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Editorial

Essential Oils as Biopesticide Ingredients

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The *Agriculture* Special Issue "Biopesticides: The Naturally Originating Plant Protection Products and Biocides", edited in 2022 by the Special Guest Editor Dra. Nikoletta Ntalii, with a paper published by Badalamenti et al. (2021) [1], has resulted in a highly cited article (with 28 citations). This paper explored the insecticidal potential of the essential oil (EO) from the flowers of *Ridolfia segetum* (L.) Moris, a Mediterranean species and traditional Sicilian food in the Apiaceae, commonly found in cereal fields and uncultivated grounds. Species from the family Apiaceae are aromatic herbs that produce essential oils used in the pharmaceutical, cosmetic, and food industries.

Recently, the interest in essential oils produced by Medicinal and Aromatic Plants (MAPs) has focused on their biocontrol potential against plant pests and diseases. This expansion of the potential uses of EOs has intensified academic and industrial research on these plant extracts. Furthermore, in the context of the EU framework aimed to achieve sustainable use of plant protection products by promoting integrated pest management (*Sustainable use of plant protection products—Publications Office of the EU*, 2020), there are numerous examples demonstrating the biopesticidal potential of EOs as antifungal, insecticidal or nematicidal agents [2–5].

In this context, the insecticidal action of EOs has been an area of intensive research [6]. Bibliometric analysis showed that more papers have been published in recent years on this group of natural insecticidal than on any other chemical class of botanical natural products [7] and the trend continues.

The effects of EOS on insects and related arthropods can be attributed to their content in mono- and sesquiterpenoids [6]. EOs and low-molecular-weight terpenoids can inhibit acetylcholinesterase (AChE) [8]. Targets in the insect nervous system include octopamine receptors [9], GABA-gated chloride channels [10], and the nicotinic receptor [11].

The bioactivity of EOs can be the result of the synergy among constituents derived from increased penetration of toxicants through the insect's integument [12]. Furthermore, mixtures in the EO composition can reduce the development of resistance [13,14] and behavioral habituation to deterrents [15]. The toxic effects of EOs can upregulate physiologically important proteins and enzymes in insects [16] and synergize insecticide toxicity by inhibiting detoxification enzymes such as the P450 [17].

The EO from *Ridolfia segetum* flowers showed important toxicity against *Culex quinquefasciatus* 3rd instar larvae, *Musca domestica* (with different toxicity on male and female flies) and *Spodoptera littoralis* 3rd instar larvae. The analysis of the EO by GC and GC-MS showed a significant presence of monoterpene hydrocarbons (90.1%) and the EO was in the chemotype dominated by α-phellandrene, terpinolene, and *p*-cymene.

This study demonstrates that a traditional food plant provides an effective EO, which can be used for the development and subsequent production of botanical insecticides against insect species of important economic impact. However, developing novel insecticides from the *R. segetum* EO needs further research.

The direct use of EOs as biopesticides has associated problems such as phytotoxicity, the quantities needed and the loss of efficiency mainly due to their volatile nature and susceptibility to degradation [18]. Therefore, further research is needed to improve the practical applications of EOs in biocontrol including upscaled production and bioassays [19].

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The chemical composition of EOs varies with location and environmental conditions [20] and the phenological state of the plant determines EO yield. EOs from MAPs are usually extracted from plants collected during the flowering period before the seeds germinate, causing a reduction in the multiplication of these plants. Therefore, the domestication of MAPs plays an important role in species conservation and EO production. Some MAP species have been domesticated and cultivated to meet the increasing demand for standardized raw material [21,22] or for the conservation of useful Crop Wild Relatives (CWRs) [23].

Examples of successful MAPs domestication include species of *Origanum*, *Mentha* and *Lippia*, *Hyptis suaveolens*, *Tagetes lucida*, *Artemisia absinthium*, L. sp., and *Satureja montana* (see [5]). Guidelines for good agricultural practices and standards for the Sustainable Wild Collection have been established [24], including grazing plans for the CWRs habitats [25].

Ridolfia segetum is a MAP that can be cultivated in arid or semi-arid lands as a potentially alternative crop. This species provides relatively high yields of EO (about 1%), and the fact that it is both a food and medicinal plant indicates that the potential use of botanical insecticides based on the EO from *R. segetum* is safe.

The successful publication of this article highlights the current importance of the topic (EOs as ingredients of safe bioinsecticides) and can encourage young researchers to pursue this important line of work.

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References

1. Badalamenti, N.; Ilardi, V.; Bruno, M.; Pavela, R.; Boukouvala, M.C.; Kavallieratos, N.G.; Maggi, F.; Canale, A.; Benelli, G. Chemical Composition and Broad-Spectrum Insecticidal Activity of the Flower Essential Oil from an Ancient Sicilian Food Plant, Ridolfia segetum. *Agriculture* **2021**, *11*, 304. [CrossRef]
2. Arraiza, M.P.; González-Coloma, A.; Andrés, M.F.; Berrocal-Lobo, M.; Domínguez-Núñez, J.A.; Da Costa, A.C.; Navarro-Rocha, J.; Calderon-Guerrero, C. Antifungal Effect of Essential Oils. In *Potential of Essential Oils*; El-Shemy, H.E., Ed.; IntechOpen: London, UK, 2018. [CrossRef]
3. Raveau, R.J.; Fontaine, S.; Lounès-Hadj Sahraoui, A. Essential oils as potential alternative biocontrol products against plant pathogens and weeds: A review. *Foods* **2020**, *21*, 365. [CrossRef] [PubMed]
4. Nikolaou, P.; Marciniak, P.; Adamski, Z.; Ntalli, N. Controlling Stored Products' Pests with Plant Secondary Metabolites: A Review. *Agriculture* **2021**, *11*, 879. [CrossRef]
5. Kesraoui, S.; Andrés, M.F.; Berrocal-Lobo, M.; Soudani, S.; Gonzalez-Coloma, A. Direct and Indirect Effects of Essential Oils for Sustainable Crop Protection. *Plants* **2022**, *11*, 2144. [CrossRef] [PubMed]
6. Isman, M.B. Commercial development of plant essential oils and their constituents as active ingredients in bioinsecticides. *Phytochem. Rev.* **2020**, *19*, 235–241. [CrossRef]
7. Isman, M.B.; Grieneisen, M.J. Botanical insecticide research: Many publications, limited useful data. *Trends Plant Sci.* **2014**, *19*, 140–145. [CrossRef] [PubMed]
8. Isman, M.B.; Tak, J.H. Inhibition of acetylcholinesterase by essential oils and monoterpenoids: A relevant mode of action for insecticidal essential oils? *Biopestic. Int.* **2017**, *13*, 71–78. [CrossRef]
9. Price, D.N.; Berry, M.S. Comparison of effects of octopamine and insecticidal essential oils on activity in the nerve cord, foregut, and dorsal unpaired median neurons of cockroaches. *J. Insect Physiol.* **2006**, *52*, 309–319. [CrossRef]
10. Tong, F.; Coats, J.R. Effects of monoterpenoid insecticides on [^{3}H]-TBOB binding in house fly GABA receptor and ^{36}Cl-uptake in American cockroach ventral nerve cord. *Pestic. Biochem. Physiol.* **2010**, *98*, 317–324. [CrossRef]
11. Tong, F.; Gross, A.D.; Dolan, M.C.; Coats, J.R. The phenolic monoterpenoid carvacrol inhibits the binding of nicotine to the house fly nicotinic acetylcholine receptor. *Pest Manag. Sci.* **2013**, *69*, 775–780. [CrossRef]
12. Tak, J.H.; Isman, M.B. Enhanced cuticular penetration as the mechanism for synergy of insecticidal constituents of rosemary essential oil in *Trichoplusia ni*. *Sci. Rep.* **2015**, *5*, 12690. [CrossRef] [PubMed]
13. Tak, J.H.; Jovel, E.; Isman, M.B. Effects of rosemary, thyme and lemongrass oils and their major constituents on detoxifying enzyme activity and insecticidal activity in *Trichoplusia ni*. *Pestic. Biochem. Physiol.* **2017**, *140*, 9–16. [CrossRef]
14. Kim, S.; Yoon, J.; Tak, J. Synergistic mechanism of insecticidal activity in basil and mandarin essential oils against the tobacco cutworm. *J. Pest Sci.* **2021**, *94*, 1119–1131. [CrossRef]
15. Akhtar, Y.; Pages, E.; Stevens, A.; Bradbury, R.; da Camara, C.A.G.; Isman, M.B. Effect of chemical complexity of essential oils on feeding deterrence in larvae of the cabbage looper. *Physiol. Entomol.* **2012**, *37*, 81–91. [CrossRef]

16. Renoz, F.; Demeter, S.; Degand, H.; Nicolis, S.C.; Lebbe, O.; Martin, H.; Deneubourg, J.L.; Fauconnier, M.L.; Morsomme, P.; Hance, T. The modes of action of *Mentha arvensis* essential oil on the granary weevil *Sitophilus granarius* revealed by a label-free quantitative proteomic analysis. *J. Pest Sci.* **2022**, *95*, 381–395. [CrossRef]
17. Gaire, S.; Zheng, W.; Scharf, M.E.; Gondhalekar, A.D. Plant essential oil constituents enhance deltamethrin toxicity in a resistant population of bed bugs (*Cimex lectularius* L.) by inhibiting cytochrome P450 enzymes. *Pestic. Biochem. Physiol.* **2021**, *175*, 104829. [CrossRef]
18. Werrie, P.Y.; Durenne, B.; Delaplace, P.; Fauconnier, M.L. Phytotoxicity of essential oils: Opportunities and constraints for the development of biopesticides. A Review. *Foods* **2020**, *14*, 1291. [CrossRef]
19. Dunan, L.; Malanga, T.; Bearez, P.; Benhamou, S.; Monticelli, L.S.; Desneux, N.; Michel, T.; Lavoir, A.-V. Biopesticide Evaluation from Lab to Greenhouse Scale of Essential Oils Used against *Macrosiphum euphorbiae*. *Agriculture* **2021**, *11*, 867. [CrossRef]
20. Laghmouchi, Y.; Belmehdi, O.; Snehaji, N.S.; Abrini, J. Chemical composition and antibacterial activity of *Origanum compactum* Benth. essential oils from different areas at northern Morocco. *S. Afr. J. Bot.* **2018**, *115*, 120–125. [CrossRef]
21. Navarro-Rocha, J.; Andres, M.F.; Diaz, C.E.; Burillo, J.; Gonzalez-Coloma, A. Composition and biocidal properties of essential oil from pre-domesticated Spanish *Satureja montana*. *Ind. Crop Prod.* **2020**, *145*, 111958. [CrossRef]
22. Lubbe, A.; Verpoorte, R. Cultivation of medicinal and aromatic plants for specialty industrial Materials. *Ind. Crop. Prod.* **2011**, *34*, 785–801. [CrossRef]
23. Perrino, E.V.; Wagensommer, R.P. Crop Wild Relatives (CWRs). Threatened and Endemic to Italy: Urgent Actions for Protection and Use. *Biology* **2022**, *11*, 193. [CrossRef] [PubMed]
24. World Health Organization. *WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants*; World Health Organization: Geneva, Switzerland, 2003.
25. Perrino, E.V.; Musarella, C.M.; Magazzini, P. Management of grazing "buffalo" to preserve habitats by Directive 92/43 EEC in a wetland protected area of the Mediterranean coast: Palude Frattarolo, Apulia, Italy. *Euro-Mediterr. J. Environ. Integr.* **2021**, *6*, 32. [CrossRef]