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Hippocratic medicinal flora on the Greek Island of Kos: Spatial distribution, assessment of soil conditions, essential oil content and chemotype analysis

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1. Introduction

Hippocrates, the "Father of Western Medicine" (460 B.C.), is considered one of the most outstanding figures in the history of medicine, due to the establishment of the Hippocratic School of Medicine (3rd and 2nd centuries B.C.) on the Greek Island of Kos. Kos is situated in the South-Eastern Aegean Sea (Fig. 1). It is characterized by a Mediterranean temperate climate and hosts a distinctive flora (1116 species and subspecies; Strid, 2016) dominated by pharmaceutical aromatic plants, which resulted in the island's medical tradition. Hippocrates' healing practices were largely based on Kos pharmaceutical flora such as *Hypericum hircinum* L., *Hypericum empetrifolium* Willd., *Crithmum maritimum* L., *Teucrium capitatum* L. (syn. *Teucrium polium* L. subsp. *capitatum* (L.) Arcang.), *Cistus salviifolius* L., *Anthemis arvensis* L., *Ferula communis* L., and *Artemisia arborescens* (Vaill.) L. (Dierbach, 1824; Largus et al., 1968; Littré, 1830). These species are also native wild Mediterranean flora (Beyrouthy et al., 2011, Ferrari et al., 2005, Özcan et al., 2001) inhabiting different geographical territories, and their pharmaceutical properties have also been widely reported.

In recent years, interest in traditional medicine, especially herbal medicines, has significantly increased in both developed and developing countries. International literature has reported the antiscorbutic, tonic, carminative and diuretic properties of *C. maritimum* (Palma, 1954) and its antioxidant activity, which is linked to its phenolic content. Extracts from this species also display antimicrobial effects against several human pathogens (Houta et al., 2013). Several studies have also demonstrated the antimicrobial activity of *C. salviifolius*, the resolvent, vermifuge and anticancer properties of *A. arvensis* and the antiviral, antioxidant, antimicrobial and antifungal effects of *H. empetrifolium* and *H. hircinum* (Barragon-Catalan et al., 2011; Bertoli et al., 2011; Demetzos et al., 2002; U.S. Department of Agriculture, Agricultural Research Service, 1992-2016; Maggi et al., 2010; Mandrone et al., 2015). The antispasmodic, antipyretic, anti-inflammatory, anti-angiogenic, antiviral and antibacterial properties of *A. arborescens* are well known (Abu Zarga et al., 1995; Costa et al., 2016; Meral and Karabay, 2002; Sinico et al., 2005). *F. communis* is known for the relief of skin infections, fever and dysentery, as well as for its antiseptic action (Al-Yahya et al., 1998; Sanna et al., 2006). *T. capitatum* (syn. *Teucrium polium* subsp. *capitatum*) is known for its antiphytoviral, anti-inflammatory and antitumour effects (Bezic et al., 2011; Menichini et al., 2008). It is also thought to have good antibacterial activity, making it a useful antiseptic for medicinal purposes (Darabpour et al., 2010).

Recording of the spatial distribution of Hippocratic Medicinal Flora (HMF) was carried out by A. Hansen in 1980 using conventional observation (Hansen, 1980). However, in recent years, the implementation of global positioning systems (GPS) and geographical information systems (GIS) has increased, and these tools are useful for evaluating plant distribution with database creation and species mapping. Knowledge of plant spatial distribution is crucial for the conservation of plants as genetic material, especially given the fact that urban and industrial growth results in constant shrinkage of species' natural habitat. This problem is further exacerbated by the impact of global climate change and potential increases in regional sensitivity (Montgomery et al., 2016).

The recent trend toward using natural medicinal plants complementarily with conventional drugs, in cases where those can be used, has led to an increasing interest in exploring and finding the plants that were used by Hippocrates, as well as analysing their chemical compounds to identify their therapeutic value. Therefore, our research focused on an extended survey conducted on Kos in order to determine the distribution of HMF at more sites, to evaluate the composition of their essential oils and the relationship between their occurrence and

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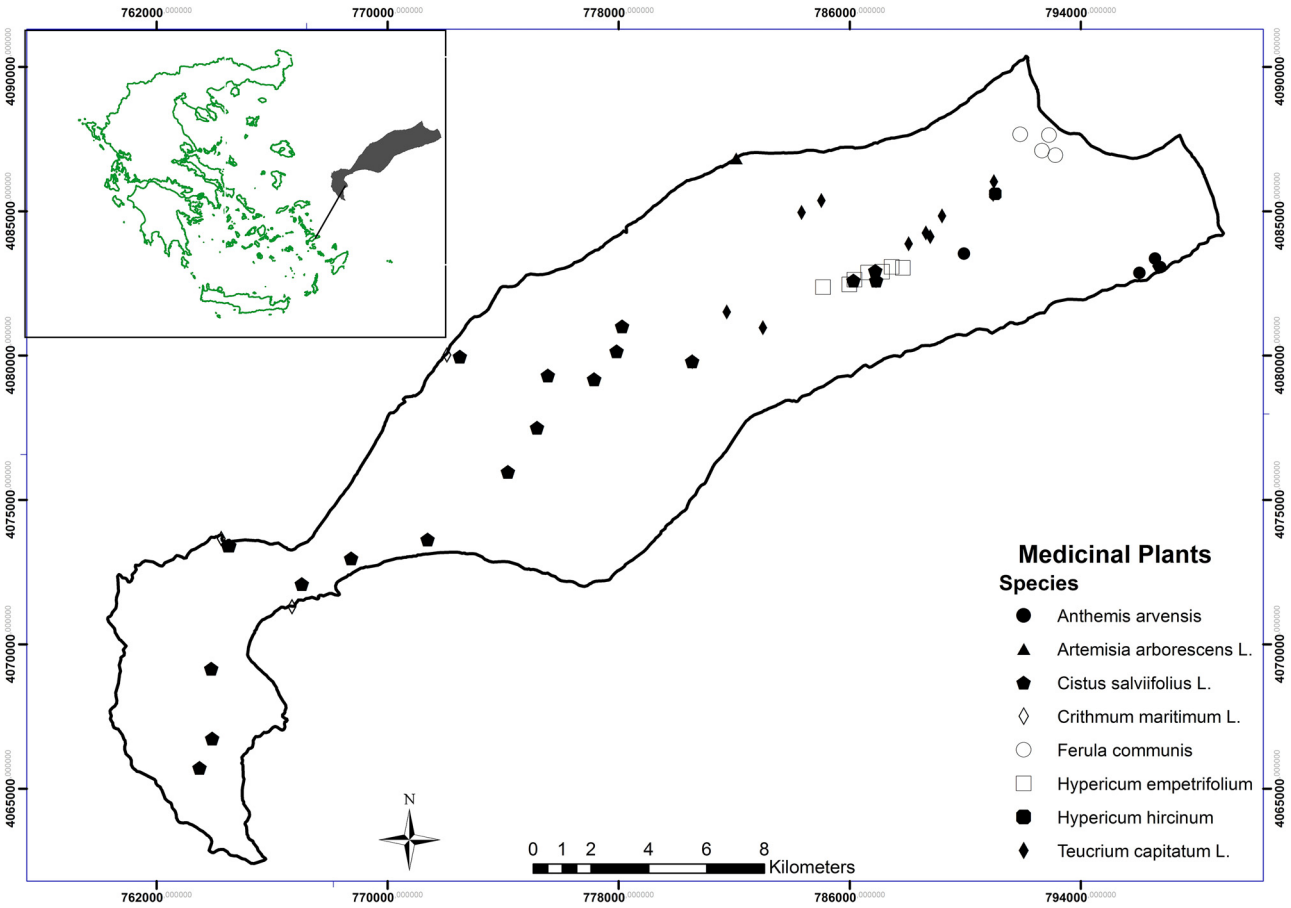

Fig. 1. Study area (Kos Island) and the sampling sites.

the soil environment. In particular, the objectives of the present study were (a) to investigate the occurrence of the aforementioned HMF, (b) to map their spatial distribution on Kos, (c) to analyse the soil environment of HMF collection sites and (d) to identify the quantitative and qualitative characteristics of their essential oils. The lack of a systematic recording of all of these factors for HMF highlights the importance of this study. The criteria for the species selection were the following: (i) they grow on Kos island, (ii) they are mentioned in Hippocrates' collection, and (iii) they feature essential oil.

2. Material and Methods

2.1. Study area

Kos is an island of the Dodecanese in the south-eastern Aegean Sea, west off the Anatolian coast of Turkey at coordinates 36°53′33.31"N, 27°17′16.05"E. It occupies an area of 287.2 km^2 and is rectangular in shape (50 km length SW–NE direction and average width of about 6 km). At the eastern part of the island, there are the Psalidi and Aliki Tigaki wetlands, registered in the Natura 2000 network (Natura 2000, 2017). The island is also occupied by Mount Dikaios (Oromedon; 843 m, 25 km long; Georgiadis, 2001).

The climate of Kos is typically Mediterranean, with a mean annual temperature of 14.8 °C. Summers are hot and dry, with a mean maximum of 30.4 °C in July and little rainfall (Tzannis, 2006). Yearly precipitation totals a mean of approximately 600 mm, with the majority falling between November and March (Kornaros, 1999). The annual mean temperature is 14.8 °C (Frantzis, 2004). The yearly mean minimum temperature is observed in February (8.1 °C) and the mean maximum in July (30.4 °C). The mean annual precipitation is approximately 600 mm, with a maximum in December and a minimum in August. The dry period lasts from April to October (Tzannis, 2006).

The island of Kos belongs to the Sub-Pelagonian geotectonic zone and lies along the ophiolitic suture of the oceanic space within the Axios zone (Mountrakis, 2010).

The main mountain bulk consists of Mount Dikaios, with limestone marble, plutonium volcanic rocks and quaternary volcanic eruption tuffs, whereas mountains of lower height such as Zini (354 m) and Latra (428 m) occupy the western part of the Kefalos area. In addition, there is a salt lake and marine sediments of different ages and of volcanic nature (Mountrakis, 2010). Unlike other islands in the region, the geology of Kos does not comprise granitic and ultramafic rocks. The schist-like rock is often weakly calcareous.

Forests contain *Juniperus oxycedrus*, *Pinus brutia, Pinus halepensis, Quercus marcolepis, Cupressus sempervirens*, and *Platanus orientalis*. *Quercus-Cupressus* forest is found on Mount Dikaios, and *Juniperus oxycedrus* subsp. *macrocarpa* and *Pinus brutia* on the Kephalos peninsula (Tzannis, 2006), sometimes mixed with low bushy brushwood vegetation, mainly consisting of *Thymus* spp., *Cistus salviifolius, Calicotome villosa, Asparagus acutifolius, Ballota acetabulosa, etc.* The lowland area consists of farmlands of torrential alluvial and lacustrine origin, and coastally, there is a salt lake area of about 1000 acres, with extensive dunes 150–200 m in width with short halophyte vegetation. The areas of Antimachia, Kardamena and Mastichari consist of a relatively flat terrain covered by farms. Outside these areas, there is typical brushwood comprising *Cistus* spp., *Thymus* spp. and implicit *Sarcopoterium spinosum* and maquis vegetation and lentisk (Tzannis, 2006).

2.2. Collection of plant material and soil samples

Six extended surveys in March, April, May, June, July and August 2014 were conducted. The plant collection included seven perennial