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Editorial

Insects, Microbes, Natural Compounds, Fish and Plant Species Biodiversity: The Innovative Ammo in the Battle against Plant Pests and Pathogens

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According to the Food and Agriculture Organization of the United Nations, the global population is projected to increase from 5700 (in 1995) to 9800 (in 2050) million people, i.e., ~72%, which undeniably means significant implications for food demand. Additionally, not only is more food needed, but this demand is further intensified by changing dietary preferences as people's concern on environmental issues rises constantly. Hence, we are witnessing an obvious shift towards higher-quality foods like organic products, produced by more environmentally benign methods. In the era of climate change, while chemical pesticides are being banned or their use is being restricted due to environmental concerns, there is an urgent need for effective biocontrol methods to protect crops from pests and pathogens. Sustainable agricultural practices, innovation in food production, and reducing food waste are critical to ensuring global food security in the face of these challenges.

Considering that crops are attacked by well studied and new pests and diseases, and at the same time farmers' arsenals are restricted, while pests and pathogens develop resistance to conventionally used pesticides, the latter are rendered useless. In this context, the present Special Issue aimed at creating a collection of scientific works studying the potential use of fungi, bacteria, natural compounds such as terpenes, insects, non-host plants, and even fish in order to control pests and diseases.

Research during the last few years has focused on discovering microorganisms with potential use against plant diseases. Those might be endophytic [1,2], compost-derived [3], originating from soil solarized soils [4], or even from oil mill waste [5]. The most state-of-the-art approaches include the use of microbial communities instead of single microorganisms to control plant diseases. In this direction, Karanastasi et al. [6] explored the potential of bacterial communities derived from compost to control *Meloidogyne javanica* nematodes and promote growth in tomatoes. Both bacterial communities used in their study, suppressed nematode reproduction and root invasion, while simultaneously enhanced growth parameters in tomatoes. In another study included in this issue, Feng et al. [7] isolated an endophytic *Bacillus siamensis* from walnut roots and used it to effectively control Walnut Anthracnose caused by *Colletotrichum acutatum*. Antifungal lipopeptides, extracellular hydrolytic enzymes, and the induction of plants' systemic resistance were the unraveled modes of action of this biocontrol agent. Unfortunately, due to strict regulations on pesticides and the high cost for the production of biological pesticides, only a few products based on microbial agents make it to crop fields as registered pesticides. Clonotri (Microspore Hellas—Sacom Hellas) (containing *Trichoderma* sp., *Clonostachys* sp., and *Glomus* sp.) and Strepse (comprising *Streptomyces* sp., *Pseudomonas* sp., and *Glomus* sp.) (MS Biotech, LTD—Roma, Italia) are two of these commercial products used by Tsolakidou et al. [8] to effectively combat wilt in greenhouse tomatoes. Clonotri was effective against *Fusarium oxysporum* f. sp. *lycopersici*, while Strepse effectively protected plants from *Verticillium dahliae*.

On the other hand, the biological control of agricultural pests is mainly focused on arthropod control, as these are responsible for approximately 20% of global crop losses

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annually [9], though depending on region, crop type, and pest management practices, losses may be higher. To date, a vast variety of biological control agents (BCAs) are available against important agricultural pests, including pathogens, predators, parasites, and parasitoids, yet these agents are usually species-specific, and their effectiveness often depends also on environmental conditions. Therefore, a continuous search for new and efficient pest-BCA interactions is compulsory, especially while new emerging pests threaten food production. For example the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), which has been listed in the EPPO A2 list. The species is a highly polyphagous pest, causing severe economic losses. It originates from the tropical and subtropical areas of the Americas but recently invaded Africa, Asia, and Oceania. In this Special Issue, Chang et al. [10] studied the potential of a synergistic insecticidal effect of *Photorhabdus luminescens* (Pl) and *Bacillus thuringiensis* (Bt) against this critical pest and demonstrated that Bt assists the invasion of Pl into the insect hemocoel, enhancing a synergistic insecticidal efficiency. These findings are important as they provide additional evidence for combining microbial factors for sustainably efficient lepidopteran control.

Of course, identifying new pest–BCA combinations is important; however, preserving and boosting already known and characterized beneficial organisms is also crucial for agriculture. In this aspect, Wojciechowicz-Żytko and Wilk [11] investigated the influence of diverse semi-natural environments on the occurrence of Syrphidae predators and concluded that hoverflies are attracted by flowering plants next to apple orchards, which enhances their migration to the orchard, finally leading to reduced colonies of *Aphis pomi* and *Dysaphis plantaginea*.

The behavior of specialist predators also depends on parameters related to their prey. As described by Mirza et al. [12], the web structures of four Tetranychidae pest species affected the performance of the coccinellid *Stethorus gilvifrons* predator, which exhibited three diverse attack behaviors in a laboratory study. These findings provide further insight and open new research pathways on factors that may be considered in IPM.

Nevertheless, understanding pest–prey and plant–insect interactions, as well as insect population dynamics, may also be significant for efficient pest control. In this Special Issue, Jiang et al. [13] provide important information on the feeding behavior of *Myzus persicae* on a number of target hosts and explain how adaptability to a host species may as well be taken into consideration when designing an integrated pest control program.

While the term "pest" in agriculture usually reminds us of insects, acari, nematodes, and sometimes mice, this Special Issue also hosted a study on the biological control of a shrimp species, *Triops longicaudatus*, which has become a major pest for California rice farmers. Biocontrol agents mentioned usually in studies are also insects and microbes, but, in this case, interestingly, a predatory fish species, *Gambusia affinis*, was effectively used by Bloese et al. [14] against the tadpole shrimp. This example underlines the potential of other, often neglected, organisms to act as biocontrol agents for the protection of crops.

Besides BCAs, integrated pest management schemes often include the use of naturally deriving compounds, such as aldehydes, alkaloids, amides, amino acids, cyanogenic glucosides, terpenes, flavonoids, polyketides, polyphenols, quinones, saccharides, and thiophenes [15], since many have been proposed as effective against various plant pests and pathogens. Nonetheless, one should not underestimate the possibility that, however efficient these may be for plant protection, they may as well be detrimental against beneficial organisms. As Kotsinis et al. [16] describe in their work, in which they tested four terpene compounds with respect to their effect on entomopathogenic nematodes (EPN), nematicidal activity was recorded for at least two of the four EPN species studied. Importantly, the virulence of the EPNs towards *Galleria mellonella* instars was not affected; however, this work shed additional light on the fact that besides studying a plant pest or disease control factor with respect to its efficiency, it is highly important to study its impact on the rest of the environment and other living organisms.

While new challenges arise due to climate change, nature can reveal new ways to surpass them. Now more than ever, the need to discover novel, effective strategies to protect

crops against pests and diseases is urgent, and this must involve further exploitation of possible biocontrol tools.

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References

1. Andreolli, M.; Zapparoli, G.; Angelini, E.; Lucchetta, G.; Lampis, S.; Vallini, G. *Pseudomonas protegens* MP12: A plant growthpromoting endophytic bacterium with broad-spectrum antifungal activity against grapevine phytopathogens. *Microbiol. Res.* **2019**, *219*, 123–131. [CrossRef] [PubMed]
2. Niem, J.M.; Billones-Baaijens, R.; Stodart, B.; Savocchia, S. Diversity profiling of grapevine microbial endosphere and antagonistic potential of endophytic *Pseudomonas* against grapevine trunk diseases. *Front. Microbiol.* **2020**, *11*, 477. [CrossRef] [PubMed]
3. Malandraki, I.; Tjamos, S.E.; Pantelides, I.; Paplomatas, E.J. Thermal inactivation of compost suppressiveness implicates possible biological factors in disease management. *Biol. Control* **2008**, *44*, 180–187. [CrossRef]
4. Tjamos, E.C.; Tsitsigiannis, D.I.; Tjamos, S.E.; Antoniou, P.P.; Katinakis, P. Selection and screening of endorhizosphere bacteria from solarized soils as biocontrol agents against *Verticillium dahliae* of solanaceous hosts. *Eur. J. Plant Pathol.* **2004**, *110*, 35–44. [CrossRef]
5. Papasotiriou, F.G.; Varypatakis, K.G.; Christofi, N.; Tjamos, S.E.; Paplomatas, E.J. Olive mill wastes: A source of resistance for plants against *Verticillium dahliae* and a reservoir of biocontrol agents. *Biol. Control* **2013**, *67*, 51–60. [CrossRef]
6. Karanastasi, E.; Kotsantonis, V.; Pantelides, I.S. Compost-Derived Bacterial Communities Offer Promise as Biocontrol Agents against *Meloidogyne javanica* and Promote Plant Growth in Tomato. *Agriculture* **2024**, *14*, 891. [CrossRef]
7. Feng, X.; Xu, R.; Zhao, N.; Wang, D.; Cun, M.; Yang, B. Isolation, Identification, and Characterization of Endophytic *Bacillus* from Walnut (*Juglans sigillata*) Root and Its Biocontrol Effects on Walnut Anthracnose. *Agriculture* **2022**, *12*, 2102. [CrossRef]
8. Tsolakidou, M.-D.; Demetriou, G.; Panagiotou, S.; Vassiliou, L.; Goulas, V.; Pantelides, I. Efficacy of Commercial Biocontrol Products for the Management of *Verticillium* and *Fusarium* Wilt in Greenhouse Tomatoes: Impact on Disease Severity, Fruit Yield, and Quality. *Agriculture* **2024**, *14*, 882. [CrossRef]
9. Fernández, M.R.; Gerasymenko, P.M.; Juteršek, I.M.; Baebler, Š.; Kallam, K.; Giménez, M.E.; Gondolf, J.; Nordmann, A.; Gruden, K.; Orzaez, D.; et al. Insect pest management in the age of synthetic biology. *Plant Biotechnol. J.* **2022**, *20*, 25–36. [CrossRef] [PubMed] [PubMed Central]
10. Chang, T.-Y.; Hsieh, C.; Wu, L.-H. Synergistic Insecticidal Effect of *Photorhabdus luminescens* and *Bacillus thuringiensis* against Fall Armyworm (*Spodoptera frugiperda*). *Agriculture* **2024**, *14*, 864. [CrossRef]
11. Wojciechowicz-Żytko, E.; Wilk, E. Surrounding Semi-Natural Vegetation as a Source of Aphidophagous Syrphids (Diptera, Syrphidae) for Aphid Control in Apple Orchards. *Agriculture* **2023**, *13*, 1040. [CrossRef]
12. Mirza, J.H.; Kamran, M.; Alatawi, F.J. Behavioral Response of a Specialist Predator, *Stethorus gilvifrons* (Coccinellidae: Coleoptera), to Cope with Web Structures of Four Different Spider Mite Pest Species. *Agriculture* **2023**, *13*, 582. [CrossRef]
13. Jiang, W.; Cheng, Q.; Lu, C.; Chen, W.; Zhao, D.; He, Y. Different Host Plants Distinctly Influence the Adaptability of *Myzus persicae* (Hemiptera: Aphididae). *Agriculture* **2022**, *12*, 2162. [CrossRef]
14. Bloese, J.; Goding, K.; Godfrey, L. Biological Control Options for the Management of Tadpole Shrimp (*Triops longicaudatus* (LeConte)) in California Rice. *Agriculture* **2024**, *14*, 1136. [CrossRef]
15. Souto, A.L.; Sylvestre, M.; Tölke, E.D.; Tavares, J.F.; Barbosa-Filho, J.M.; Cebrián-Torrejón, G. Plant-Derived Pesticides as an Alternative to Pest Management and Sustainable Agricultural Production: Prospects, Applications and Challenges. *Molecules* **2021**, *26*, 4835. [CrossRef] [PubMed] [PubMed Central]
16. Kotsinis, V.; Dritsoulas, A.; Ntinokas, D.; Giannakou, I.O. Nematicidal Effects of Four Terpenes Differ among Entomopathogenic Nematode Species. *Agriculture* **2023**, *13*, 1143. [CrossRef]