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Editorial

Medicinal and Aromatic Plants (MAPs): The Connection between Cultivation Practices and Biological Properties

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Cultivation management is essential to balance fundamental parameters for medicinal and aromatic plants (MAPs) such as biomass and the production of high-quality essential oils and extracts, with remarkable properties. Nowadays, there is a growing interest in industry, academia, agriculture, and health sciences in MAPs, due to the significant biological properties of these plants, which are related to the presence of a series of compounds (phenols, flavonols/flavonoids, alkaloids, polypeptides, vitamins, catechins, phytoestrogens, carotenoids, chlorophyll, minerals, etc.).

With the world's population increasing rapidly, the production of food will have to double, biodiversity will be eliminated, and water quantity and quality will be reduced. Moreover, there will be no new croplands to cultivate, and the ones already in use will be deteriorated through overfertilization and/or bad fertilization. Medicinal and aromatic plants and their essential oils and other extracts are more than just a modern fad. Apart from being a source of food, many MAP species are used as non-food industrial products, pharmaceuticals, herbal health products, cosmetics, plant protection products, etc. For their industrialization, cultivations should be standardized in a way that produces materials with constant and repeatable attributes and components. This could be accomplished by defining the proper nutrient needs for each species, along with proper cultivation practices. Research activities are needed to determine the needs of each crop, industrial or edible, in order to secure plant uniformity in relation to the cultivation practices applied.

This Special Issue collects current research related to the cultivation practices of medicinal and aromatic plants (extensive and intensive cultivations, organic vs. conventional cultures, introduction of species to cultivation systems, hydroponics, abiotic and biotic stress, etc.) and how these can affect biomass production (fresh or dried), nutritional value, and the biological properties (antioxidant, antibacterial, insecticidal, cytotoxic, repellent, attractant, etc.) of the extracts or/and essential oils.

Although the introduction of unexploited species of MAPs in cultivation schemes is receiving attention, the actual growing practices and the needs for optimum yield and quality of the newly introduced species usually remain unknown. Maggini et al. [1] introduced the spontaneous medicinal herb *Reichardia picroides* (L.) Roth in a floating hydroponic system to evaluate the effects of salinity on plant's yield and quality. Results of this study revealed that low salinity levels of 50 mM NaCl enhanced the concentration of the bioactive compounds without affecting the crop's yield. Higher salinity levels reduced yield but improved the edible parts of the plant in terms of bioactive molecules while lowering the amount of nitrate ions. Plants' responses to salinity involve complex mechanisms, while the level of the effect is species-specific. The response of each species can be evaluated using precise cultivation systems such as hydroponics. Salinity, in terms of NaCl concentration, is a growing problem in agriculture, degrading soil quality, while the increased electrical conductivity (EC) (increased concentrations of minerals) may have the same negative effects on plant growth and quality. However, medicinal and aromatic plants may not only withstand these adverse conditions, but they may show increased productivity or even enhanced quality in such conditions. As fresh water sources suitable for irrigation are becoming limited, the use of low-quality water sources and hydroponic growing systems have been suggested as the main alternatives. Towards that goal, two medicinal plants species (*Pelargonium graveolens* and *Verbena officinalis*) were employed by Chrysargyris et al. to examine the responses when cultivated under high salinity and high conductivity [2]. Verbena plants appeared with increased antioxidant capacity and high mineral accumulation under saline conditions, better tolerating the saline levels compared to geranium. Additionally, this study revealed the potential and the promising results of using low-quality irrigation water for the hydroponic cultivation of the tested species, as the increased concentration of nutrients in the nutrient solutions did not significantly affect the growth and yield of the species.

However, intensive crop production and irrational use of fertilizers and agrochemicals have questionable effects on the quality of crops, while the sustainable use of water for agricultural purposes needs to be on the front line. In another study by Chrysargyris et al. [3], one of the most predominant medicinal plants species, spearmint, was produced under different cultivation practices (organic vs. conventional) while different irrigation schemes were applied to the plants. The applications had a strong effect on plant growth and physiology and on the biosynthesis and bioactivity of the secondary metabolites. Significant effects were evidenced only in the second harvest, where bioactive compounds (phenols and flavonoids) and the antioxidant capacity were increased in the organically grown plants. As spearmint's EO is well referenced for its insecticidal and insect-repellent activity, in the same study, the produced EOs from the treated plants were tested against the European grapevine moth, *Lobesia botrana* Schiff. The antennal responses of the female adults to the essential oils were evaluated by electroantennography (EAG), exhibiting strong activity, regardless the origin of the EOs. This finding ensures that despite the differences in composition between different cultivation and irrigation regimes, organically grown *M. spicata* plants combined with a deficit irrigation plan can be an equal option to the conventional ones, as part of a strategy to protect vineyards in a more sustainable and environmentally friendly manner. Another MAP species was used as a potential source of natural of bio-pesticides in the study of Dasenaki et al. [4]. A series of extracts and fractions from different parts of Lentisk (*Pistacia lentiscus* L.) were evaluated for their larvacidal effect against *L. botrana* using a series of bioassays. Even though the leaves and bark extracts had no effect against the insects' larvae, fruit extracts had strong bioactivity, providing larval mortality that exceeded 90%. Results revealed that the extracts produced from lentisk's fruit and their fractions, rich in fatty acids such as oleic acid and linoleic acid, exhibited strong insecticidal activity, revealing the promising potential of *P. lentiscus* fruits, a species widely distributed across the Mediterranean basin, as a source of natural insecticides in order to protect vineyards in the area.

Medicinal and aromatic plants are well appreciated for their antioxidant and biocidal activities. Nevertheless, there is a great variation in these activities that is related to the species, the environmental/climatic conditions (temperature, UV radiation, and light density), the age of the plant, the cultivation practices applied, and the harvesting period. Chrysargyris et al. [5] collected three MAP species, sage (*Salvia officinalis* L.), sideritis (*Sideritis perfoliata* L. subsp. *perfoliata*), and spearmint (*Mentha spicata* L.), grown in areas of different altitudes (mountain area and plain area). These samplings were conducted throughout a calendar year (autumn, winter, spring, and summer) in order to examine the effects of season, aiming to uncover possible correlations between the antioxidant activity, mineral content, and essential oil (EO) yield and composition. It is of great importance to mention here that plants were of the same age, originated from the same maternal plantation, and were under the same cultivation regime (same producer). The results revealed that plants collected in summer had higher EO yield and tended to accumulate iron (Fe), while phosphorus (P) and sodium (Na) appeared in higher values during winter. Plants grown in the plain area had increased mineral content (nitrogen, potassium, sodium, and calcium) compared to the ones collected from the mountain areas. Parameters such as altitude and season had a strong impact on the content of the main compounds of the EOs in all tested species. Antioxidant activity and total phenolic content greatly varied, and the correlation indices proved that they are species-, season-, and altitude-dependent. These findings can be valuable to introduce the cultivation of sage, sideritis and spearmint in specific ecosystems, determining the season and areas for harvesting the plants, in order to produce high-value products.

The introduction of MAP species into cultivation schemes is considered a great practice for producing high-quality raw plant material, with stable and reproducible properties, in quantities that will satisfy industry and consumers, avoiding at the same time the potential extinction or elimination of the native populations. Tomou et al. [6] have employed rapid and precise analytical methods in order to evaluate the quality of cultivated MAP species and to identify their chemical footprint. Using NMR (nuclear magnetic resonance) the authors provided the first report on a comparative study of the phytochemical profiles of two conventionally cultivated *Sideritis* species, *S. cypria* Post and *S. perfoliata* L. subsp. *perfoliata*, both known as "mountain tea" and used widely in traditional medicine. The report showed that both species were rich in bioactive specialized products, and their profile, in general, was similar to the profile of other cultivated species of the genus. Nevertheless, three iridoids (ajugol, monomelittoside, and melittoside) and one flavone were present only in the infusion of *S. perfoliata* subsp. *perfoliata*, while phenylethanoid glycoside and acteoside were detected in both species.

The biosynthesis and accumulation of secondary metabolites in MAPs are influenced by a series of factors such as the genotype, the environment, and the pre- and postharvest handling and practices, to name a few. Grdiša et al. [7] studied the pattern of the accumulation of six pyrethrin compounds on natural pyrethrum populations (*Tanacetum cinerariifolium* (Trevir.) Sch. Bip) at eight developmental stages of the flower heads of the plant. Pyrethrin is a metabolite of great importance, as it serves as a highly effective natural insecticide. For all the studied populations, the plants' pyrethrins tended to increase, with the highest increase rate noticed at the transition from the first to the second developmental stage, and reached the highest content during the fourth stage (reaching up to 1.14%), when 2–5 rows of disc flowers were open, suggesting that this is the optimal stage for harvesting the highest bioactive compound content.

Among the cultivation practices, fertilization plays a vital role in plant development, and among macronutrients, nitrogen fertilization is of the most important for growth, physiology, and regulation of metabolites. An outstanding medicinal plant of the Chinese ethnomedicine, commonly used against inflammatory diseases, is *Bupleurum scorzonerifolium* Willd. (Apiaceae). Rich in saikosaponins, the quality and the yield of the species depend highly on nitrogen fertilization. Sun et al. [8] cultivated *Bupleurum* plants under three different nitrogen levels (without, low and high nitrogen) and examined the quality and metabolomic response of the plant's different parts (flowers, main shoots, lateral shoots, and roots) to the applied nitrogen levels. The results showed that high nitrogen level increases *Bupleurum* yield and quality only in aerial parts, especially flowers, but there was no significant effect on roots. Additionally, 84 metabolites were identified (mostly organic acids, amino acids, carbohydrates, and lipids); these metabolites are involved in carbon and nitrogen metabolisms, and this study provided a primary metabolic network diagram associated with *Bupleurum* and nitrogen fertilization. These metabolites were mostly up-regulated at high nitrogen levels in flowers, but the opposite was revealed for the roots, while four metabolites (D-fructose, lactose, ether, and glycerol) were recognized as key compounds of the plant under nitrogen fertilization.

Among the different factors that affect crop production is the uniformity of crop establishment, which depends on seed germination and seedling emergence and is driven by seed metabolic enzymes. To investigate this topic, Perveen et al. [9] employed safflower (*Carthamus tinctorius* L.) to assess the most effective laser dose for better seed germination and seedling vigor, in relation with the changes in germination enzyme activities, seed thermodynamics and seed metabolite levels. The seeds of safflower are a source of edible oil, rich in linoleic acid, which is used to reduce the risk of heart attack. The application of different doses of low-power He-Ne laser (632.8 nm) increased a series of metabolites and enzymes, such as amylase, protease, and glucosidase, and improved seed features. An increase was also noticed in free fatty and amino acids, in pigments such as chlorophyll and carotenoids, and in total soluble sugars of the radiated seeds. This study revealed that the improvements in the seed thermodynamic attributes boosted the physiological and biochemical metabolism and accelerated seed germination, with an improvement in seed energy levels.

Another cultivation practice that has a strong impact on plants' yield and metabolic profile is grafting. Plant grafting is a vegetative propagation technique that connects two severed plant segments together, one to provide the rootstock and the other to provide the harvested upper part, the scion. Purdy et al. [10] developed a one-step tailor-made grafting methodology for medicinal Cannabis (*Cannabis sativa*) that uses a freshly cut scion grafted to a freshly cut donor stem, which will become the rootstock. The advantages of this new method are that it requires minimal manual handling, in a way that reduces labor costs, and provides higher yields. During the study, the varieties with the desirable attributes were selected and were combined in a way to produce higher biomass and higher yields in Δ9-tetrahydrocannabinolic acid (THCA) content, which ended up increasing by up to 62.5% per plant.

This Special Issue collected a series of new approaches on how the cultivation practices and appropriate applications on medicinal and aromatic plants offer the opportunity to optimize yield and to achieve a uniform and high-quality final product. Careful management is essential to balance high growth in biomass with the production of increased bioactive properties—two fundamental parameters for profitable production and environmental and human safety. Medicinal, aromatic, and ornamental plants have become significant elements in people's lives, due to their aesthetic, industrial, and pharmaceutical use and their role in urban greening. Future research is needed to focus on the identification of the needs of each species, at every step, including their growth, developmental, and metabolic stages. Scientists from various disciplines (agronomists, chemists, pharmacists, biologists) need to combine forces and work towards that goal in order to provide MAPs of higher and stable quality and quantity.

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References

1. Maggini, R.; Benvenuti, S.; Leoni, F.; Incrocci, L.; Pardossi, A. Effects of NaCl on hydroponic cultivation of *Reichardia picroides* (L.) Roth. *Agronomy* **2021**, *11*, 2352. [CrossRef]
2. Chrysargyris, A.; Petropoulos, S.; Prvulovic, D.; Tzortzakis, N. Performance of hydroponically cultivated geranium and common verbena under salinity and high electrical conductivity levels. *Agronomy* **2021**, *11*, 1237. [CrossRef]
3. Chrysargyris, A.; Koutsoumpeli, E.; Xylia, P.; Fytrou, A.; Konstantopoulou, M.; Tzortzakis, N. Organic cultivation and deficit irrigation practices to improve chemical and biological activity of *Mentha spicata* plants. *Agronomy* **2021**, *11*, 599. [CrossRef]
4. Dasenaki, I.; Betsi, P.; Raptopoulos, D.; Konstantopoulou, M. Insecticidal effect of *Pistacia lentiscus* (Anacardiaceae) metabolites against *Lobesia botrana* (Lepidoptera: Tortricidae). *Agronomy* **2022**, *12*, 755. [CrossRef]
5. Chrysargyris, A.; Evangelides, E.; Tzortzakis, N. Seasonal variation of antioxidant capacity, phenols, minerals and essential oil components of sage, spearmint and sideritis plants grown at different altitudes. *Agronomy* **2021**, *11*, 1766. [CrossRef]
6. Tomou, E.; Lytra, K.; Chrysargyris, A.; Tzortzakis, N.; Skaltsa, H. NMR fingerprint comparison of cultivated *Sideritis* spp. from Cyprus. *Agronomy* **2021**, *11*, 1503. [CrossRef]

7. Grdiša, M.; Jeran, N.; Varga, F.; Klepo, T.; Ninčević, T.; Šatović, Z. Accumulation patterns of six pyrethrin compounds across the flower developmental stages-comparative analysis in six natural Dalmatian Pyrethrum populations. *Agronomy* **2022**, *12*, 252. [CrossRef]
8. Sun, J.; Li, W.; Zhang, Y.; Guo, Y.; Duan, Z.; Tang, Z.; Abozeid, A. Metabolomics analysis reveals potential mechanisms in *Bupleurum* L. (Apiaceae) induced by three levels of nitrogen fertilization. *Agronomy* **2021**, *11*, 2291. [CrossRef]
9. Perveen, R.; Wang, X.; Jamil, Y.; Ali, Q.; Ali, S.; Zakaria, M.; Afzaal, M.; Kasana, R.; Saleem, M.; Fiaz, S. Quantitative determination of the effects of He–Ne laser irradiation on seed thermodynamics, germination attributes and metabolites of Safflower (*Carthamus tinctorius* L.) in relation with the activities of germination enzymes. *Agronomy* **2021**, *11*, 1411. [CrossRef]
10. Purdy, S.; Hewavitharana, A.; Azman Halimi, R.; Magner, N.; Peterswald, T.; Trebilco, A.; Kretzschmar, T.; Hailstones, D. A One-Step grafting methodology can adjust stem morphology and increase THCA yield in medicinal cannabis. *Agronomy* **2022**, *12*, 852. [CrossRef]