Botanical Amendments for Synthetic Nematicides

Subjects: Plant Sciences
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The intensification of agriculture has created concerns about soil degradation and toxicity of agricultural chemicals to non-target organisms. As a result, there is great urgency for discovering new ecofriendly tools for pest management and plant nutrition. Botanical matrices and their extracts and purified secondary metabolites have received much research interest, but time-consuming registration issues have slowed their adoption. In contrast, cultural practices such as use of plant matrices as soil amendments could be immediately used as plant protectants or organic fertilizers.

Keywords: biofumigation ; botanical amendment ; Meloidogyne ; nematode ; organic fertilization ; soil incorporation

1. Introduction

The most notorious below-ground agricultural targets are phytoparasitic nematodes; after their infection of plants, other soil borne pathogens often follow, such as *Fusarium* spp., *Phytophthora* spp., and *Pseudomonas* spp. The recently rated top 10 nematode pest genera include the root-knot (*Meloidogyne*), cyst (*Heterodera* and *Globodera*), and root lesion (*Pratylenchus*) nematodes [[1]]. Nematodes attack numerous crops and are responsible for estimated losses of more than EUR 157 billion per year [[2]]. On the other hand, free-living and non-phytoparasitic nematodes are ubiquitous, possess several beneficial roles in soils, and are considered good bioindicators for environmental monitoring because their populations are sensitive to environmental contaminants and because they are well classified into diverse functional groups [[3][4]]. Likewise, soil bacteria and fungi are important components of the functional biodiversity required to maintain sustainable agroecosystems [[5]]. Because preserving this essential soil biota is a specific protection goal in pesticide environmental risk assessment, recent studies have focused on the response of the soil microbial community to the so-called low-risk pesticide classes and botanically derived nematicidal preparations [[6][7][8]].

2. Botanical Amendments as Substitutes for Synthetic Nematicides

Indeed, great efforts are being made worldwide towards the development of more ecofriendly crop protection tools that protect non target organisms and other aspects of the environment. European Union legislation requires extensive experimental data for plant protection products prior to authorization, so as to avoid ecotoxicity concerns. For the most part, formulations of synthetic chemicals have been drastically restricted in usage because of their adverse environmental side effects and subsequent non-inclusion in Annex I of 91/414/EEC [[9]]. The most representative multipurpose soil sterilant, methyl bromide, has been unavailable since 2005 because of the Montreal Protocol, and no other compound has replicated its role in crop protection [[10]]. Moreover, new synthetic nematicides are expensive to develop, and inconsistent efficacy often renders the use of the currently available synthetic nematicides inadequate as a stand-alone pest control method. As a result, non-chemical methods to control soil pathogens and parasites are highly desirable, although such strategies also have limitations. For instance, solarization is expensive and may affect beneficial soil organisms, flooding cannot be performed in all locations and its efficacy depends on the crop and nematode species, and cultivar resistance to plant-parasitic nematodes may break under elevated temperatures and is species-dependent [[11]].

Most noteworthy is that many synthetic nematicides belong to the same chemical groups (e.g., organophosphates and carbamates) as many insecticides and acaricides, and they are often very toxic to soil microarthopods such as mites [[12]]. Many mites such as *Cosmolaelaps simplex*, a soil mite present in citrus orchards, prey on nematodes [[13]]. This mite hunts for plant-parasitic nematodes such as *Meloidogyne incognita* and the citrus nematode *Tylenchulus semipenetrans* and can significantly decrease their numbers [[14]]. Other predatory mites inhabiting soil and feeding on plant-parasitic nematodes include *Lasioseius penicilliger* [[15]], *Lasioseius subterraneous*, *Protogamasellus mica* [[16][17]], *Lasioseius scapulatus*, and *Gaeolaelaps aculeifer* [[18]]. Interestingly, the presence of organic manure generally increases the number of predatory mites in soil [[19]]. Consequently, the limited usage of synthetic pesticides and the application of other, ecofriendly methods may decrease plant infestation by nematodes, limit environmental pollution, and decrease the costs of plant production.

With respect to developing ecofriendly plant protection products, interest in botanical insecticides has surged since 2000 [[20]]. Countless types of plant secondary metabolites—including alcohols, aldehydes, fatty acid derivatives, terpenoids and phenolics—contribute independently or jointly to many biological processes. These metabolites may attract or repel nematodes, stimulate or inhibit egg-hatching, or exhibit nematicidal properties [[21][22][23]]. Nematicidal compounds naturally present in plants as products of secondary metabolism have been well documented in recent years [[22][23][24][25]]. Most importantly, these secondary metabolites form complexes that often act at multiple or novel target sites, thus reducing the likelihood of pest development of resistance [[26][27]]. Different natural molecules may affect directly nematode biology and behavior [[21][28]] but also interfere with respect to nematodes and other soil microfauna interaction, although this relationship needs extensive research. In this context, it has been found that volatile substances such as short-chain alcohols or aldehydes, acetate, or other secondary metabolites such as terpenes attract predators that feed on herbivores [[29][30]]. Last, toxicity to pests and pathogens may be provided by botanical amendments by virtue of their decomposition products, induced changes in soil physical and chemical properties, and their effects on biological antagonists [[31][32][33][34]].

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