Impact of organic amendments on Entomopathogenic Nematodes-an overview

Abstract:

Healthy soil enhances crop yield.In order to increase the organic matter content of soil for sustainable and healthy soil,organic amendments are applied in the field. Build-up of insect pest populations under organic production system is problematic which not only reduces yield but also lowering crop quality. Integrated Pest Management (IPM) strategies that incorporate cultural management, biological management, use of resistant varieties are viable options for reduction of pest population.Among the biocontrol agents, Entomopathogenic nematodes (EPNs) are efficacious against various insect pests in a variety of habitats. However, the effectiveness of EPNs against insect pests is largely dependent on the method of application and nematode survival under field conditions. Cultural management practice such as application of organic amendments can alter the soil health that enables their occurrence and activity.Understanding the interactions is essential to reveal ways to enhance the potential of EPNs as biocontrol agents in a particular soil type,environmental condition and agricultural scenario.This review provides a brief overviews of impact of organic amendments on EPNsfrom the standpoint of pestmanagement.

Key words: Organic agriculture, Pests, Cultural management, Biological management, Organic amendments, sawdust, Entomopathogenic nematodes(EPNs).

Introduction

Agricultural production depends on healthy soils to maintain essential soil functions such as carbon, nutrient, and water cycling. Usually, soil quality has been characterized by the presence of nutrients and water and their availability to the crop [1]. The development of agricultural practices have largely enhanced crop yield; but protecting the crops against herbivores and diseases is problematic[2]. Insect pests destroy 18-26% of the world's total crop production annually, with an estimated cost of more than $470billion [3]. Attempts to control this problem with chemical pesticides have resulted in significant environmental damage, harm to beneficial insects, humans and other animals. Alternative to chemical pesticides include IPM strategies that incorporate cultural practices like crop rotation, cover crops and organic amendments;use of resistant varieties;biocontrol agents including parasitoid wasps, entomopathogenic fungi, Bt toxins, entomopathogenic nematodes (EPNs) etc. Among all the biocontrol agents,EPNs in the families Steinernematidae and Heterorhabditidaeare efficacious against numerous insect pests in a variety of habitats. There are no negative impacts of EPNs on the environment, human health and non-target organisms when compared to pesticides [4]. For long-term pest management,theyhave the potential to recycle in their host populations .However, in the agro-ecosystem, EPN are affected by various abiotic soil properties such as soil texture, moisture, temperature, and soil organic matter, which might be considerably altered by agricultural management practices[5]. Farmers add soil amendments such as compost to increase organic matter content, improve soil aeration, soil porosity, and soil water holding capacity.EPNs in many agricultural soils are mixed with soil amendments [6]. Application in the field by using compost as a carrier might protect the nematodes against UV damage, buffer temperature extremes and promote contact between the nematodes and the pest insects [7].

Entomopathogenic Nematodes(EPNs) in the soil environment

As the soil entomopathogens are closely associated with their environment, any disturbance of the soil structure (i.e.tillage) could cause a change in activity or survival of pathogens. Soil physical and chemical characteristics play an important role in the abundance, distribution and structure of nematode communities.EPNs occur in soils of natural and agricultural areas worldwide[8]. Environmental variables, soil characteristics and anthropogenic activities may affect their diversity and occurrence. They occur in their non-feeding stage, called infective juvenile (IJ), capable of locating suitable hosts .IJs invade insect bodies through the mouth, anus, spiracles, or cuticle and release their bacterial symbionts, γ-Proteobacteria (*Xenorhabus* spp. bacteria for *Steinernema* spp. and *Photorhabdus* spp. bacteria for *Heterorhabditis* spp.) into the insect's hemolymph [9]. The bacteria release toxins to kill the insect, and proliferate in the cadaver. The IJs consume the bacteria, complete their development, and reproduce. After one or more generations of nematodes inside the cadaver, new IJs leave to seek new hosts in the soil[10].As the soil is their native habitat, EPN have a marked potential to control soil insects where there is protection from UV radiation and rapid desiccation[11]. However,the effectiveness of EPNs against insect pests is largely dependent on the method of application and nematode survival under field conditions[12]. Inside the soil matrix, EPNs are exposed to a broad biodiversity of soil organisms, potential insect host, predators, microbial pathogens, freeliving nematodes as competitors, and chemical attractants and repellents released by plants and other soil organisms [13]. EPNs use soil cracks and openings caused by root growth to move through the soil matrix. EPNs exploit volatile organic compounds emitted by roots in response to herbivory to locate damaged root systems and thereby insect hosts. EPNs foraging behavior is therefore greatly influenced by root architecture and their effectiveness negatively correlated with root complexity [14].All these factors affect the survivorships, reproduction, host searching capacity and movement of EPN in many agricultural soils [15,16]. For survival, IJs must cope with soil and environmental conditions, overcome competitors for hosts, and avoid predators and other soil organisms .When applied, many EPNs do not persist in soil longer than a few weeks or months [17]. some native EPN populations, adapted to a particular environment, have been shown to persist over many years [18]. Presence of hosts within the field can provide a chance for EPN to reproduce and increase persistence of EPN up to two years in the field [19].

Agricultural management practices: Use of compost

Agricultural management practices can modify soil properties in ways that may disrupt or enhance the abundance and activity of beneficial organisms in the soil.A large diversity of microorganisms has the potential to protect plants against pests and diseases if applied in an appropriate manner.The application of organic amendment like compost enriched with antagonists or beneficial microorganisms holds great promise in agricultural and horticultural ecosystem since compost itself inherently infers benefits to soil and plant growth[20].Beneficial effects of compost are dependent on the quality of the organic matter, most likely including its inhabiting biology and its biochemical stability.The water holding capacity of the soil can be enhanced by increasing soil organic matter content due to its effects on soil texture, porosity, and bulk density.Using compost or a compost and mulch mix improved plant growth and yield [21], provided pest control, and benefitted natural enemies [22,23]. Learning more about the factors that determine the prevalence of the organisms that are directly associated with EPN, can provide additional information on how farming practices might contribute to this important feature of soil health.Soils with high levels of natural organic matter and minimal soil disturbance sustain larger numbers of soil microorganisms, including EPNs and associate organisms [24]. It is generally observed that irrigation, tillage and fertilization affect the viability, reproduction and insecticidal activities of EPNs. Diverse interactions between EPNs and other members of the soil community exist, from plants and fungi to arthropods and annelids[25]. These interactions influence EPN performance under field conditions, specifically, if they contribute to the variability limiting EPNs efficacy and wide-scale adoption. Soil texture, temperature, moisture, agronomic practices, soil antagonists, and host resources are major factors affecting nematode persistence in the soil environment [26], and could be responsible for the differences in detection of entomopathogenic nematodes among different habitats. Agricultural management affects both soil quality variables and EPN distribution. Soil conditions could also be manipulated so that nematodes are established and sustained for prolonged periods after inundative releases. If soil organic content does increase both water holding capacity and water retention then possibly it may also extend the time over which an initial application of the IJs of EPNs would be efficacious as biocontrol agents[27].

Various studies have measured the effect of different organic (physical status, nutrient content, nutrient mineralization rate, and decomposition products)and inorganic fertilizers on nematode fitness. The addition of compost was shown to increase the overall nematode presence, while modifying species compostion, favouring bacterivorous taxa and decreasing the ratio of fungivorous nematodes [28].Composts may also improve the virulence of EPNs compared to certain other soil types [29],application of compost may encourage nematode establishment and recycling, although immaturely-cured compost may negatively affect EPNs virulence [20]. In general, application of EPNs into composts, mulches, or other soil amendments rather than soil may protect EPNs from UV damage and buffer them from temperature and moisture extremes while promoting EPN movement and contact with pests [7]. Plant bodies contain various amounts of cellulose, chitin, flavonoids, lignin, phenols, ricin, saponins, tannins, terpinoids, etc., which significantly affect the growth of microorganisms and thus affect the resulting cooperating soil microbiome during the decomposition. However, the accumulation of compost in soils can affect the presence and abundance of the nematode community when applied regularly over time [30].Georgis et al., [7],Herren et al.[20] andHoitink and Boehm[31]used compost as a carrier for field application of EPN use in a wide array of agricultural and horticultural systems. Bednarek and Gaugler [32] observed that organic manure resulted in increased densities of native population of *Steinernema feltiae* as influenced by host population under field condition. Campos-Herrera *et al*., [33-35] found a positive effect of organic soil management on EPN populations.

Effect of Sawdust as organic amendmenton EPNs

Sawdustisan organic waste of the saw-milling, pulp, paper, and wood processing industries. When used as mulch, sawdust mulch enhances soil structure, improves aeration in heavy soils, enhances water absorption and penetration, and conserves moisture and reduce evaporation and ultimately the distribution of soil elements within the plant growth profile. Sawdust is a carbonaceous organic substance with a high carbon to nitrogen ratio 300:1. Application of sawdust mulch has been found to increase soil oxygen diffusion rate, promote a more uniform soil temperature, reduce surface crusting and soil bulk density, and improve aeration porosity and soil moisture content. Sawdust mulch is a viable and sustainable soil management practice [36]. Ground covers by applying sawdust can significantly affect soil temperature and moisture in the top 12cm of soil, which may directly influence pathogen activity or survival. Type of tillage appeared to be the primary factor affecting soil entomopathogens whereasconservation tillage apparently conserves entomopathogens and alternate hosts[37].

A compost and woodchip/sawdust mulch caused mortality of Japanese beetle, *Popillia japonica* population in blueberry with application of *H.bacteriophora* when temperatures are optimal to mulches [38].

Deol *et al*.,[39] used a peat and bark based potting medium to deliver EPN to the soil via the use of infected host cadavers, concluding that this application method extended nematode survival and virulence to 180 days (at 25^{o}C) in comparison with 60 days through aqueous application.The use of compost as a carrier to deliver EPN directly to the soil could therefore be useful for agricultural settings.

Heterorhabditiszealandica together with pine chips, wheat straw, pine wood shavings, blackwood and applewood chips were evaluated to control diapausing codling moth, *Cydia pomonella* larvae; after application it was observed that IJs of *H. zealandica* were having < 10% persistence [40].The type of compost used (mulch soil amendment) based on its feedstock composition, the concentration of nutrients, and organic matter mixed with a specific type of soil texture had a significant effect on the tolerance of *H.bacteriophora* to different dehydration periods. Using Petri dish assays, the mulch soil amendment resulted in the highest *G.mellonella* larval mortality rate as compared to different organic compost application concentrations (mass:mass). Virulence and efficacy decreased over 7 days of progressive dehydration. Infectivity and survivorship of IJs of *H.bacteriophora* was improved by the use of organic compost as the soill undergoes progressive moisture loss [29].

Conclusion and future perspectives

There are various factors that define EPN population dynamics in agro-ecosystems. To improve the efficacy of EPNs as biocontrol agent in the field, knowledge about the physical nature of the agricultural soil environment is important Lack of predictability is partly a function of poor nematode persistence in the soil.Around 10% of the initial inoculum of EPNs may be present in the soil seven days after application[41].Many agricultural practices expose EPNs to extreme conditions (temperature,UVlight etc.) that significantly reduce their biocontrol potential, even reaching the extinction of the natural populations. Their identification can allow us establishing the best practices to favor suitable ecological scenarios to enhance their activity. Improper selection of nematode species and strains for the climatic conditions at the release site as well as for the insect community present have been cited as possible factors affecting field performance [42].Identifying the abiotic and biotic factors responsible for the persistence of endemic nematode populations, particularly the host community, may improve the matching of species and strains with the conditions of the habitat in which nematodes are released[43].Given the drawbacks of the current application methods and the low field survival rates of EPN, there is a need for more efficient delivery methods for EPN into the field either through application of compost like sawdust to increase their persistence [44]. As a first step towards the development of new biological control methods for sustainable agriculture, a comprehensive inventory of selected beneficial organisms of a given agroecosystem is required, together with application method as well as knowledge about the factors that might determine their abundance and survival.

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