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Exploitation of Apiaceae Family plants as valuable renewable source of essential oils containing crops for the production of fine chemicals: Part II

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ABSTRACT

Twenty-one indigenous in Greece Apiaceae *taxa* were collected from the wild and their potencies as Essential Oils (EOs) producing crops as well as novel renewable sources for the production of Fine Chemicals (FCs) were evaluated. Their EOs and FCs production capabilities were estimated on the basis of several experimental and field data, identifying the two *Cachrys taxa*, *C. cristata* and *C. ferulacea* as the most potent EO producing crops with estimated production yields per hectare exceeding the 30 L for each oil, of which 19 L is myrcene in *C. cristata* and 8.5 L γ-terpinene in *C. ferulacea*. Furthermore, the following five taxa were identified for first time as potential EOs producing industrial crops: *Bifora testiculata*, *Chaerophyllum aromaticum*, *Echinophora tenuifolia*, *Opopanax chironium* and *Ferulago nodosa*. In total, thirteen EOs retrieved from twelve different *taxa* were determined as potent renewable resources for the production of sixteen environmentally important FCs, such as aldehydes, esters, aromatic compounds, unsaturated hydrocarbons, monoterpenes and sesquiterpenes. Among FCs investigated herein, nine constitute mature commercial subjects. From them, seven being produced synthetically and only 2 are retrieved from natural resources. Additionally, we have identified for the first time 4 plants as renewable sources for the retrieval of the commercially important molecules 2-dodecen-1-al, myrcene, *cis*-ocimene, methyl eugenol, α-phellandrene and terpinolene, compounds with price fluctuation varying 2.12–0.02 €/mL.

1. Introduction

Since the dawn of humanity, agriculture has exploited several renewable resources such as sunlight and rainwater – for the production of life necessities. The gradual evolution-progress of human civilization directed this favorable and sustainable source of numerous products toward the adaptation of more intensive farming systems that require enormous energy inputs, mostly in the form of fossil fuels and agrochemicals (Pimentel, 2013). Despite the outstanding increase in productivity – driven by this input – agriculture has yet to prove its role in modern society's needs. After almost 10,000 years of evolution, crop diversity is decreasing (Khoury et al., 2014) and the bulk of agricultural products is limited to food, fibers, fodders and recently fuels.

The aforementioned production clade combined with the introduction of various genetically modified crops, which increasingly substitutes the agricultural biodiversity, have narrowed the global agricultural production platform. Thus, the fundamental drivers of present study were established upon the growing public concern on several environmental issues affecting people's prosperity and environmental sustainability. These conceptions have identified as extremely hazardous the impacts of several industrial sources of pollution. Among them, the chemical industry accounts as the most prominent source of numerous persistent and extremely toxic pollutants, such as heavy metals (Ohe et al., 2004), dioxins (Dyke and Amendola, 2007) and a series of persistent organic pollutants (Liu et al., 2007). All these pollutants have been proved hazardous for environment (Lev, 1993).

In this context, the substitution of synthetic chemical industry inputs by natural products arises as a socially favorable, economically viable and environmentally sustainable target. Therefore, the exploitation of potential new crops is considered as a fully justified and promising research target, which is expected to reorient

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Table 1
The investigated Apiaceae *taxa* of the study (C.N., Code Number; W_D, Weight distilled; Y_{EO}, Essential Oil Yield; W_m, mean average weight; A_m, mean average land coverage).

Genus	Species	C.N.	W_D (g)	Y_{EO} (ml/kg)	W_m (kg/plant)	A_m (m^2/plant)	Location
Echinofoerae							
Echinophora	*spinosa*	9[d]	290	1.03	0.25	0.4	Is. Zakynthos
	tenuifolia	8[c]	480	8.54	0.25	0.4	Is. Crete
Scandiceae							
Chaerophyllum	*aromaticum*	18[c]	*855*	3.98	*0.26*	0.34	*Mt Oiti*
	heldreichii[a]	20[b]	530	1.32	0.23	0.37	Mt. Parnon
	aromaticum	15[d]	210	2.38	0.21	0.31	Mt. Smolikas
Scandix	australis	14[d]	70	1.43	0.01	0.1	Mt. Smolikas
	pecten-veneris	23[d]	450	2.22	0.015	0.15	Athens
		48[d]	400	0.25	0.015	0.17	Mt. Parnassos
Coriandreae							
Bifora	*testiculata*	30[d]	33	1.52	0.02	0.01	Mt. Parnassos
Smyrnieae							
Cachrys	*cristata*	62[d]	130	3.08	0.87	0.38	Is. Crete
	ferulacea	16[c]	270	4.81	0.54	0.42	Mt. Madara
Conium	*divaricatum*[a]	35[b]	500	0.8	0.37	0.56	Mt. Parnassos
Heptaptera	*colladonioides*[a]	27[d]	435	0.11	0.17	0.21	Mt. Parnon
Scaligeria	*cretica*	37[b]	200	2.5	0.14	0.24	Vouliagmeni
Smyrnium	*rotundifolium*	44[b]	530	1.7	0.16	0.18	Mt. Parnassos
Peucedaneae							
Anethum	*graveolens*	51[c]	260	3.85	0.25	0.36	Mt. Parnassos
Ferula	*communis*	32[d]	610	0.33	4.8	0.6	Mt. Parnassos
Ferulago	*nodosa*	43[b]	400	1.75	0.35	0.27	Mt. Parnassos
Johrenia	*distans*[a]	49[d]	340	0.29	0.27	0.09	Mt. Ymittos
Opopanax	*chironium*	47[d]	930	0.54	2.4	0.4	Mt. Parnassos
Peucedanum	*officinalle*	19[b]	*180*	4.44	*0.09*	0.23	*Mt Oiti*
	vittijugum	11[d]	100	0.5	0.07	0.18	Mt. Parnon
		13[d]	650	0.08	0.08	0.19	Mt. Parnon
	neumayeri	5[b]	600	0.83	0.37	0.24	Mt. Smolikas

Names of plant species have be provided in Italics.
[a] Endemic.
[b] Evergetis et al. (2012).
[c] Evergetis et al. (2013).
[d] Presented here for first time.

the agricultural evolution and diversification toward both maternal crops and final products perspectives. Fine Chemicals (FCs) constitute a favorable target for this diversification, since their manufacture is considered as a priority issue for the European Commission (2006). Thus, there is a vigorous research interest directed toward the development of environmentally safe means for their production. The present study falls within this framework addressing several issues, mostly concerning the production volumes, residual toxicity and solvent use, offering thus an environmentally sound alternative method for the production of these valuable products.

This endeavor constitutes the second, and concluding, part of a campaign concerning the exploitation of nature's wealth as an alternative resource of industrial raw materials. In this context, the Apiaceae Family was defined as the targeted source of investigation in respect to their plants Essential Oils (EOs) and FCs content-production abilities (Evergetis and Haroutounian, 2014). For this purpose a novel methodology was developed exploiting the meta-data of plant collection, which incorporates the average land coverage and plant weight, allowing the preliminary estimation of crop potentials, through a broad range biodiversity screening (Evergetis and Haroutounian, 2014). Herein we present the data concerning the collection, documentation and their EOs and FCs production potentials determination for 24 plant samples belonging to 21 *taxa* (from15 genera). Furthermore we have focused on the exploitation of the commercial significance of the proposed target FCs, through the screen of their market availability, price range and current production origin.

2. Materials and methods

2.1. Plant materials

Herbal material retrieved from 21 different species of the Apiaceae family, Apioideae subfamily belonging to five tribes and 15 different genera, was selected for investigation within the framework of this study. Nine of them are endemic of Greece and were collected from various habitats of the country, including subalpic pastures & screes, coniferous & deciduous forests, coastal & urban areas and agricultural land.

All samples were obtained in the vegetative stage of late flowering-early seed development and consisted of whole plants (aerial parts and roots), measured both in weight and land coverage per plant, as a mean average of the sample distilled. Each sample was documented by a voucher specimen of the related *taxon* and is deposited in the herbarium of the Agricultural University of Athens, Greece. Full record of the investigated *taxa* is provided in Table 1.

The *taxa* identification was performed using as primary taxonomic key the *Flora Europaea* (Tutin et al., 1968) and supplementary – when appropriate – additional regional *Floras* (Sibthorp, 1804; Halacsy, 1900; Rechinger, 1943; Strid, 1981; Turland et al., 1993; Georghiou and Delipetrou, 2010). The nomenclature used was in accordance with the proposed by Pimenov and Leonov (1993).

2.2. Essential Oils isolation and analyses

Plant material was distilled fresh in a Clevenger-type apparatus using as heat source a Microwave Accelerated Reaction System