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Biocontrol in Horticultural Crops

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Abstract

Biocontrol (biological crop protection) offers an alternative to toxic chemicals that are increasingly being banned or restricted in many parts of the world. Ongoing research is broadening the applicability of biocontrol, but currently it is most used for protected crops where environmental conditions can be controlled. Several entomopathogenic bacteria, fungi and nematodes are currently widely commercialised for use in biocontrol and, thanks to calls for more sustainable practices in agriculture and reduced chemical burden, they are rapidly increasing their market share. However, to realise the full potential of biocontrol, greater collaborative efforts between and across industry and academia are essential, for the development of improved formulations, and for the identification and characterisation of available microbial species that can be harnessed for use in biocontrol.

Keywords: Biocontrol; Biopesticides; Biological control; Horticulture

Introduction

Biological crop protection – often referred to as 'biocontrol' – aims to manage plant pests and diseases while reducing potential harm to the environment, non-targeted species and human health. Biocontrol harnesses natural resources and relationships (e.g., natural enemies), as herbivory, predation, parasitism, disease and competition lead to the highly selective and targeted management of pestilent species [1].

Biocontrol products tend to be divided into four categories, by product type:

Macroorganisms: invertebrate predators, parasites and beneficial nematodes;

Microorganisms: viruses, bacteria and fungi;

Semiochemicals: substances emitted by plants and animals (e.g. pheromones) whose primary purpose is communication, are target specific and have a non-toxic mode of action;

Natural substances: plant extracts or other nature-sourced materials (and their identical synthetic versions).

Already widely used in the horticulture, forestry, and turf and amenity sectors, biocontrol is growing increasingly popular as it appears to offer an alternative to toxic chemicals that are increasingly being banned or restricted in many parts of the world [2]. This is reflected in high-profile initiatives such as the European Commission's *Farm to Fork Strategy* and *Sustainable Use Directive* (2009/128/EC); Europe is preparing to remove 505 pesticides by 2030 and increase organic farming from 8 to 25%.

Biocontrol is now an important part of sustainable crop protection and production, enjoying social acceptability, promoting economic productivity, and engendering environmental stewardship [3]. Therefore, biocontrol satisfies the three-way concept of sustainable development as defined in the United Nations (UN) 2030 agenda, more commonly known as the UN Sustainable Development Goals (SDGs).

In addition. the rapid uptake of biocontrol reflects considerable advances over the past couple of decades, in terms of both the discovery and registration of new biocontrol agents that can effectively control pests and diseases in real-world settings, and in their formulation.

Implementation challenges

As a field of research, biocontrol continues to advance. However, its successful use usually depends on the consideration and understanding of the fact that biocontrol agents are frequently living organisms. Macrobial and microbiological biocontrol solutions contain selected beneficial invertebrate predators or parasites, beneficial nematodes, bacteria, fungi or viruses. These organisms are either natural enemies of the target pests, of they produce toxins, vitamins, enzymes and hormones that can act antagonistically on plant pests, or they might produce vitamins, enzymes and hormones that can boost the plants' immune systems to infection [4].

Obviously, if living organisms are to be effective, they need to be kept alive. Moreover, they need to be kept in a state in which they can achieve their best efficacy. This has led to numerous breakthroughs in formulating biocontrol products, as the needs to protect the organisms during storage, application and use have been recognised as key to successful implementation. For example, research into bioencapsulation has notably increased in recent years [5]. Encapsulation can protect the beneficial microorganism from desiccation and UV light, while helping them to reach their targets more evenly using conventional spraying equipment, and even helping them to adhere to those targets on delivery.

It is hoped that research such as this will broaden the applicability of biocontrol, which presently tends to be used most for glasshouse crops, which are grown in more controlled and predictable conditions than arable and broadacre produce.

Biocontrol in horticulture today

For protected crops, where the growing environment can be controlled, a range of biological control agents can be introduced via a specific schedule designed in order to achieve optimal efficacy for plant pest or disease control.

Examples include the use of entomopathogenic nematodes and fungi in the management of the black vine weevil larvae, *Otiorhynchus sulcatus*. The black vine weevil is a major pest of ornamental nursery stock and soft fruit in many parts of the world. Damage is caused primarily by the root-feeding larvae, resulting in reduced vigour and plant death. The banning of a number of insecticides (e.g. imidacloprid, chlorpyrifos) over recent years left the horticultural industry in a very vulnerable position. However, the susceptibility of the black vine weevil to entomopathogenic nematodes is well established, with numerous authors publishing papers using a wide array of nematodes species from commercial sources [6,7].

Table 1: Some of the most used entomopathogenic bacteria and fungi are currently commercialised for use in biocontrol [8].

Entomopathogenic bacteria		Entomopathogenic fungi	
Bacteria species	**Main target pests**	**Fungal species**	**Main target pests**
Bacillus thuringiensis aizawai	Armyworms, diamondback moth	*Beauveria bassiana*	Wide range of insects and mites
Bacillus thuringiensis kurstaki	Lepidoptera	*Beauveria brongniartii*	*Helicoverpa armigera*, Berry borer, Root grubs
Bacillus thuringiensis israelensis	Mosquitoes and Black flies	*Hirsutella thompsonii*	Spider mites
Bacillus thuringiensis tenebrionis	Colorado potato beetle	*Isaria fumosorosea*	Whitefly
Bacillus thuringiensis sphaericus	Mosquitoes	*Metarhizium anisopliae*	beetles and caterpillar pests; grasshop-pers, termites
Burkholderia spp.	Chewing and sucking insects and mites; nematodes	*Metarhizium brunneum*	*Agriotes* species
Saccharopolyspora spinosa	Insects	*Paecilomyces lilacinus*	Plant pathogenic nematodes
Chromobacterium subtsugae	Chewing and sucking insects and mites	*Paecilomyces fumosoroseus*	Insects, Mites, Nematodes, Thrips
Bacillus firmus	Nematodes	*Verticillium lecanii*	Mealy bugs and sucking insects
		Lecanicillium lecanii	Aphids, leafminers, mealybugs, scale insects, thrips, whiteflies
		Myrothecium verrucaria	Nematodes

The highly successful use of *Bacillus thuringiensis* (Bt) and several other bacterial species led to the further discovery of many new microbial species and strains, some of which have been translated into commercial products [8]. Bacterial entomopathogens include several *Bacillaceae*, *Serratia*, *Pseudomonas*, *Yersinia*, *Burkholderia*, *Chromobacterium*, *Streptomyces*, and *Saccharopolyspora* species. Table 1 provides a summary of some of the most used bacteria in biocontrol today.

Commercialised fungi comprise different strains of *Beauveria bassiana*, *B. brongniarti*i, *Metarhizium anisopliae*, *Verticillium*, *Lecanicillium*, *Hirsutella*, *Paecilomyces*, and *Isaria* species. *B. bassiana* represents one of the most used fungal bioinsecticide, with *B. bassiana* and *B. brongniartii* strains showing varying levels of virulence against diverse targets and being used as active substances in diverse formulations [8].

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Entomopathogenic nematode species in the *Heterorhabditis* and *Steinernema* genera act as obligate parasites and, because of their symbiosis with entomopathogenic bacteria in the *Photorhabdus* and *Xenorhabdus* genera, these species possess significant potential as biocontrol agents [9]. As well as the black vine weevil, entomopathogenic nematodes are already used commercially for the control of numerous soil dwelling pests, including beetle larvae, caterpillars, cutworms, leaf miners and thrips.

The future

Biocontrol agents have been registered for a number of indications and they are rapidly increasing their market share. However, there remains a multitude of horticultural pests for which biocontrol agents have not yet been identified. As well as continued work on better formulations to optimise efficacy and application, a lack of coordinated research into the enormous variety of microbial species, many of which still need to be identified and characterised, is hindering our ability to harness the full potential of biocontrol.

Better collaborative efforts between and across industry and academia is essential to addressing this short fall, as is the creation of a global consortium for identifying and cataloguing microbes with biological control potential. By developing a robust screening process and cataloguing system, we can better understand and harness the potential of soil microbiomes, leading to effective and sustainable pest and disease control solutions. Such an effort would not only contribute to the growth of the biopesticides market but also promote environmental sustainability and biodiversity conservation. Several initiatives in this area, aimed at creating open-access global microbial databases, are known to be at an early stage and have the potential to provide greater alignment, more information sharing, and opportunities for research collaboration.

With ever more biocontrol agents being discovered and formulated, the only remaining obstacle to biocontrol is the regulatory process, which has long been considered to be too slow, too expensive, and generally inappropriate for biological products [10,11]. The recent regulatory changes in Brazil, which are setting a new standard for the biocontrol industry, show how an environment that supports clean, green agriculture can result in a dramatic increase in sustainable farming. The Brazilian market for biologically-based pesticides and bioinoculants grew 67% during the 2021-22 season following regulatory reform, and it is hoped that other countries and Competent Authorities will soon emulate these achievements. This should in turn advance the biocontrol sector as a whole, and drive greater sustainability in horticulture.

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