horticulturae

MDPI

Editorial

Production and Quality of Medicinal and Aromatic Plants: Recent Findings on Stress Effects, Elicitors, Harvesting and Market Development

Saeid Hazrati [1,*], Andrea Ertani [2] and Silvana Nicola [2,*]

[1] Department of Agronomy and Plant Breeding, Faculty of Agriculture, Azarbaijan Shahid Madani University, Tabriz 53714-161, Iran
[2] Department of Agricultural, Forest and Food Sciences, VEGMAP, University of Turin, 10095 Turin, Italy
* Correspondence: saeid.hazrati@azaruniv.ac.ir (S.H.); silvana.nicola@unito.it (S.N.)

There is an expanding interest worldwide in medicinal and aromatic plants (MAPs) due to their use as raw materials in the production of medicinal, aromatic and cosmetic products. Consumers are becoming more health-conscious, paying attention to sustainably produced natural ingredients of known origin driving the rising demand for plant-based extracts from the pharmaceutical, food and beverage, cosmetic and agrochemical industries. At present, about one-third of the drugs used in human societies comprise medicines of a natural or herbal origin [1]. Despite the vast growing interest on plant-based extracts, the sector still needs high technological improvements. Many MAPs are cultivated on very small surfaces, although encompassing hundreds of species. Advanced and modern growing techniques are not well established yet in this sector, while the wild harvest of MAPs is still the common practice. Consequently, growers are facing relevant technical challenges to produce plants and active compounds as efficiently as possible to meet market needs.

Many plant species, including medicinal and aromatic plants, provide a wide range of health-promoting phytochemicals (e.g., secondary metabolites) that play a role in key physiological processes, including defense, adaptation and interactions with their environments. The phytochemical content of plants varies mainly with genetics and phenology; however, pre-harvest effects, such as irrigation, fertilization, light, salinity and biostimulant application, and post-harvest effects can affect and modulate the phytochemicals. The goal of this Special Issue, entitled "Production and Quality of Medicinal and Aromatic Plants", is to examine recent advances in Medicinal and Aromatic Plant practices and strategies that can contribute to maintaining or increasing quality and quantity of the product. This Special Issue compiles seven articles that are concerned with the effects of abiotic stresses, elicitors, harvesting and market developments on the modulation of Medicinal and Aromatic Plants. It includes six research articles and one review. Most of the contributions address pre-harvest and post-harvest conditions and investigate whether cultivation practices can modulate the yield and nutritional value of medicinal crops under abiotic stresses.

Medicinal plants are strongly affected by a high concentration of soluble salt, which affects almost all functions of the plant, as well as growth, yield and phytochemical compounds. Salinity stress may stimulate or inhibit the emission of volatile compounds (VCs) in plant materials, suggesting that these substances can be responsible for stress defense strategies. For this purpose, the effect of salinity stress was examined on the laurel (*Laurus nobilis* L.), a strict endemic species of the natural vegetation of the Mediterranean region, known for its medicinal, aromatic, forest, ornamental and culinary properties. This species produces a valuable essential oil (EO). Ben Ayed et al. [2] reported that the concentrations of NaCl (0, 50, 100 and 150 mM) in irrigation water affected the VCs in the leaves of *L. nobilis* as salinity increased. NaCl concentrations of 50 and 100 mM stimulated an increased

Citation: Hazrati, S.; Ertani, A.; Nicola, S. Production and Quality of Medicinal and Aromatic Plants: Recent Findings on Stress Effects, Elicitors, Harvesting and Market Development. *Horticulturae* **2022**, *8*, 1109. https://doi.org/10.3390/horticulturae8121109

Received: 14 November 2022
Accepted: 22 November 2022
Published: 25 November 2022

amount of sesquiterpene hydrocarbon families. Contrarily, NaCl decreased the oxygenated monoterpenes and monoterpene hydrocarbons as well as aliphatic aldehydes. Similarly, the VCs of the laurel leaf varied with the concentration of NaCl used. This was more noticeable for the major component (1,8-cineole), which decreases when sodium chloride concentration increases, particularly at 100 mM. *L. nobilis* occurs wild in a variety of environments, is highly curative and possesses an array of cosmetic and medicinal properties; thus, future studies should investigate which plants might be useful as marginal grasses in arid and semi-arid regions that are characterized by high salinity or low-quality water.

Elicitors are biofactors, chemicals, hormones or other substances that trigger physiological, morphological and phytochemical responses in target organisms. Utilizing elicitors improves the assimilation of secondary metabolites and phytopharmaceuticals. There are several precursors of biotic elicitors (e.g., endophytes microbes and plant cell wall components) and abiotic elicitors (e.g., metal ions and inorganic compounds) that are normally applied. These compounds are able to enhance the assimilation of secondary metabolites via the stimulation of defensive responses, biochemical modification and accretion of phytoalexin [3]. The periwinkle (*Catharanthus roseus* L. (G.) Don) plant represents a major source of vital terpenoid indole alkaloids and natural antioxidants, which are widely used in cancer chemotherapy. In this context, Farouk et al. [4] evaluated the role of two periwinkle endophytes (Streptomyces sp. and Bacillus sp.) with or without abiotic elicitors (aluminum chloride, tryptophan and chitosan) on plant biomass, physio-biochemical attributes, phytopharmaceutical constituents and alkaloid production. Plant growth, nitrogen, phosphorus, potassium, carotenoids, ascorbic acid and alkaloid yields significantly increased after inoculation with endophytes as elicitors. Furthermore, the inoculation reduced hydrogen peroxide concentration and malondialdehyde enzyme activity without affecting flavonoids or anthocyanins significantly. In this regard, Streptomyces sp. was more effective than Bacillus sp. Using chitosan as a foliar spray significantly increased plant growth, chlorophyll, ions, antioxidant capacity, phytopharmaceutical constituents (total soluble phenols, flavonoids and anthocyanin) and alkaloid yield, accompanied by oxidative biomarker declines. Additionally, aluminum chloride application generally increased oxidative biomarkers, which resulted in decreased chlorophyll concentrations, plant growth and ion concentrations. Plant growth, chlorophyll, ions, antioxidants and alkaloid levels increased by using tryptophan or chitosan with endophyte microbes, while oxidative biomarkers decreased. Conversely, aluminum chloride induced oxidative damages in plants along with a reduction in symptoms such as chlorophyll, ions and phytopharmaceutical constituents. The results showed that using *Streptomyces* sp. as a bio-inoculant and chitosan as a foliar spray could increase periwinkle plant biomass, phytopharmaceutical accumulation and alkaloid production. Increased biomass coupled with alkaloid production could lead to a reduction in the cost of making bis-indole alkaloid through such interactions.

Jasmonic acid (MeJA), salicylic acid (SA), chitosan and UV-A and UV-B radiation can stimulate the production of secondary metabolites. Kim et al. [5] examined the effect of different concentrations of MeJA, SA and chitosan supply on phenolic compounds in *Pimpinella brachycarpa* Nakai at different harvested timings. The chitosan, SA and MeJA enhanced the production of phenolic compounds, while the untreated plants showed the lowest phenolic content. Additionally, the supply of 0.3% chitosan, 0.1 mM SA and 0.1 mM MeJA resulted in an average 1.4-fold increase in the phenolic content compared to the lowest total phenolic content detected in the untreated plants. The highest content of most of the single phenolic compounds followed a similar trend according to the treatment type, with the chitosan treatment showing the highest content, followed by SA and then MeJA treatments. Thus, the study demonstrated that the treatment with optimal concentrations of these elicitors for an optimal period of time increases the production of phenolic compounds in *P. brachycarpa* Nakai. Based on these findings, one of the most promising possibilities is to develop strategies to improve the amount of phenolics produced by *P. brachycarpa* Nakai, which will benefit its use as an edible herb and in folk medicine.

One of the most important stages in the production and processing of medicinal and aromatic plants is the harvesting and post-harvesting phases, which has a strong impact on the quantity and quality of the final product. Essential oil is highly dependent upon environmental conditions, such as day/night temperature, relative humidity, light and light quality (quantity and quality). Hazrati et al. [6] studied the diurnal variation of the EO content and the composition of *Salvia officinalis* L. The results showed that harvesting time may contribute significantly to the EO yields and compositions of sage. The results clearly indicate that EO in sage is subjected to significant hourly changes (differing times during the day and night) in both the quantitative and qualitative properties. EO yield was the highest with harvesting between 4:00 and 6:00 p.m., whereas with harvesting between 4:00 and 6:00 a.m., the minimum yield percentage was observed. These results indicate an interesting pattern of accumulation and then degradation (or conversion) of certain metabolites throughout the day. *Cis*-thujone was detected at the highest amount when the plants were collected at 04:00–06:00 a.m. In addition, *trans*-thujone was another dominant compound: and the highest amount of this compound was obtained between 10:00 and 00:00 p.m. and lowest value was obtained between 10:00 and 12:00 a.m. The results can be associated with several factors that influence secondary metabolite biosynthesis, including light intensity, temperature and humidity. Three harvest timings, including 04:00–06:00 a.m., 2:00–4:00 p.m. and 4:00–6:00 p.m., were suggested by the authors as appropriate, considering the EO yield, quantity and quality of sage.

Fresh garlic (*Allium sativum* L.) bulbs are well-known for their pungent aroma and distinctive taste, which is not preferred by many people. Processing garlic, instead, can minimize the intense taste of this vegetable, increasing its marketability as well as preserving its medicinal properties. Black garlic has recently gained increasing attention in the pharmaceutical market as an expensive exotic medicinal food. For this reason, the study by Sunanta et al. [7] showed that the initial moisture content of fresh garlic plays a crucial role on the physicochemical attributes of the finished product. Black garlic products with a high moisture content are lighter in color and texture and have a low acidity. In contrast, the darker product can be achieved by dehydrating more materials (moisture content < 50%) in order to obtain a sweet-mellow taste, elastic texture and higher acidity. Additionally, the authors found a difference in the quantity of water-soluble compounds due to the low initial moisture content in the finished product, enhancing its antioxidant potentials. The results from this study can be used to establish the criteria for raw material quality control and to minimize the losses from waste production.

Fresh produce consumption and the use of fresh herbs as flavoring agents in various culinary preparations have increased in recent years due to consumer demands for healthier lifestyles. Over the past few years, consumers around the world have also started visiting farmers' markets and shopping at local grocery stores. Fresh produce, particularly leafy greens and herbs, can be contaminated by human pathogens in a variety of ways. Producing, harvesting, processing and distributing foods can result in contamination. The consumption of raw produce or using it as a garnish in prepared foods can pose food safety and health hazards. By properly handling, washing, preparing and storing fresh produce, consumers can enhance their food dishes as well as prevent or reduce the risk of foodborne illness. Su et al. [8] evaluated the microbiological quality, including the aerobic plate count (APC), generic *Escherichia coli* and total coliforms (TC), and human pathogens (*Salmonella* spp). Overall, the APC of the produce samples from national chains was lower than that from farmers' markets and locally owned grocery stores. Cilantro (*Coriandrum sativum* L.) had a significantly highest APC among the tested produce types. Among the four types (cilantro, green onion, Jalapeño peppers and serrano peppers) of produce analyzed, those present in distribution chains had significantly lower APC populations than those present in farmer's markets and local markets, and cilantro had higher APC populations than the other three types of produce. Moreover, risk factor analysis revealed that TC populations in green onions were significantly higher than those in serrano peppers, and no human pathogens were detected in any of the tested fresh produce (*Salmonella* spp., *E. coli* O157:H7, or *Shigella sonnei*/*Shigella* spp.). Fresh produce that is frequently consumed raw or used to garnish dishes requires consumer vigilance and practice due to high APC and TC prevalence rates.

In the review, Jastrombek et al. [9] described the cultivation, quality aspects, sustainable production and uses of hops (*Humulus lupulus* L.) in subtropical areas of Brazil. This review addresses the history of hop cultivation in Brazil and characterizes the main climatic elements of three emerging subtropical growing regions located at different latitudes, such as air temperature, photoperiod, solar radiation and water availability, to provide support for the development of new technologies for hop cultivation, including supplemental lighting, irrigation and mulching.

This Special Issue provides excellent scientific contributions to the field of the production and quality of medicinal and aromatic plants. This issue includes papers from more than one author and explores a variety of areas associated with medicinal and aromatic plants, providing information by each published paper with considerable significance for researchers, technicians and students interested in both fields.

Author Contributions: Conceptualization S.H. and S.N.; Writing S.H. and S.N.; Reviewing and editing S.N. and A.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We are grateful to the editor assistants and staff of *Horticulturae* for their support during the course of this Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Elkordy, A.A.; Haj-Ahmad, R.R.; Awaad, A.S.; Zaki, R.M. An Overview on Natural Product Drug Formulations from Conventional Medicines to Nanomedicines: Past, Present and Future. *J. Drug Deliv. Sci. Technol.* **2021**, *63*, 102459. [CrossRef]
2. Ben Ayed, A.; Zanin, G.; Aissa, E.; Haouala, F. Volatile Oil Components of Laurel (*Laurus nobilis* L.) Leaves Obtained from Plants Cultivated under Salinity Stress Conditions. *Horticulturae* **2022**, *8*, 442. [CrossRef]
3. Thakur, M.; Bhattacharya, S.; Khosla, P.K.; Puri, S. Improving Production of Plant Secondary Metabolites through Biotic and Abiotic Elicitation. *J. Appl. Res. Med. Aromat. Plants* **2019**, *12*, 1–12. [CrossRef]
4. Farouk, S.; AL-Huqail, A.A.; El-Gamal, S.M.A. Improvement of Phytopharmaceutical and Alkaloid Production in Periwinkle Plants by Endophyte and Abiotic Elicitors. *Horticulturae* **2022**, *8*, 237. [CrossRef]
5. Kim, N.S.; Jung, D.H.; Jung, C.R.; Jeon, K.S.; Park, H.W.; Park, S.U. Improvement of Phenylpropanoid Production with Elicitor Treatments in *Pimpinella brachycarpa* Nakai. *Horticulturae* **2020**, *6*, 108. [CrossRef]
6. Hazrati, S.; Beidaghi, P.; Beyraghdar Kashkooli, A.; Hosseini, S.J.; Nicola, S. Effect of Harvesting Time Variations on Essential Oil Yield and Composition of Sage (*Salvia officinalis*). *Horticulturae* **2022**, *8*, 149. [CrossRef]
7. Sunanta, P.; Pankasemsuk, T.; Jantanasakulwong, K.; Chaiyaso, T.; Leksawasdi, N.; Phimolsiripol, Y.; Rachtanapun, P.; Seesuriyachan, P.; Sommano, S.R. Does Curing Moisture Content Affect Black Garlic Physiochemical Quality? *Horticulturae* **2021**, *7*, 535. [CrossRef]
8. Su, Y.; Hsu, W.-Y.; Huang, T.-S.; Simonne, A. Evaluation of the Microbiological Quality of Fresh Cilantro, Green Onions, and Hot Peppers from Different Types of Markets in Three U.S. States. *Horticulturae* **2021**, *7*, 122. [CrossRef]
9. Jastrombek, J.M.; Faguerazzi, M.M.; de Cássio Pierezan, H.; Rufato, L.; Sato, A.J.; da Silva Ricce, W.; Marques, V.V.; Leles, N.R.; Roberto, S.R. Hop: An Emerging Crop in Subtropical Areas in Brazil. *Horticulturae* **2022**, *8*, 393. [CrossRef]