. Phenylmethyl benzoate	0.6	-
20. Borneol	1.6	2.9	58. Farnesyl acetone	0.6	-
21. Terpinen-4-ol	29.9	0.6	59. Hexahydro farnesyl acetone	tr	-
22. α-Terpineol	11.6	1.9	60. 2-Hydroxy-l-decanyl benzoate	-	tr
23. Dihydrocarveol	-	tr	61. Hexadecanoic acid	tr	-
24. Myrtenol	tr	1.9	*Monoterpene hydrocarbons*	21.3	64.6
25. Verbenone	1.5	2.2	*Oxygenated monoterpenes*	51.6	19.1
26. *(Z)*-Carveol	1.1	0.6	*Sesquiterpene hydrocarbons*	7.1	6.3
27. Carvone	1.0	tr	*Oxygenated sesquiterpenes*	4.3	-
28. Cuminaldehyde	0.6	-	*Aromatics*	11.6	4.2
29. Piperitone	0.5	-	*Aliphatics*	4.2	5.8
30. *(E)*-Myrtanol	-	0.5	Total	100.0	100.0
31. Geranial	tr	tr			
32. Bornyl acetate	tr	2.6			
33. Thymol	-	2.4			
34. Carvacrol	-	1.8			
35. *n*-Tridecane	-	1.5			
36. α-Cubebene	0.6	-			
37. *(Z)*-Carvyl acetate	tr	-			
38. α-Yilangene	tr	4.0			

* Duru *et al*. (2003)

Table 29. Chemical composition of nine fruit oils of *Pistacla lentiscus* from Algeria*

Compound	%	Compound	%
1. Tricyclene	0.1- 1.7	42. β-Bourbonene	tr - 0.3
2. α-Thujene	tr - 0.2	43. β-Elemene	0.1 - 0.6
3. α-Pinene	9.4 - 51.5	44. Benzyl isovalerate	tr - 0.5
4. Camphene	0.5 - 5.8	45. β-Caryophyllene	0.4-1.9
5.Sabinene	0.1 - 11.6	46. β-Gurjunene	tr - 0.1
6.β-Pinene	2.8 - 17.3	47. Isoamyl benzoate	tr - 0.5
7. Myrcene	0.9 - 69.7	48. α-Humulene	0.1 - 0.5
8. α-Phellandrene	tr - 2.2	49. *allo*-Aromadendrene	tr - 0.4
9. δ-3-Carene	tr - 0.2	50. γ-Muurolene	tr - 0.5
10. α-Terpinene	tr - 1.7	51. γ-Gurjunene	- - 0.1
11. *p*-Cymene	0.2 - 3.7	52. Germacrene D	tr - 2.9
12. Limonene*	0.8 - 24.1	53. *epi*-Bicyclosesquiphellandrene	- - 0.1
13. β-Phellandrene*	0.4 - 2.5	54. Bicyclogermacrene	tr - 0.2
14. (*Z*)-β-Ocimene	tr - 2.0	55. α-Muurolene	0.1 - 0.5
15. (*E*)-β-Ocimene	0.3 - 6.0	56. β-Bisabolene	tr - 0.1
16. γ-Terpinene	- - 3.3	57. γ-Cadinene	tr - 0.6
17. 2-Nonanone	0.1 - 0.5	58. δ-Cadinene	0.1 - 1.3
18.Terpinolene	0.1 - 1.3	59. Cubebol	- - 0.1
19. Isoamyl 2-methylbutyrate	0.1 - 0.2	60. Cadina-1,4-diene	- - 0.1
20. Perillene	tr - 0.9	61. α-Cadinene	tr - 0.2
21. Isamyl-isovalerate	0.1 - 0.8	62. Elemol	- - 0.2
22. δ-Fenchol	tr - 0.2	63. Germacrene D-4-ol	tr - 0.3
23. *cis*-*p*-Menth-2-en-1-ol	tr - 0.2	64. Spathulenol	- - 0.3
24. *trans*-*p*-Menth-2-en-1-ol	0.1 - 0.3	65. Caryophyllene oxide	0.1 – 1.1
25. Camphene hydrate	tr - 0.2	66. Humulene epoxide ll	tr - 0.4
26. Borneol	tr - 0.3	67. 1-*epi*-Cubenol	tr - 0.4
27. Cryptone	tr - 0.5	68. γ-Eudesmol	- - 0.1
28. Terpinen-4-ol	0.3 - 6.3	69. *T*-Muurolol	0.1 - 0.8
29. α-Terpineol	0.3 - 2.6	70. α-Muurolol	- - 0.3
30. Myrtenol	tr - 0.2	71. *T*-Cadinol	tr - 0.2
31. *trans*-Carveol	- - 0.5	72. β-Eudesmol	- - 0.1
32. *cis*-Carveol	- - 0.2	73. α -Cadinol	0.2 - 0.9
33. Methyl thymol	- - 0.7	74. α -Bisabolol	tr - 0.2
34. Cuminaldehyde	tr - 0.2	75. Benzyl benzoate	- - 0.1
35. Isoamyl hexanoate	-- 0.3	76. Hexadecanoic acid	- - 0.2
36. Bornyl acetate	0.2 - 3.3	77. *Monoterpene hydrocarbons*	70.4 - 94.0
37. 2-Undecanone	0.1 - 0.6	78. *Oxygenated monoterpenes*	1.1 - 12.2
38. α-Cubebene	- - 0.4	79. *Sesquiterpene hydrocarbons*	1.7 - 6.9
39. α-Longipinene	- - 0.5	80. *Oxygenated sesquiterpenes*	0.4 - 4.7
40. α-Yanglene	- - 0.3	81. *Others*	0.6 - 3.1
41. α-Copaene	tr - 0.2	Total	89.7 - 99.7

* Mecherara-Idjeri *et al.* (2008b)

Table 30. Chemical composition of nine fruit oils of *Pistacia lentiscus* from Algeria*

Compound	1	2	3	4	5	6	7	8	9
1. Monoterpene hydrocarbons	83.1	85.7	80.3	93.8	94.0	87.3	79.6	70.4	76.7
2. Oxygenated monoterpenes	7.3	5.3	3.7	2.5	1.1	1.5	4.3	5.7	12.2
3. Sesquiterpene hydrocarbons	6.9	3.7	9.4	1.7	2.5	8.0	8.7	5.6	4.3
4. Oxygenated sesquiterpenes	1.6	1.8	2.8	0.5	0.4	1.2	4.6	4.7	2.3
5. Others	0.8	1.6	1.4	0.8	0.6	1.0	1.5	3.1	1.5
Total	99.7	98.1	97.6	99.3	98.6	99.0	98.7	89.5	97.0

* Mecherara-Idjeri *et al*. (2008b).

28.0%), medium (44.4 and 45.4%) or high level (62.8 and 69.7%) of myrcene. Other important components were α-pinene (9.4-19.5%) or limonene (24.1% in one sample). This group has a considerable variation of limonene (0.8-24.1%). The oils of the second group (3 samples) were dominated by α-pinene (37.9-51.5%). The second most important constituent was either β-pinene (17.3%), myrcene (16.8%) or sabinene (11.6%) in 3 samples (Mecherara-Idjeri *et al*., 2008b). Myrcene, previously reported (Wyllie *et al*., 1990; Boelens and Jimenez, 1991; Bonsignore *et al*., 1998a; Congiu *et al*., 2002; Vidrich *et al*., 2004) as the main component of the fruit oil, has a very low content (0.9) in one of the samples analysed by Mecherara-Idjeri *et al*., 2008b).

The characterization of the constituents of the essential oil (EO) from aerial parts (leaves, juvenile branches, and flowers when present) of *Pistacia lentiscus* growing wild in 5 localities of Sardinia (Italy) and harvested between April and October, was reported. A total of 45 compounds accounting for 97.5-98.4% of the total EO were identified, and the major compounds were α-pinene (14.8-22.6%), β-myrcene (1-19.4%), *p*-cymene (1.6-16.2%), and terpinen-4-ol (14.2-28.3%). The yields of EO (v/dry w) ranged between 0.09 and 0.32%. Similar content of the major compounds was found in samples from different origins and seasonal variability was also observed (Table 31) (Barra *et al*., 2007).

Air-dried parts of *Pistacia lentiscus*, collected from three different regions in Morocco produce essential oil in 0.2% yields. The chemical composition of *Pistacia lentiscus* oils changes with regions. The variations in chemical composition are important between plant populations. A total of 45 constituents were identified. The major oil components of *Pistacia lentiscus* from Oulmes were α-pinene (16.5-38.5%), β-myrcene (10.2-11.5%) and limonene (6.8-9.8%), while terpinen-4-ol (32.7-43.8%), α-pinene (7.1-13.5%) and bornyl acetate (6.8-10.3%) were the main constituents of Chaouen oil. For *Pistacia lentiscus* from Mehdia, terpinen-4-ol (14.5-19.3%), caryophyllene oxide (6.5-10.3%) and limonene (6.7-8.1%) were the major components. The effect of harvesting time on the oil production and chemical composition was also examined at different vegetative stages (Dec.-June). For the three locations, the best oil content was obtained during the flowering period March - June (Zrira *et al*., 2003). Germanicol (12.8%), thunbergol (8.8%), himachalene (7.4%), *trans*-squalene (6.7%), terpinyl propionate (6.7%), 3,3-dimenthol (6.2%) and cadina-1,4-diene (5.1%) are the major constituents of the oil of the leaves of *Pistacia lentiscus* collected from Morocco (Mharti *et al*., 2011).

Said *et al*. (2011) etudied the inter-population variability of terpenoid composition in leaves of *Pistacia* lentiscus from Algeria. Three different altitudes were selected to study the variability of terpenoid composition from leaves of female plants of *Pistacia lentiscus* L. throughout the elevation gradient. GC-MS analyses showed that terpenoid contents change with altitude. Forty nine compounds were identified with a high interpopulation variability for low- and midaltitude sites that also exhibited the same major components when data were

Table 31. Analysis of essential oil major compounds (%) of *Pistacia lentiscus* from different harvesting stations in the four different harvesting period*

Compound	Harvesting period**			
	1	2	3	4
1. α-Pinene	22.6	21.5	14.6	15.6
2. Sabinene	8.1	4.2	4.6	3.8
3. β-Pinene	3.6	3.9	2.3	3.2
4. Myrcene	1.0	1.1	1.1	1.3
5. *α*-Phellandrene	0.1	5.7	6.9	8.1
6. *α*-Terpinene	t	3.7	7.3	3.7
7. *p*-Cymene	16.2	5.4	1.1	1.5
8. Limonene	2.2	1.9	0.7	5.0
9. β-Phellandrene	2.4	3.4	4.5	3.3
10. γ-Terpinene	0.3	6.2	8.8	10.6
11. α-Terpinolene	t	2.1	2.8	3.5
12. Terpinen-4-ol	28.3	23.4	26.6	14.9
13. α-Terpineol	2.7	3.4	3.5	4.3
Total	84.8	82.5	81.3	74.5

**1= full blooming (April); 2 = end of blooming (May); 3 = growth of juvenile branches (July); 4 = growth of juvenile branches (October); t = trace (< 0.05%).

*Barra *et al*. (2007)

expressed on dry weight basis. However, Two-Way-ANOVA followed by Tukey's post hoc test showed that monoterpene hydrocarbons increased with elevation, giving values of 21.7, 37.5 and 221.5 μg g 1 dw for low- mid- and highlands, respectively. On the other hand, applying Principal Component Analysis with data expressed in percentage of the chromatogram of the volatile extract led to the identification of three chemotypes associated with altitudinal levels. In highlands (Group I), the major compounds were β-caryophyllene (12%), δ-cadinene (9.3%) and a-pinene (6.3%) while in midlands (Group II), β-caryophyllene (11.5%), δ-cadinene (8.6%) and caryophyllene oxide (6.8%) were the main components. In lowlands (Group III) δ-cadinene (10.9%), cubebol (10.5%) and β-bisabolene (7.7%) were chiefly present.

Several studies have been reported on the chemical composition of the essential oil of *Pistacia lentiscus*, collected from the following countries:

1. Algeria (Benyoussef *et al*., 2005; Dob *et al*., 2006; Mecherara-Idjeri *et al*., 2008a-c).
2. Egypt (Aboutabl *et al*., 1990; De Pooter *et al*., 1991).
3. France (Peyron, 1966; Castola *et al*., 2000).
4. Greece (Katosiotis and Oikonomou, 1984; Magiatis *et al*., 1999; Chryssavgi *et al*., 2008; Gardeli *et al*., 2008).
5. Italy (Calabro and Curro, 1974; Castola *et al*., 1996, 2000; Bonsignore *et al*., 1998a; Verzera *et al*., 2001; Congiu *et al*., 2002; Vidrich *et al*.., 2004; Barra *et al*., 2007; Lo Presti *et al*., 2008).
6. Morocco (Zrira *et al*., 2003; Amhamdi *et al*., 2009; Derwich *et al*., 2010).
7. Palestine (Fleisher and Fleisher, 1992).
8. Spain (Boelens and Jimenez, 1991; Fernández *et al*., 2000).
9. Tunisia (Ben Douissa *et al*., 2005).
10. Turkey (Duru *et al*., 2003; Kordali *et al*., 2003; Kivçak *et al*., 2004).

11. U. S. A. (Roitman *et al*., 2011).

Ben Douissa *et al*. (2005) identified 27 compounds, representing 58% of the total essential oil from leaves of *Pistacia lentiscus*, growing in Tunisia. α-Pinene (17%), γ-terpinene (9%) and terpinen-4-ol were characterized as the main constituents (Table 32). About 104 constituents in the oil from leaves of *Pistacia lentiscus* from Eastern Morocco. From these components, about 40 could be identified and quantified, comprising over 88.6% of the oil.

Table 32. Chemical composition of essential oil of *Pistacia lentiscus**, growing in Algeria.

Components	(%)	Components	(%)
Monoterpene hydrocarbons		*Monoterpene esters*	
1. Tricyclene	0.9	15. Isoamyl isovalerate	0.8
2. α-Phellandrene	2.8	16. (-)-Bornyl acetate	1.5
3. α-Pinene	16.8	17. 2-Undecanone	2.2
4. Camphene	4.0	*Monoterpene alcohols*	
5. Sabinene	5.7	18. 4-Terpineol	11.9
6. β-Pinene	4.3	*Sesquiterpenes*	
7. Myrcene	1.2	19. α-Copaene	0.4
8. α-Phellandrene isomer	3.7	20. β-Elemene	0.5
9. α-Terpipene	3.1	21. β-Caryophyllene	1.9
10. β-Phellandrene	8.9	22. α-Humulene	0.7
11. β-Terpinene	0.5	23. α-Amorphene	1.0
12. *trans*-β-Ocimene	0.6	24. Germacrene	3.3
13. γ-Terpinene	5.5	25. α-Muurolene	0.7
14. Terpinolene	1.5	26. δ-Cadinene	2.1
		27. 1,4-Cadinadiene	2.1

* Ben Douissa *et al*. (2005)

According to Amhamdi *et al*. (2009) the main constituents of the oil were myrcene (39.2%), limonene (10.3) β-gurjunene (7.8), germacrene (4.3%), α-pinene (2.9%), muurolene (2.9), α-humulene (2.6), epi-bicyclosesquiphellandrene (2.5), and β-pinene (2.2). The results of this study shows both qualitative and quantitative differences with oils from *Pistacia lentiscus* of other countries (Amhamdi *et al*., 2009). Twenty-three compounds representing 77.22% of the total essential oil (1.02%) composition were identified in the leaves of the plant, collected in Morocco. Monoterpene hydrocarbons were found to be the major group compounds, the main being α-pinene (24.25%) followed by β-pinene (12.58%), limonene (7.56%), α-terpinene-4-ol (6.98%), α-terpineol (4.89%), β-caryophyllene (3.15%), verbenol (3.05%), linalool (2.85%), camphene (2.32%) and myrcene (2.09%). The other identified compounds are isoledene, 3-carene, cymene, α-phellandrene, *p*-cymen-8-ol, terpinolene, *cis*-ocimene, α-farnesene, camphor, borneol, spathulenol, myrcene and globule (Derwich *et al*., 2010). The major compounds of the essential oil, obtained from *Pistacia lentiscus* growing in Tunisia, are terpinene-4-ol (23.32%), α-terpineol (7.12%) and β-caryophyllene (22.62%) (Bechrouch *et al*., 2010).

Forty-six compounds were characterized from the essential oil of *Pistacia lentiscus* twigs, of Turkish origin, with sabinene (23.2%), α-pinene (19.4%), germacrene D (14.1%), limonene (6.9%), β-phellandrene (6.5%), terpinene-4-ol (5.7%), and β-caryophyllene (5.7%) as the main constituents. Terpinene-4-ol (29.2%), β-caryophyllene (29.2%), and p-cymene (7.1%) were identified as the major components among the 64 compounds characterized in the essential oil of leaves. Sixty-eight compounds were found in the essential oil of *Pistacia lentiscus* var. *chia* leaves with germacrene D (20.1%), myrcene (13.9%), β-caryophyllene (10.8%), and α-terpinyl acetate (4.8%) as the major constituents. Myrcene (27.4%), germacrene D (21.7%), and β-caryophyllene (7.2%) were found to be the main components among 50 compounds characterized in the essential oil of *Pistacia lentiscus* var. *chia* twigs (Kivcak *et al*., 2004).

The essential oil (0.1-0.2%) from the plant growing in France contains 41% terpenes, 17% esters and 9% sesquiterpenes from which the following compounds were identified: α- and β-pinenes, camphene, α- and γ-terpinene, α- and β-phellandrene, cymene, myrcene, limonene, and sabinene, 4-terpineol, borneol, hexenol, octenol, hexenal, octenal, cinnamaldehyde, dihydrocinnamaldehyde, higher fatty aldehydes, benzaldehyde, acetaldehyde, isopulegone, and menthone, and hexenyl esters (Peyron, 1966). There are several other reports about the analysis of the essential oil of *Pistacia lentiscus*. Calabro and Curro (1974) reported that it contained 57% terpene fraction, in which the major constituents were α-pinene (10.7%) and myrcene (25.2%) of the total oil. The major components were the monoterpenes α-pinene, β-pinene, myrcene, and limonene. Several sesquiterpenes, aliphatic esters, ketones, and phenolic compounds such as thymol and carvacrol were also identified (Wyllie *et al*., 1990). Supercritical CO_2 extraction coupled to a fractional seperation technique (SFE) was used to isolate essential oil (separated from waxes) from the leaves and berries of *Pistacia lentiscus* from a Sardenian Southeast area (Costa Rey). In the case of the leaf essential oil, the yield was 0.45% by weight of the charged material. The chemical composition of the oil revealed the presence of β-caryophyllene (31.38%), germacrene D (12.05%) and γ-cadinene (6.48%). Remarkable differences were noticed in the corresponding hydrodistilled oil, composed chiefly by β-pinene (18.71%), β-phellandrene (12.83%) and β-caryophyllene (13.22%). The yield of volatile oil obtained on treating the berries was only 0.2%. β-Myrcene, α-pinene and α-phellandrene were the compounds characteristic of the oil obtained with both methods, SFE and hydrodistillation (Congiu *et al*, 2002). The data obtained by Barra *et al*. (2007) (Table 31) are not in agreement with those reported by Congiu *et al.* (2002). Both *ex situ* volatile emission of fruits and leaves of *Pistacia lentiscus* are shown in Tables 17 and 18.

The essential oil and gum of *Pistacia lentiscus* var. *chia* contains α-pinene, β-myrcene, β-pinene, limonene β-caryophyllene, (Koutsoudaki *et al*., 2005; Zachariadis and Langioli, 2012). Verbenone, α-terpineol, linalool and *trans*- pinacarvol were also reported as the major components of the same gum (Paraschos *et al*., 2011).

The polymer fraction of mastic resin from *Pistacia lentiscus* was characterized as *cis*-1,4-poly-β-myrcene. The molecular weight distribution of the polymer was broad and stretched up to 100,000 Da. The compound is reported as the first known example of a naturally occurring polymer of a monoterpene (Van den Berg *et al*., 1998).

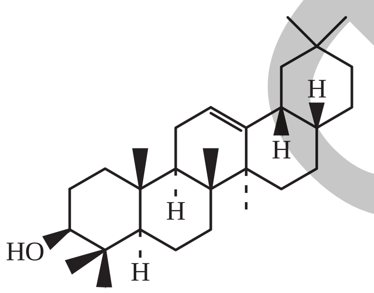
The study of changes in terpene content and emission in potted Mediterranean woody species (including *Pistacia lentiscus*), revealed that all species severely decreased their terpene emission rates under drought conditions (Llusia and Penuelas, 1998).

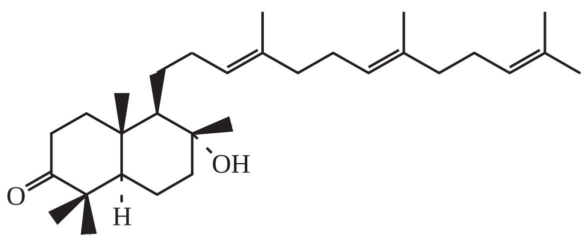
Triterpenes and Sterols

Oleoresins from *Pistacia* species are mainly composed of triterpenoids and essential oil constituents (mainly terpenes). Chemical composition of several oleoresins from *Pistacia* species in triterpenes (penta- and tetra- cyclic) and essential oils constituents, ever reported in the literature, are reviewed (Assimopoulou and Papageorgiou, 2007). Abdel-Rahman and Youssef (1975) reported that the active ingredients of mastic, a resin from *Pistacia lentiscus* were perhaps terpenolic acids.

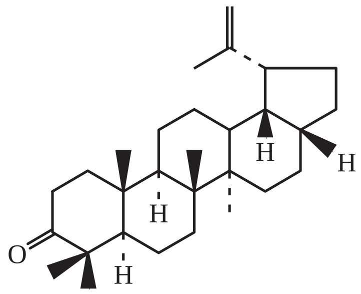
Several triterpene acids and triterpene alcohols have been isolated from the resin as well as from the galls of the plant infected with insects. The triterpene alcohols, lupeol and cycloartenol, and the sterol, β-sitosterol (free and esterified with polyhydroxy acids) were found in leaves and small branches of the plant. Lupeol was the principle constituent of the plant which also contained a series of esters with palmitic, stearic, oleic, linoleic and linolenic acids (Tabacik-Wlotzka *et al*., 1967). Monaco *et al*. (1973b) studied the triterpenoid constituents of the galls produced by the insect *Aploneura lentisci* on the young leaves of *Pistacia lentiscus*, collected in various areas of Central and Southern Italy at the end of summer. They looked like flat small beans 2-3 cm long, of a green colour with their red veins. Ether extraction of minced galls gave a waxy extract in a 2.6% yield which was separated into an acid fraction (41%) and a neutral fraction (55%). From the acid fraction (after treating with diazomethane) 9 esters were identified: masticadienonate, dihydromasticadienonate, oleanonate, masticadienolate, dihydromasticadienolate, 3-epimasticadienolate, oleanolate, dihydro-3-epimasticadienolate, and 3-epiolenanolate. From the neutral fraction, the following 8 neutral triterpenes were isolated: β-amyrone, β-amyrin, oleanonic aldehyde, oleanolic aldehyde, 28-hydroxy-β-amyrone, dammarenediol, erythrodiol, and masticadiendiol. According to Monaco *et al.* (1973b), it is not possible to relate the substances found in the galls to those in the plant, though the resin of *Pistacia lentiscus*, also known as gum mastic (Tabacik-Wlotzka and Pistra, 1967) has already been shown to contain masticadienonic, isomasticadienonic and oleanonic acids and tirucallol (Barton and Seonane, 1956; Seonane, 1956). This is because the resin producing varieties of *Pistacia lentiscus* grow in the Middle East (Tabacik-Wlotzka and Pistra, 1967), while the plants examined by Monaco *et al*. (1973b) do not produce any resin. Boar *et al*. (1984) reported that gum mastic, the neutral resin of *Pistacia lentiscus* contains the bicyclic triterpenoid diol (**77**), representing an apparent trapped intermediate of squalene 2,3-epoxide cyclization. Later, Marner *et al*. (1991) found in the neutral fraction of gum mastic a noirtriterpenoid (**88**) and two ketones (**89**, **90**) representatives of the polypodane and norlupane type respectively. The significance of these results for the geometry of the epoxysqualene cyclase/substrate interaction in the plant is discussed (Marner *et al*., 1991). A polypodane-type bicyclic triterpenoid, (8*R*)-3β,8-dihydroxypolypoda-13*E*,17*E*,21-triene was isolated from *Pistacia lentiscus* oleogum resin (Morad *et al*., 2011).

88





89



90

The galls produced by *Pemphigella cornicularia* (I) and *Pemphigella utricularia* (II) on the leaves of *Pistacia terebinthus* (III) and the gall produced by *Tetrenema lentisci* on *Pistacia lentiscus* were analyzed and compared with normal leaves. Chemically, the diseased tissues tended to be like young normal tissues. Mature galls of I and II contained *d*-borneol whereas the host leaves of III did not (Salgues, 1958).

From Moroccan *Pistachia lentiscus* leaf a wide range of chemical structures: terpenes, sesquiterpenes, alcohols, phenols, ketones, terpene alcohols, esters, etc., were detected (Guenet and Aubanel, 1991).

Thirty-seven triterpenes were identified, 12 in the acidic and 25 in the neutral fraction of *Pistacia lentiscus* and *Pistacia terebinthus* var. *chia*. In the liqiud collection resin 10 compounds were identified in the acidic and 23 in the neutral fraction, while 16 compounds were not contained in the traditionally collected resin. The main triterpenes in both resin samples collected traditionally and using stimulating agents were: isomasticadienonic acid (23.6 and 26.3% wt./wt. of the triterpenic fraction), 28-norolean-17-en-3-one (16.3 and 17.5% wt./wt. of the triterpenic fraction) and masticadienonic acid (5.8 and 6.0% wt./wt. of the triterpenic fraction respectively) (Assimopoulou and Papageorgiou, 2005b).

In the study of Assimopoulou and Papageorgiou (2005a), triterpenes, including minor components, were identified and quantified in both neutral and acidic fraction of *Pistacia lentiscus* var. *chia* resin, grown exclusively in Chios island (Greece), collected traditionally, as well as by the use of stimulating agents (liquid collection). It was proved that these two resin samples were composed of several different minor triterpenes. In the traditional collection of the resin, 36 triterpenes were identified, 23 of which are minor compounds (five in the acidic and eighteen in the neutral fraction). In the liqiud collection resin eight compounds were identified in the acidic and eleven in the neutral fraction, while seven compounds were not contained in resin traditionally collected. The main triterpenes in both resin samples collected traditionally and by use of stimulating agents were in the following order: isomasticadienonic acid (24 and 22.5% wt./wt. of triterpenic fraction), masticadienonic acid (9.3 and 14.7% wt./wt. of triterpenic fraction) and 28-norolean-17-en-3-one (19 and 36% wt./wt. of triterpenic fraction respectively).

Flavonoids and Other Phenolics

The flavonoids identified from the plant, growing in Egypt, are shown in Table 19 (Kawashty *et al.*, 2000). The leaves of *Pistacia lentiscus*, growing in Galilee (Palestine) contains myrecetin (1331 mg/kg extract), in addition to the isoflavone genistein (Vaya and Mahmood, 2006). The major anthocyanin of the berries has been identified as cyanidin 3-*O*-glucoside. Delphinidin 3-*O*-glucoside and cyanidin 3-*O*-arabinoside have also been found in minor quantities (Longo *et al*., 2007).

The presence of tannins in the plant has been reported by several researchers (Perkin and Wood, 1898; Anon, 1932; Reinboth, 1938; Poggi, 1949; Murko and Djokovic, 1980-1981; Sanz, 1992, 1993). According to Murko and Djokovic (1980-1981), the tannin content of leaves and bark of pistachio trees (*Pistacia lentiscus* and *Pistacia terebinthus* species), growing in Yugoslavia was 14-16 and 21-23%, respectively. The tannins were highly active and the pistachio leaves and bark may be regarded as a valuable source of tannin production. The tannins are of the gallocatechol type; they contain substantial amounts of gallotannin and free gallic acid. Alkaline hydrolysis yielded phloroglucinol, pyrogallol and protocatechuic acid and acetic acid (Murko and Djokovic, 1980-1981).

Three major classes of secondary metabolites were detected in the leaves of *Pistacia lentiscus*: gallic acid and galloyl derivatives of both glucose and quinic acid; flavonol glycosides; and anthocyanins, namely delphinidin 3-*O*-glucoside and cyanidin 3-*O*-glucoside.

Low amounts of catechin were also detected. The concentration of galloyl derivatives was extremely high, representing 5.3% of the leaf dry weight, and appreciable amounts of myricetin derivatives were also detected. These findings are reported useful in establishing a relationship between the chemical composition of the leaf extract and the previously reported biological activity of *Pistacia lentiscus*, and may also assign a new potential role of *Pistacia lentiscus* tissue extracts in human health care (Romani *et al*., 2002). The presence of gallic acid and 5-*O*-galloyl, 3,5-*O*-digalloyl, 3,4,5-*O*-trigalloyl quinic acid derivatives in the leaves has been reported (Baratto *et al*., 2003). Digallic acid was isolated from the fruits (Bhouri *et al*., 2010). A polymeric procyanidin, possessing a hypotensive activity was isolated from the plant (Sanz *et al.*, 1992,1993). *Pistacia lentiscus* crude extract had colouring power from yellow to brown depending on pH, on wool, cotton and silk (Usai *et al*., 1998).

Other Constituents

Quinic acid was isolated from young leaves of the plant, and shikimic acid from both young and mature leaves (Plouvier, 1960). α-Tocopherol (vitamin E), naturally occurring in *Pistacia* leaves was identified as the antioxidant component of *Pistacia lentiscus* (Cerrati *et al*., 1992). The contents of α-tocopherol (% on dry weight) in leaves of *Pistacia lentiscus* and *Pistacia lentiscus* var. *chia*, collected from Turkey in February were 0.004334 and 0.005308 %, respectively (Kıvçk and Akay, 2005). According to Ozer *et al*. (2007), the extracts of *Pistacia lentiscus*, *Pistacia lentiscus* var. *chia* and *Pistacia terebinthus* leaves can be suggested as suitable additives in α-tocopherol containing formulations.