Acta Botanica Hungarica 65(1–2), pp. 35–51, 2023
DOI: 10.1556/034.65.2023.1-2.2

TAXONOMY, ETHNOBOTANY, PHYTOCHEMISTRY AND BIOLOGICAL ACTIVITIES OF *THYMUS SATUREJOIDES*: A REVIEW

N. Chaachouay[1]*, A. Azeroual[2] and L. Zidane[3]

[1]*Interdisciplinary Research Laboratory in the Sciences, Education, and Training (IRLSET), Hassan First University, 50 Rue Ibnou Lhaytham, B. P. 577, 26002 Settat, Morocco; E-mail: noureddine.chaachouay@uhp.ac.ma (*corresponding author)*
[2]*Agri-Food and Health Laboratory (AFHL), Faculty of Sciences and Techniques of Settat, Hassan First University, P. O. Box 382, 26000 Settat, Morocco*
[3]*Plant, Animal Productions and Agro-industry Laboratory, Department of Biology, Faculty of Sciences, Ibn Tofail University, B. P. 133 14000, Kenitra, Morocco*

(Received: 9 December 2021; Accepted: 30 January 2023)

Thymus saturejoides is an endemic species of the Lamiaceae family, native to Morocco and Algeria with a restricted distribution to the High Atlas, Middle Atlas, Anti-Atlas, Middle Atlantic Morocco, and the Saharan Atlas regions of Morocco, and the Aures Mountains in Algeria. This research focused on taxonomy, ethnobotany, chemical compounds, and biological and pharmacological actions of *T. saturejoides*. Folk medicine has documented continued use of this plant species. The review summarises the scientific literature and experimental research from the databases including Google Scholar, Semantic Scholar, ResearchGate, Academia.edu, PubMed, and PubFacts. Finally, we have provided a complete document on ethnobotany, phytochemistry, and biological properties fields of *T. saturejoides*.

Key words: biological activities, ethnobotany, folk medicine, phytochemistry, taxonomy, *Thymus saturejoides*

INTRODUCTION

Medicinal wild plants have been adopted worldwide by indigenous communities, playing a crucial role in the therapy of human and livestock diseases (Batanouny *et al.* 1999). Herbal remedies are in high demand right now, and their popularity is growing by the day (Oga *et al.* 2016, Singh and Jawaid 2012, Verma and Singh 2008). The majority of current medications have been developed from isolated components of medicinal plants based on ethnopharmacological usage in recent years (Heinrich 2010, Houghton 1995). Due to the biologically chemical ingredients present in them, medicinal plants have antioxidant, antimicrobial, and therapeutic properties (Hosseinzadeh *et al.* 2015, Silva and Fernandes Júnior 2010), especially those species of Lamiaceae family (e.g. Perrino *et al.* 2021, Valerio *et al.* 2021); and may be extensively employed, as they are effective as synthetic drugs (Mgbeahuruike *et al.* 2017).

Thymus L. belongs to the Lamiaceae family, which includes over 215 species of herbaceous perennials and small shrubs worldwide. They are native to the Mediterranean area (Ghasemi Pirbalouti *et al.* 2015, Stahl-Biskup and Sáez 2002). *Thymus* thrives in a moderate to warm, dry, sunny environment with little to no shade. It requires full sunlight to flourish to its maximum capacity. *Thymus* plants commonly grow on rocks or stones. Therefore, they must have well-drained soils. It grows best on light, well-drained soils with a pH of between 5 and 8. Thyme species thrive on gritty, rocky soils unsuited for a wide variety of other plants (Morales 2002, Stahl-Biskup and Sáez 2002). *Thymus* aerial parts and active compounds are widely utilized as therapeutic herbs. This genus is one of the most popular worldwide because of its volatile ingredients. Carvacrol and thymol are the primary constituents of most *Thymus* essential oils. *Thymus* essential oil has antioxidant, antiseptic, antimicrobial, antifungal, and antiparasitic properties (Lawrence and Tucker 2002, Li *et al.* 2019, Morales 1997, Nabavi *et al.* 2015).

T. saturejoides Coss. is a perennial shrub (10–60 cm in height) belonging to the Lamiaceae family and the genus *Thymus*. Therefore, this medicinal plant occurs in a few major floristical divisions, including Saharan Atlas (Grouz), Anti-Atlas (Kest), High Atlas (Ait M'hamed, Valley Amazmiz, Ait Mezan, Seksaoua, Matouga, Tezah), Middle Atlas, and Middle Atlantic of Morocco (Abda, Souss, Titeki) (Chambouleyron *et al.* 2015, Dobignard and Chatelain 2010, Fennane and Ibn Tattou 2005). It is mentioned in the USAID-funded National Development Strategy for the aromatic and medicinal plants sector, which aims to enable the sector to shift from supplying raw materials to a genuinely industrial sector.

T. saturejoides, often known as "Zaâitra", is a Moroccan medicinal plant used to treat whooping bronchitis, cough, and rheumatism through infusions and decoctions. Antimicrobial antitoxic, analgesic, anticoagulant, and antimycobacterial activities of this medicinal plant have been demonstrated. Besides, this medicinal plant is employed in the cosmetic, aromatic flavouring, essential oils, and perfume food industries, and also for the preservation of many food products (Aicha *et al.* 2013, Al Faız *et al.* 2006, Bellakhdar 1997, 2006). The present research summarises the traditional uses, taxonomy, phytochemical constituents, and pharmacological benefits of *T. saturejoides*.

RESULTS

Botanical description

T. saturejoides, known as thyme in English and Zaâitra in Arabic (Tables 1 and 2), is an upright shrub, up to 60 cm tall, with many branches (Rankou *et al.* 2020). The leaves are spatulate, the inflorescence is composed of loose

Table 1
Taxonomy of *Thymus saturejoides* Coss.

Kingdom	Plantae
Phylum	Tracheophyta
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Tribus	Mentheae
Genus	*Thymus* L.
Species	*Thymus saturejoides* Coss.
Synonyms	*Origanum saturejoides* (Coss.) Kuntze *Thymus pseudomastichina* (Ball) Murb. *Thymus saturejoides* subsp. *pseudomastichina* (Ball) Dobignard *Thymus saturejoides* Coss. subsp. *saturejoides*

Table 2
Common names for thyme

Language	Common names
Amazigh	Tazukennit
Arabic	Zaâitra
English	Thyme
French	Thym saturéoïde

glomeruli, and the corolla is pink or pale pink (Fig. 1). It reproduces both sexually (seed) and asexually (stem splinter, cuttings, and layering). The flowers are organized in ovoid glomerules (Fig. 2). The corolla is bilabiate (0.5 cm) with whitish or pink petals (Aicha *et al.* 2013, El-Bakkal *et al.* 2020, Zenasni *et al.* 2014). The most common types of dissemination are gravity (barochore), wind (anemochore), water (idrochore), birds (ornithochore), bats (chiropterochore), insects (entomochore), and humans. Do not confuse *T. saturejoides* Coss. with *Thymus pallidus* Coss. ex Batt. which is marked by small white flowers and small, uncut leaves at the top.

Fig. 1. T. saturejoides in the southwest region of Morocco (Peltier 2019)

Traditional uses

Traditional medicine has remained the most economical and readily available form of therapy in resource-poor societies' primary health care systems. Traditional herbal remedies rely on medicinal plants, and many contemporary medications are derived indirectly from them (Karunamoorthi *et al.* 2013, Maroyi 2013, Tyler 1999). Plants have been used medicinally for thousands of years. According to texts, the medicinal usage of plants dates back to 4,000–5,000 BC, and the Chinese were the first to employ natural herbal concoctions as medicines (Hosseinzadeh *et al.* 2015). Traditional usage of herbal medicines indicates a long history of use, which is undoubtedly true for many items marketed as "traditional herbal medicines". In many developing countries, a considerable part of the indigenous peoples depends on traditional medicine and medicinal plants to address their health-care requirements (Clark 1996). Natural products have played an essential role in the treatment and prevention of human ailments all over the globe. There has been a surge of interest in natural product chemistry studies in the latest years (Clark 1996, Newman *et al.* 2000). This degree of interest is due to several causes, including the astonishing variety of chemical structures and biological activity seen in naturally occurring secondary metabolites and the development of sophis-

Fig. 2. Inflorescence of *T. saturejoides* (Peltier 2019)

ticated tools for detecting biologically active natural products (Hosseinzadeh *et al.* 2015). Medicinal plants are sources of novel pharmaceuticals, and a substantial portion of contemporary medicine is derived indirectly from plants (Suzuki 2004). Many conventional healthcare professionals no longer hesitate to offer plants, herbal supplements, or complementary or alternative medicine (CAM) therapy to their patients to treat specific ailments efficiently. There are around 250,000 flowering plant species, according to estimates (Chi 1994, Farnsworth 1990, Jones *et al.* 2006, Newman *et al.* 2000).

T. saturejoides is a flowering plant in the Lamiaceae mint family. The thymus is a medicinal plant frequently utilised in the food and pharmaceutical sectors. *T. saturejoides* is more often used in therapeutic dose forms than other *Thymus* species (Ghasemi Pirbalouti *et al.* 2015). In traditional medicine, *T. saturejoides* is grown in many nations by most people, particularly those in rural regions who rely on herbal treatments to cure various ailments (Bellakhdar 1997, Chaachouay *et al.* 2020). It is considered an essential flavouring agent, generally used in herbal tea, very much appreciated for its tonic and stimulant properties (Bellakhdar 1997). Besides, the species is a widely used natural remedy, and the leaves were largely employed as aromatic and cosmetic (Bellakhdar 2006). This thyme species is a well-known aromatic shrub used extensively throughout the Mediterranean basin as a culinary herb in herbal medicine for the treatment of a range of ailments, including gastric ulcers,

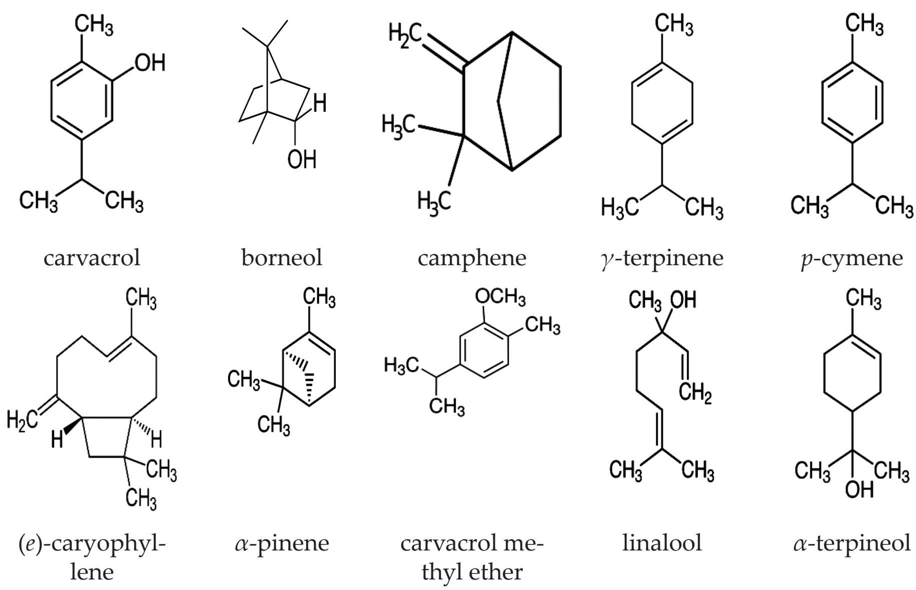

Fig. 3. Chemical structure of ten major compounds present in *T. saturejoides*

Table 3
Different chemical constituents of *T. saturejoides.*

Compounds	References
apigenin, apigenin-7-o-glucoside, alloaromadendrene, alloocimene, aromadendrene, α-amorphene	Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Khouya *et al.* 2019, Kouar *et al.* 2019, Rahmouni *et al.* 2019, Sbayou *et al.* 2016
bicyclogermacrene, borneol, bornyl acetate, bornyl formate, cis-α-bisabolene, β-bourbonene	Chraibi *et al.* 2016, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Rahmouni *et al.* 2019, Taoufik *et al.* 2017
caffeic acid, chlorogenic acid, calamenene, calarene, camphene, camphene hydrate, camphenilone, camphor, carvacrol, carvacrol methyl ether, carvenone, carveol, carvone, caryophyllene oxide, cedrene oxide, copaene, crithmene, *p*-coumaric acid, *p*-cymen-8-ol, *p*-cymene, 1,10-di-epi-cubenol, 1,8 cineole, 3-δ-carene, α-cadinol, α-campholenal, α-campholene aldehyde, α-cubebene, α-curcumene, β-caryophyllene, β-cubebene, γ-cadinene, γ-costol, δ-cadinene, camphre	Alaoui-Jamali *et al.* 2018, Asdadi *et al.* 2014, El Bouzidi *et al.* 2013, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Khouya *et al.* 2019, Kouar *et al.* 2019, Lemrhari *et al.* 2016, Rahmouni *et al.* 2019, Sbayou *et al.* 2016, Taoufik *et al.* 2017, Wang *et al.* 1992
dehydro-*p*-cymene, dihydrocarvone 1, dihydrocarvone 2, dodecamethylcyclohexasiloxane, (*z*)-dihydrocarvone	Jaafari *et al.* 2007, Rahmouni *et al.* 2019, Sbayou *et al.* 2016
eriodictyol, eriodictyol-7-o-glucoside, eucalyptol, eugenol	Asdadi *et al.* 2014, Ismaili *et al.* 2004, Khouya *et al.* 2019, Kouar *et al.* 2019, Taoufik *et al.* 2017
ferulic acid, fenchone, α-ferulene, α-farnesene	Chraibi *et al.* 2016, Jaafari *et al.* 2007, Kouar *et al.* 2019, Sbayou *et al.* 2016
geraniol formate, geranyl linalool, germacrene-d-4-ol, germacrene, guaia-3,9-diene, guaiazulene, α-guajene, α-gurjunene, β-gurjunene, germacrene d	El Bouzidi *et al.* 2013, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Lemrhari *et al.* 2016, Sbayou *et al.* 2016, Taoufik *et al.* 2017
hesperetin, hyperoside, hexahydroindan, hotrienol, α-humulene	El Bouzidi *et al.* 2013, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Khouya *et al.* 2019, Montanari 2013, Ramchoun *et al.* 2015, Sbayou *et al.* 2016
isoborneol, isobornyl acetate, isobornyl formate, isoledene, isothymol methyl ether, β-ionone, 2-isopropyl-4-methylanisole,	Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Sbayou *et al.* 2016
luteolin, luteolin-3′-o-glucuronide, luteolin-7-o-glucoside, ledene, ledol 6-epi-cubenol, limonene, linalool, linalyl propionate, (*e*)-linalool oxide, cis-linalool oxide, β-linalool	El Bouzidi *et al.* 2013, Ismaili *et al.* 2004, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Lemrhari *et al.* 2016, Ramchoun *et al.* 2015, Sbayou *et al.* 2016, Zerrifi *et al.* 2020
myrcene, *p*-menth-2-en-1-ol, *p*-mentha-1.8-diene, (*e*)-p-menthan-2-one, α-muurolene, γ-methylionone, γ-muurolene, γ-muurolol, monoterpene hydrocarbons	El Bouzidi *et al.* 2013, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Lemrhari *et al.* 2016

Table 3 (continued)

Compounds	References
oleanolic acids, octan-3-one, octen-3-ol, (*e*)-*β*-ocimene, 3-octanol, cis-ocimene, *β*-oplopenone, oxygenated monoterpenes, oxygenated sesquiterpenes	Asdadi *et al.* 2014, Ismaili *et al.* 2004, Jaafari *et al.* 2007, Sbayou *et al.* 2016, Zerrifi *et al.* 2020
pentasiloxane, pinocarveol, trans-1,2-diphenylcyclobutane, trans-pinocarveol, *α*-panasisen, *α*-pentasiloxane, *α*-phellandrene, *α*-pinene, *β*-patchoulene, *β*-phellandrene, *β*-pinene, pentasiloxane	Alaoui-Jamali *et al.* 2018, Asdadi *et al.* 2014, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Kouar *et al.* 2019, Sbayou *et al.* 2016, Zerrifi *et al.* 2020
quercetin,	Khouya *et al.* 2019
rosmarinic acid	Khouya *et al.* 2019, Ramchoun *et al.* 2015
sabinene, santolina triene, spathulenol, (*e*)-sabinene hydrate, (*z*)-sabinene hydrate, trans-sabinene hydrate, sesquiterpene hydrocarbons	Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Kasrati *et al.* 2014, Sbayou *et al.* 2016
thymonin, thymol methyl ether, thymol methyl ether, terpinen-4-ol, terpinolene, thuja-2,4(10)-diene, thujone, thymol, tricyclene, 3-tetradecen-5-yne, 3-thujen-2-one, *α*-terpineol, *α*-thujene, *γ*-terpinene	Alaoui-Jamali *et al.* 2018, Asdadi *et al.* 2014, Ismaili *et al.* 2004, Jaafari *et al.* 2007, Jirovetz *et al.* 2012, Rahmouni *et al.* 2019, Sbayou *et al.* 2016, Taoufik *et al.* 2017
ursolic acid	Ismaili *et al.* 2004
valencene, (*e*)-verbenol, verbenone	Jaafari *et al.* 2007, Sbayou *et al.* 2016

anti-diabetic, whooping cough, bronchitis, rheumatism respiratory and digestive tracts disease (Aicha *et al.* 2013, Chaachouay *et al.* 2021, Chaachouay and Zidane 2019, El Azzouzi and Zidane 2015, El HassaniM *et al.* 2013, Fouad and Lahcen 2020, Ouhaddou *et al.* 2014).

Phytochemistry

More than 150 natural products have been isolated and identified from diverse parts of *T. saturejoides*. Among them, flavonoids, terpenoids, tannins, quinones, saponins, and phenolic acids are considered to be major categories of compounds, some of which exhibit potential biological activities in vitro and in vivo (Table 3).

The abundant chemical components in *T. saturejoides* are carvacrol, borneol, camphene, *γ*-terpinene, *p*-cymene, (*e*)-caryophyllene, *α*-pinene, carvacrol methyl ether, linalool, and *α*-terpineol.

BIOLOGICAL ACTIVITIES

Antimycobacterial activity

The antibacterial activity *T. saturejoides* was evaluated against. Three bacterial strains: *Pseudomonas aeruginosa* (ATCC® 9027), *Staphylococcus aureus* (ATCC®6538), and *Escherichia* *coli* (ATCC® 8739), and two fungal strains: *Candida albicans* (ATCC®10231), and *Aspergillus brasiliensis* (ATCC®16404) by using disc diffusion method EUCAST with some modifications, as reported by (Taarabt *et al.* 2021). Essential oil activity was assessed, by measuring the inhibition zone diameters, including the diameter of discs. The results indicated that maximum activity was observed against *Escherichia coli* (13.00 mm). Moderate activity was observed against *Staphylococcus aureus*, with an inhibition zone of (8.50 mm). *Pseudomonas aeruginosa* was considered resilient since a small inhibition zone (7.50 mm) was observed (Taarabt *et al.* 2021).

In another study, essential oils from thyme were tested for antimycobacterial activity against three standard strains: *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 29213), *Pseudomonas aeruginosa* (ATCC 27853), and five clinically isolated strains: *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Enterococcus faecium* (Sbayou *et al.* 2016). The antimicrobial activity of *T. saturejoides* essential oil against eight species of microorganisms was assessed by evaluating the diameter of the inhibition zones and the measurement of minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values. *T. saturejoides* essential oil inhibited the growth of all the tested microorganisms, including the clinically derived strains, except *Pseudomonas aeruginosa*. According to the disc diffusion results, the inhibition zones of bacteria ranged from 0 ± 0 to 23 ± 0 mm. The MBC values were equivalent to the MIC values, confirming the bactericidal effect of the essential oil tested. *Staphylococcus aureus* ATCC 29213 was the most sensitive strain with MIC = MBC = 0.312 µl/ml (Sbayou *et al.* 2016).

Antioxidant activity

Many investigations have discovered the antioxidant activity of essential oil of *T. saturejoides* by different test systems – namely 2,2-diphenyl-1-picrylhydrazyl (DPPH), β-carotene/linoleic acid, ABTS assay, and TBARS assays (Junejo *et al.* 2018). The reduction ability of DPPH radical formation was determined by the decrease in its absorbance at 517 nm induced by antioxidants. In a research study, the tested essential oils exhibit a strong reduction of DPPH radical (IC50 = 0.25 ± 0.03 mg/mL) compared with ascorbic acid (IC50 = 0.25 ± 0.03 mg/mL) as standard antioxidant (Junejo *et al.* 2018). However, the β-carotene/linoleic acid assay showed a moderate antioxidant capacity (I% = 81.78 ± 0.37%) compared to BHT (I% = 98.13 ± 0.94%) as positive control (Junejo *et al.* 2018). These strong antioxidant activities might be caused by the high content of phenol compounds and flavonoids, which have been reported to be implicated in free radical scavenging (Junejo *et al.* 2018).

In another work, the antioxidant activity was carried out using ABTS assay, which measures the ability of antioxidants to scavenge the (ABTS+•) radical generated in the aqueous phase. As revealed in the study of El Hamdani *et al.* (2015), *T. saturejoides* exhibit a potent antioxidant activity (IC50 = 14.65 μg/mL). These scavenging abilities are much lower than that of ascorbic acid used as a reference antioxidant (IC50 = 1.96 μg/mL) (El Hamdani *et al.* 2015).

Anti-inflammatory activity

The anti-inflammatory activity of thyme has been studied in a number of ways, including the investigation conducted by Ismaili *et al.* (2004). Four extracts at increasing polarity were prepared from the leaves of *T. saturejoides* and assayed for the in vivo topical anti-inflammatory effect using the croton oil ear test in mice, at the dose of 300 g/cm^2. As reported by some authors (Ismaili *et al.* 2004), all the less polar extracts exerted some anti-inflammatory activity, inducing 24% (hexane), 29% (chloroform-methanol), and 65% (chloroform) edema inhibition, while methanol extract was inactive. The total extract (1,000 g/cm^2) induced 55% edema inhibition, while the corresponding dose of the chloroform extract (376 g/cm^2) exerted 66% inhibition. Consequently, the chloroform extract gives also the highest contribution to the anti-inflammatory activity of *T. saturejoides* leaves (Ismaili *et al.* 2004). In vivo topical anti-inflammatory effect of methanol and chloroform extracts of *T. saturejoides* leaves was investigated, using the croton oil ear test in mice, which showed that chloroform extract induced significant edema inhibition (at inhibition dose ID_{50} of 282 $\mu g/cm^2$), only three times lower than that of the standard conventional drug indomethacin used as a positive control (ID_{50} = 93 $\mu g/cm^2$), while the methanolic extract did not show any topical anti-inflammatory activity (Ismaili *et al.* 2004). Another study (Khouya *et al.* 2019) has evaluated in vivo the anti-inflammatory activity of *T. saturejoides* crude extracts and fractions (methanol, dichloromethane, aqueous, and ethyl acetate) using croton-oil-induced ear edema and carrageenan-induced paw edema in mice and rats. The results of this research showed that topical applications of the dichloromethane and ethyl acetate fractions (1 mg/ear) reduced significantly ear edema volume of 31.60% and 27.16%, respectively, after 4 h of treatment.

Synergistic effect

The synergy between cefixime and essential oils has been investigated by determining the MIC of cefixime in presence of *T. saturejoides* essential oils at a low concentration (MIC/4), based on preliminary tests. MIC was defined as the lowest concentration of cefixime, in combination with essential oils at MIC/4, inhibiting the visible growth of tested strains (Kasrati *et al.* 2014). As reported by Kasrati *et al.* (2014), of the 21 combinations tested between *T. saturejoides* essential oils samples and cefixime, no antagonistic effect was observed, while 14 (67%) showed total synergism, 4 (19%) had partial synergistic interaction, and 3 (14%) had no effect. The best synergistic effect was obtained with an MIC index ranging from 0.29 to 0.5 (Kasrati *et al.* 2014).

Analgesic effect

The analgesic effect of thyme was evaluated by Elhabazi *et al.* (2008). The effect of aqueous, butanoic, and ethyl-acetate extracts of thyme was tested on the nociceptive response in mice using a formalin test as a model of nociception (Elhabazi *et al.* 2008, Habib 2015). The results obtained showed that the treatment with aqueous and butanoic extracts (50, 100, 200, and 300 mg/kg, i.p.) of *T. saturejoides* induced a marked inhibition of the nociceptive response in both neurogenic and inflammatory phases of the formalin test. Results reported by Elhabazi *et al.* revealed that the *T. saturejoides* showed marked inhibition on the formalin nociceptive response. These results showed that the aqueous and butanoic fractions were effective in both phases of the model, however, the ethyl acetate fraction and ASA failed to inhibit the first phase nociceptive response (Elhabazi *et al.* 2008). In conclusion, these results provide evidence that *T. saturejoides*, possess active compounds that exhibit marked analgesic effect, confirming and justifying the popular uses of this medicinal plant to relieve some pains.

Anticoagulant activity

The anticoagulant activity of aqueous extracts of *T. saturejoides* was tested in vitro using partial thromboplastin time and prothrombin time activated (Khouya *et al.* 2019). The anticoagulant activity of the series of the tested aqueous *T. saturejoides* extracts at different concentrations were assessed in seconds, as clotting time measured in APTT and PT tests. The following concentrations of extracts were used in the clotting mixtures: 11.43, 5.71, 2.86, 1.43, 0.71, 0.36 and 0.18 mg/mL (Khouya *et al.* 2019). Blood samples were collected by cardiac puncture with a syringe from healthy rats. The extracts of *T. saturejoides* demonstrated the most anticoagulant activity in the APTT test. They completely inhibited the plasma clot development in the concentrations of 2.86 and 5.72 mg/mL in the clotting mixtures, respectively, and both strongly extended times of clotting still was the concentration of 0.18 mg/mL in the clotting mixtures ($P < 0.01$) (Khouya *et al.* 2019). Another study (Hmidani *et al.* 2019) used three in vitro assay methods to investigate the anticoagulant action of *T. saturejoides*: activated partial thromboplastin time (APTT), prothrombin time (PT), and thrombin time (TT). The results obtained in the study conducted by Hmidani *et al.* (2019) show that the aqueous extracts of this medicinal plant prolonged significantly the PT, APTT, and TT in a concentration-dependent manner when compared to the negative control.

Algicidal activity

Fatty acids, polyphenols, terpenoids, and polyethers are among the antialgal allelochemicals reported in the literature (Ni *et al.* 2012, Tebaa *et al.* 2018, Zhang *et al.* 2005). Moreover, numerous researches have looked at the algicidal efficacy of *T. saturejoides* extracts. *T. saturejoides* Coss. contains polyphenols, tannins, flavonoids, and fatty acids that limit algal growth, according to a prior study (Tebaa *et al.* 2018). In the study tannins and flavonoids as potential allelochemicals made a significant contribution to algal inhibition (Tebaa *et al.* 2018). The potential synergy between tannins and flavonoids may account for the maximum inhibition 95.93% ± 0.49 noted in *T. saturejoides* (Tebaa *et al.* 2018). Tannins have a toxic activity against filamentous fungi, yeasts, and bacteria, the antimicrobial activity of tannins could be due to their ability to form complexes with transport proteins (Omojate Godstime *et al.* 2014, Scalbert 1991).

Antiparasitic effect

T. saturejoides essential oils from different plant parts were studied against humans, viruses, and plant parasites. Santana *et al.* (2014) examined the toxicity of *T. saturejoides* essential oils against insect pest's larvae of *Spodoptera littoralis*, insect adults of *Myzus persicae* and *Rhopalosiphum padi*, as well as against adults and eggs of root-knot nematodes *Meloidogyne javanica*. A strong antifeedant effect of *T. saturejoides* essential oils were observed against *S. littoralis* larvae (EC50 = 36.9 ± 22.7 $\mu g/cm^2$), *Myzus persicae* adults (EC50 = 53.53 ± 6.5 $\mu g/cm^2$), and *R. padi* (EC50 = 49.0 ± 6.6 $\mu g/cm^2$). The study conducted by Avato *et al.* (2017) showed that *T. saturejoides* essential oils exhibit a promising nematicidal activity against *Meloidogyne incognita* juveniles (mortality rate of 10.6 ± 0.7%) and adults of *Pratylenchus vulnus* (100 ± 0.0%) and Xiphinema index (14.9 ± 0.7%) and that, after 48 h, this effect was dose-dependent. Moreover, Kasrati *et al.* (2014) reported a considerable insecticidal activity of *T. saturejoides* essential oils against adults of pest *Tribolium castaneum* responsible for stored-product deterioration (lethal dose values of LD50 = 0.315 $\mu l/cm^2$ and LD90 = 0.71 $\mu l/ cm^2$).

Acaricidal effect

In a study, essential oils from thyme were evaluated for acaricidal activity against *Varroa mite* (Ramzi *et al.* 2017). The tests were carried out at an apiary with 24 colonies of *Apis mellifera* bees, placed in Dandant-Blatt hives. The daily average ambient temperature and relative humidity (RH) ranged from 17 to 30 °C and 75 to 82%, respectively (Ramzi *et al.* 2017). All colonies had similar levels of open and sealed brood (Ramzi *et al.* 2017). Six treatments of *T. saturejoides* essential oils (different combinations of compounds) and Bayvarol (2 × strip/hive: 3.6 mg of Flumethrin) were used for testing their efficacy against *Varroa* mite. The treatments (8 including Bayvarol and control) were randomly assigned to the 24 bee colonies with three replicates for each treatment (Ramzi *et al.* 2017). Before treatments, the infestation (natural *Varroa* mites-fall) was on average of 2.08 (± 2.22) fallen mites/hive/day and the variability between the colonies was greatly important. All *Varroa* mites captured on sticky boards died after treatments, confirming the acaricidal action. The efficacy of essential oils, however, is determined by their chemical composition, notably the concentrations of main components.

CONCLUSIONS

The current study revealed numerous medicinal properties of *T. saturejoides* that could help in several medical diseases. Besides that, the focus of the research is to enlist several chemical components which exert diversified pharmacological effects on various sicknesses. Enormous studies were done for this medicinal plant; however novel pharmacological activities were briefly discussed in this study. From the reviewed literature, it can be concluded that the most important constituents of *T. saturejoides*, which are pharmacologically active and the main target of scientific studies, are carvacrol, borneol, camphene, γ-terpinene, *p*-cymene. As a result, these natural medications could be considered for preclinical and clinical research in a variety of diseases and pathological conditions. The studies concerning herbal remedies should be taken into more consideration since the efficacy and safety of many herbal medicines are still uncertain, with inadequate or irregular methods. Considering this, more reliable trials are required in the future to assess the *T. saturejoides* active phytocompounds safety and efficacy, in treating different pathological conditions.

REFERENCES

Aicha, N., Rachida, T. C. and El Abdelmalek, M. (2013): Micropropagation of Thymus satureioides Coss. an endangered medicinal plant of Morocco. – *J. Agric. Technol.* **9**(2): 487–501.

Al Faız, C., Alami, I. T. and Saıdi, N. (2006): Domestication of some MAP species. In: Al Faız, C. (ed.): Biological diversity, cultural and economic value of medicinal, herbal and aromatic plants in Morocco. – *Annual Rep.* **2006–2007**: 15–22.

Alaoui-Jamali, C., Kasrati, A., Leach, D. and Abbad, A. (2018): Étude comparative de l'activité insecticide des huiles essentielles des espèces de thyms originaires du Sud-Ouest Marocain. – *Phytothérapie* **16**(5): 268–274. https://doi.org/10.3166/s10298-016-1051-6

Asdadi, A., Alilou, H., Akssira, M., Hassani, L. M. I., Chebli, B., Moutaj, R., Gonzặlez-Mas, C. and Blặzquez, M. A. (2014): Chemical composition and anticandidal effect of three thymus species essential oils from southwest of Morocco against the emerging nosocomial fluconazole-resistant strains. – *J. Biol. Agric. Healthcare* **4**(11): 16–26.

Avato, P., Laquale, S., Argentieri, M. P., Lamiri, A., Radicci, V. and D'Addabbo, T. (2017): Nematicidal activity of essential oils from aromatic plants of Morocco. – *J. Pest Sci.* **90**(2): 711–722. https://doi.org/10.1007/s10340-016-0805-0

Batanouny, K. H., Aboutabl, E., Shabana, M. and Soliman, F. (1999): The wild medicinal plants in North Africa: history and present status. – *Acta Horticult.* **500**: 183–188. https://doi.org/10.17660/actahortic.1999.500.26

Bellakhdar, J. (1997): *Contribution à l'étude de la pharmacopée traditionnelle au Maroc: La situation actuelle, les produits, les sources du savoir (enquête ethnopharmacologique de terrain réalisé de 1969 à 1992)*. – PhD Thesis, Université Paul Verlaine-Metz.

Bellakhdar, J. (2006): *Plantes médicinales au Maghreb et soins de base. Précis de phytothérapie moderne.* – Editions le Fennec, 386 pp.

Chaachouay, N., Douira, A. and Zidane, L. (2021): Herbal medicine used in the treatment of human diseases in the Rif, Northern Morocco. – *Arab. J. Sci. Engin.* **47**: 131–153. https://doi.org/10.1007/s13369-021-05501-1

Chaachouay, N., Douira, A., Hassikou, R., Brhadda, N., Dahmani, J., Belahbib, N., Ziri, R. and Zidane, L. (2020): *Etude floristique et ethnomédicinale des plantes aromatiques et médicinales dans le Rif (Nord du Maroc)*. – PhD Thesis, Département de Biologie, Université Ibn Tofail, Kénitra. https://tel.archives-ouvertes.fr/tel-03376377

Chaachouay, N. and Zidane, L. (2019): *Ethno-medicinal studies on medicinal plants used by people of Rif, Morocco*. – 5th International Electronic Conference on Medicinal Chemistry, MDPI. https://doi.org/10.3390/ecmc2019-06406

Chambouleyron, M., Bidat, M., Ibn Tattou, M., Molero, J., Montserrat, J.-M., Pyke, S. and Léger, J.-F. (2015): Contribution à la connaissance de la flore vasculaire du Maroc oriental: Plaine de Lamrija et revers nord des monts de Debdou. – *Bull. Inst. Scie. Rabat, Sect. Sci. de la Vie* **37**: 1–16.

Chi, C. (1994): Integrating traditional medicine into modern health care systems: Examining the role of Chinese medicine in Taiwan. – *Social Sci. Medicine* **39**(3): 307–321. https://doi.org/10.1016/0277-9536(94)90127-9

Chraibi, M., Farah, A., Lebrazi, S., El Amine, O., Houssaini, M. I. and Fikri-Benbrahim, K. (2016): Antimycobacterial natural products from Moroccan medicinal plants: chemical composition, bacteriostatic and bactericidal profile of Thymus satureioides and Mentha pulegium essential oils. – *Asian Pacific J. Trop. Biomed.* **6**(10): 836–840. https://doi.org/10.1016/j.apjtb.2016.08.002

Clark, A. M. (1996): Natural products as a resource for new drugs. – *Pharm. Research* **13**(8): 1133–1141.

Dobignard, A. and Chatelain, C. (2010): *Index synonymique de la flore d'Afrique de nord. Vol. 1. Pteridophyta, Gymnospermae, Monocotyledoneae.* – Conservatoire et Jardin Botaniques de Genève.

El Azzouzi, F. and Zidane, L. (2015): La flore médicinale traditionnelle de la région de Béni-Mellal (Maroc). – *J. Appl. Biosci.* **91**(1): 8493–8502. https://doi.org/10.4314/jab.v91i1.8

El Bouzidi, L., Jamali, C. A., Bekkouche, K., Hassani, L., Wohlmuth, H., Leach, D. and Abbad, A. (2013): Chemical composition, antioxidant and antimicrobial activities of essential oils obtained from wild and cultivated Moroccan Thymus species. – *Ind. Crops Prod.* **43**: 450–456. https://doi.org/10.1016/j.indcrop.2012.07.063

El Hamdani, N., Fdil, R., Tourabi, M., Jama, C. and Bentiss, F. (2015): Alkaloids extract of Retama monosperma (L.) Boiss. seeds used as novel eco-friendly inhibitor for carbon steel corrosion in 1 M HCl solution: electrochemical and surface studies. – *Appl. Surface Sci.* **357**: 1294–1305. https://doi.org/10.1016/j.apsusc.2015.09.159

El Hassani, M., Douiri, E. M., Bammi, J., Zidane, L., Badoc, A. and Douira, A. (2013): Plantes médicinales de la Moyenne Moulouya (Nord-Est du Maroc). – *Ethnopharmacol.* **50**: 39–54.

El-Bakkal, S. E., Zeroual, S., Elouazkiti, M., Mansori, M., Bouamama, H., Zehhar, N. and El-Kaoua, M. (2020): Comparison of yield chemical composition and biological activities of essential oils obtained from Thymus pallidus and Thymus satureioides Coss. grown in wild and cultivated conditions in Morocco. – *J. Ess. Oil-Bearing Plants* **23**(1): 1–14. https://doi.org/10.1080/0972060x.2019.1708216

Elhabazi, K., Ouacherif, A., Laroubi, A., Aboufatima, R., Abbad, A., Benharref, A., Zyad, A., Chait, A. and Dalal, A. (2008): Analgesic activity of three thyme species, Thymus satureioides, Thymus maroccanus and Thymus leptobotrys. – *Afr. J. Microbiol. Res.* **2**(10): 262–267.

Farnsworth, N. R. (1990): Bioactive compounds from plants. – *Ciba Foundation Symp.* **154**(2).

Fennane, M. and Ibn Tattou, M. (2005): Flore vasculaire du Maroc: Inventaire et chorologie. Vol. 1. – *Trav. Inst. Sci., Sér. Bot.*, Rabat, **37**.

Fouad, Z. and Lahcen, Z. (2020): Antidiabetic medicinal plants in Morocco: Ethnobotanical survey of the population of Beni Mellal. – *Plant Archives* **20**(1): 337–343.

Ghasemi Pirbalouti, A., Emami Bistghani, Z. and Malekpoor, F. (2015): An overview on genus Thymus. – *J. Med. Herbs* **6**(2): 93–100.

Habib, M. R. (2015): Evaluation of analgesic and sedative-anxiolytic potential of paderia foetida leaf extract. – *Am. J. Biomed. Sci.* **7**(2): 98–104. https://doi.org/10.5099/aj150200098

Heinrich, M. (2010): Ethnopharmacology in the 21st century-grand challenges. – *Frontiers in Pharmacol.* **1**: 8. https://doi.org/10.3389/fphar.2010.00008

Hmidani, A., Bouhlali, E. D. T., Khouya, T., Ramchoun, M., Filali-Zegzouti, Y., Alem, C. and Benlyas, M. (2019): Antioxidant, anti-inflammatory and anticoagulant activities of three Thymus species grown in southeastern Morocco. – *Future J. Pharm. Sci.* **5**(1): 1–6. https://doi.org/10.1186/s43094-019-0005-x

Hosseinzadeh, S., Jafarikukhdan, A., Hosseini, A. and Armand, R. (2015): The application of medicinal plants in traditional and modern medicine: a review of Thymus vulgaris. – *Int. J. Clinic. Med.* **6**(09): 635. https://doi.org/10.4236/ijcm.2015.69084

Houghton, P. J. (1995): The role of plants in traditional medicine and current therapy. – *J. Altern. Compl. Med.* **1**(2): 131–143. https://doi.org/10.1089/acm.1995.1.131

Ismaili, H., Milella, L., Fkih-Tetouani, S., Ilidrissi, A., Camporese, A., Sosa, S., Altinier, G., Della Loggia, R. and Aquino, R. (2004): In vivo topical anti-inflammatory and in vitro antioxidant activities of two extracts of Thymus satureioides leaves. – *J. Ethnopharmacol.* **91**(1): 31–36. https://doi.org/10.1016/j.jep.2003.11.013

Jaafari, A., Mouse, H. A., Rakib, E. M., M'Barek, L. A., Tilaoui, M., Benbakhta, C., Boulli, A., Abbad, A. and Zyad, A. (2007): Chemical composition and antitumor activity of different wild varieties of Moroccan thyme. – *Rev. Bras. Farmacog.* **17**: 477–491. https://doi.org/10.1590/s0102-695x2007000400002

Jirovetz, L., Schmidt, E., Höferl, M., Wanner, J., Abbad, A. and Gochev, V. (2012): Comparative study on essential flower and leaf oils of four different wild species of thyme from Morocco. – *Proceeds 4th Int. Congr. Aromatic and Medicinal Plants*.

Jones, W. P., Chin, Y.-W. and Kinghorn, A. D. (2006): The role of pharmacognosy in modern medicine and pharmacy. – *Curr. Drug Targets* **7**(3): 247–264. https://doi.org/10.2174/138945006776054915

Junejo, J. A., Gogoi, G., Islam, J., Rudrapal, M., Mondal, P., Hazarika, H. and Zaman, K. (2018): Exploration of antioxidant, antidiabetic and hepatoprotective activity of Diplazium esculentum, a wild edible plant from North Eastern India. – *Future J. Pharm. Sci.* **4**(1): 93–101. https://doi.org/10.1016/j.fjps.2017.10.005

Karunamoorthi, K., Jegajeevanram, K., Vijayalakshmi, J. and Mengistie, E. (2013): Traditional medicinal plants: a source of phytotherapeutic modality in resource-constrained health care settings. – *J. Evidence-Based Compl. Altern. Med.* **18**(1): 67–74. https://doi.org/10.1177/2156587212460241

Kasrati, A., Jamali, C. A., Fadli, M., Bekkouche, K., Hassani, L., Wohlmuth, H., Leach, D. and Abbad, A. (2014): Antioxidative activity and synergistic effect of Thymus saturejoides Coss. essential oils with cefixime against selected food-borne bacteria. – *Ind. Crops Prod.* **61**: 338–344. https://doi.org/10.1016/j.indcrop.2014.07.024

Khouya, T., Ramchoun, M., Hmidani, A., Amrani, S., Harnafi, H., Benlyas, M., Zegzouti, Y. F., Nazih, E. H., Ouguerram, K. and Alem, C. (2019): Acute toxicity and antiproliferative and procoagulant activities of fractions derived from Thymus satureioides of the Moroccan High Atlas. – *S. Afr. J. Bot.* **121**: 568–576. https://doi.org/10.1016/j.sajb.2019.01.005

Kouar, J., Lamsaddek, A., Benchekroun, R., El Amrani, A., Cherif, A., Bellahcen, T. O. and Kamil, N. (2019): Comparison between electrocoagulation and solvent extraction method in the process of the dechlorophyllation of alcoholic extracts from Moroccan medicinal plants Petroselinum crispum, Thymus satureioides and microalgae Spirulina platensis. – *SN Appl. Sci.* **1**(1): 1–9. https://doi.org/10.1007/s42452-018-0137-1

Lawrence, B. M. and Tucker, A. O. (2002): *The genus Thymus as a source of commercial products*. – In: Stahl-Biskup, E. and Sáez, F. (eds): Thyme: the genus Thymus. CRC Press, pp. 266–276.

Lemrhari, A., Zouhair, R., El Kahkahi, R., Elidrissi, M., Amchrouk, A. and Elhourri, M. (2016): Chemical composition and differentiation of essential oils of Morocco's different varieties of thyme. – *Global J. Pure Appl. Chem. Res.* **4**(1): 30–35.

Li, X., He, T., Wang, X., Shen, M., Yan, X., Fan, S., Wang, L., Wang, X., Xu, X. and Sui, H. (2019): Traditional uses, chemical constituents and biological activities of plants from the genus Thymus. – *Chem. and Biodiv.* **16**(9): e1900254. https://doi.org/10.1002/cbdv.201900254

Maroyi, A. (2013): Traditional use of medicinal plants in south-central Zimbabwe: review and perspectives. – *J. Ethnobiol. Ethnomed.* **9**(1): 1–18. https://doi.org/10.1186/1746-4269-9-31

Mgbeahuruike, E. E., Yrjönen, T., Vuorela, H. and Holm, Y. (2017): Bioactive compounds from medicinal plants: Focus on Piper species. – *S. Afr. J. Bot.* **112**: 54–69. https://doi.org/10.1016/j.sajb.2017.05.007

Montanari, B. (2013): *The future of agriculture in the High Atlas Mountains of Morocco: the need to integrate traditional ecological knowledge*. – In: Mann, S. (ed.): The future of mountain agriculture. Springer Geography, Springer, Berlin, Heidelberg, pp. 51–72. https://doi.org/10.1007/978-3-642-33584-6_5

Morales, R. (1997): Synopsis of the genus Thymus L. in the Mediterranean area. – *Lagascalia* **19**(1–2): 249–262. https://doi.org/10.2307/2807833

Morales, R. (2002): *The history, botany and taxonomy of the genus Thymus*. – In: Stahl-Biskup, E. and Sáez, F. (eds): Thyme: the genus Thymus. CRC Press, pp. 1–43.

Nabavi, S. M., Marchese, A., Izadi, M., Curti, V., Daglia, M. and Nabavi, S. F. (2015): Plants belonging to the genus Thymus as antibacterial agents: From farm to pharmacy. – *Food Chem.* **173**: 339–347. https://doi.org/10.1016/j.foodchem.2014.10.042

Newman, D. J., Cragg, G. M. and Snader, K. M. (2000): The influence of natural products upon drug discovery. – *Nat. Product Rep.* **17**(3): 215–234. https://doi.org/10.1039/a902202c

Ni, L., Acharya, K., Hao, X. and Li, S. (2012): Isolation and identification of an anti-algal compound from Artemisia annua and mechanisms of inhibitory effect on algae. – *Chemosphere* **88**(9): 1051–1057. https://doi.org/10.1016/j.chemosphere.2012.05.009

Oga, E. F., Sekine, S., Shitara, Y. and Horie, T. (2016): Pharmacokinetic herb-drug interactions: Insight into mechanisms and consequences. – *Eur. J. Drug Metab. Pharmacokin.* **41**(2): 93–108. https://doi.org/10.1007/s13318-015-0296-z

Omojate Godstime, C., Enwa Felix, O., Jewo Augustina, O. and Eze Christopher, O. (2014): Mechanisms of antimicrobial actions of phytochemicals against enteric pathogens, a review. – *J. Pharm. Chem. Biol. Sci*. **2**(2): 77–85.

Ouhaddou, H., Boubaker, H., Msanda, F. and El Mousadik, A. (2014): An ethnobotanical study of medicinal plants of the Agadir Ida Ou Tanane province (southwest Morocco). – *J. Appl. Biosci.* **84**: 7707–7722. https://doi.org/10.4314/jab.v84i1.5

Peltier, J.-P. (2019): Flore et groupements végétaux du sud-ouest marocain.

Perrino, E. V., Valerio, F., Jallali, S., Trani, A. and Mezzapesa, G. N. (2021): Ecological and biological properties of Satureja cuneifolia Ten. and Thymus spinulosus Ten.: two wild officinal species of conservation concern in Apulia (Italy). A preliminary survey. – *Plants* **10**: 1952. https://doi.org/10.3390/plants10091952

Rahmouni, A., Saidi, R., Khaddor, M., Pinto, E., Gomes, E. D. S. J. C. and Maouni, A. (2019): Chemical composition and antifungal activity of five essential oils and their major components against Fusarium oxysporum f. sp. albedinis of Moroccan palm tree. – *Euro-Med. J. Environ. Integr*. **4**(1): 1–9. https://doi.org/10.1007/s41207-019-0117-x

Ramchoun, M., Sellam, K., Harnafi, H., Alem, C., Benlyas, M., Khallouki, F. and Amrani, S. (2015): Investigation of antioxidant and antihemolytic properties of Thymus satureioides collected from Tafilalet Region, south-east of Morocco. – *Asian Pac. J. Trop. Biomed.* **5**(2): 93–100. https://doi.org/10.1016/s2221-1691(15)30151-9

Ramzi, H., Ismaili, M. R., Aberchane, M. and Zaanoun, S. (2017): Chemical characterization and acaricidal activity of Thymus satureioides C. & B. and Origanum elongatum E. & M. (Lamiaceae) essential oils against Varroa destructor Anderson & Trueman (Acari: Varroidae). – *Ind. Crops Prod.* **108**: 201–207. https://doi.org/10.1016/j.indcrop.2017.06.031

Rankou, H., M'Sou, S., Ait Babahmad, R. A. and Diarra, A. (2020): *Thymus saturejoides*. – The IUCN Red List of Threatened Species 2020: e.T139600868A139601223. https://doi.org/10.2305/iucn.uk.2020-1.rlts.t139600868a139601223.en.

Santana, O., Andres, M. F., Sanz, J., Errahmani, N., Abdeslam, L. and González-Coloma, A. (2014): Valorization of essential oils from Moroccan aromatic plants. – *Nat. Prod. Comm.* **9**(8): 1934578X1400900812. https://doi.org/10.1177/1934578x1400900812

Sbayou, H., Boumaza, A., Hilali, A. and Amghar, S. (2016): Chemical composition and antibacterial and antioxidant activities of Thymus satureioides Coss. essential oil. – *Int. J. Pharm. Pharmaceut. Sci.* **8**(10): 183–187. https://doi.org/10.22159/ijpps.2016v8i10.13742

Scalbert, A. (1991): Antimicrobial properties of tannins. – *Phytochemistry* **30**(12): 3875–3883. https://doi.org/10.1016/0031-9422(91)83426-l

Silva, N. C. C. and Fernandes Júnior, A. (2010): Biological properties of medicinal plants: A review of their antimicrobial activity. – *J. Venom. Anim. Toxins Incl. Trop. Diseases* **16**(3): 402–413. https://doi.org/10.1590/s1678-91992010000300006

Singh, R. and Jawaid, T. (2012): Cinnamomum camphora (Kapur). – *Pharmacogn. J.* **4**(28): 1–5. https://doi.org/10.5530/pj.2012.28.1

Stahl-Biskup, E. and Sáez, F. (2002): *Thyme: the genus Thymus*. – CRC Press.

Suzuki, N. (2004): Complementary and alternative medicine: a Japanese perspective. – *Evidence-Based Compl. Altern. Med.* **1**(2): 113–118. https://doi.org/10.1093/ecam/neh029

Taarabt, K. O., Ouaabou, R., Lahlali, R. and Ennahli, S. (2021): Antimicrobial activity and chemical constitution of essential oil from Moroccan thyme (Thymus satureioides C.) on five microbial contaminants. – *Not. Sci. Biol.* **13**(3): 10975–10975. https://doi.org/10.15835/nsb13310975

Taoufik, F., Anejjar, A., Asdadi, A., Salghi, R., Chebli, B., El Hadek, M. and Idrissi Hassani, L. M. (2017): Synergic effect between Argania spinosa cosmetic oil and Thymus satureioides essential oil for the protection of the carbon steel against the corrosion in sulfuric acid medium. – *J. Mater. Environ. Sci.* **8**: 582–593.

Tebaa, L., Douma, M., Tazart, Z., Manaut, N., Mouhri, K. H. and Loudiki, M. (2018): Assessment of the potentially algicidal effects of Thymus satureioides Coss. and Artemisia herba alba L. against Microcystis aeruginosa. – *Appl. Ecol. Environ. Res.* **16**(1): 903–912. https://doi.org/10.15666/aeer/1601_903912

Tyler, V. E. (1999): Phytomedicines: back to the future. – *J. Nat. Prod.* **62**(11): 1589–1592. https://doi.org/10.1021/np9904049

Valerio, F., Mezzapesa, G. N., Ghannouchi, A., Mondelli, D., Logrieco, A. F. and Perrino, E. V. (2021): Characterization and antimicrobial properties of essential oils from four wild taxa of Lamiaceae family growing in Apulia. – *Agronomy* **11**: 1431. https://doi.org/10.3390/agronomy11071431

Verma, S. and Singh, S. P. (2008): Current and future status of herbal medicines. – *Veterinary World* **1**(11): 347. https://doi.org/10.5455/vetworld.2008.347-350

Wang, Y., Yang, Z.-Y. and Burton, D. J. (1992): Nickel catalyzed reaction of iodofluoroacetates with alkenes as a facile route to α-fluoroesters. – *Tetrahedron Letters* **33**(16): 2137–2140. https://doi.org/10.1016/0040-4039(92)88160-7

Zenasni, L., Gaboun, F., Mousadak, R., Benjouad, A. and Al Faiz, C. (2014): Essential oil composition and biomass productivity of Moroccan endemic Thymus satureioides Coss. & Ball. growing in the Agoundis Valley. – *J. Med. Plants Res.* **8**(12): 504–512. https://doi.org/10.5897/jmpr2014.5373

Zerrifi, S. E. A., Kasrati, A., Tazart, Z., El Khalloufi, F., Abbad, A., Oudra, B., Campos, A. and Vasconcelos, V. (2020): Essential oils from Moroccan plants as promising eco-friendly tools to control toxic cyanobacteria blooms. – *Ind. Crops Prod.* **143**: 111922. https://doi.org/10.1016/j.indcrop.2019.111922

Zhang, J., Cui, M., He, Y., Yu, H. and Guo, D. (2005): Chemical fingerprint and metabolic fingerprint analysis of Danshen injection by HPLC-UV and HPLC-MS methods. – *J. Pharm. Biomed. Analysis* **36**(5): 1029–1035. https://doi.org/10.1016/j.jpba.2004.09.009