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Efficacy of Entomopathogenic Fungi *Beauveria bassiana* in Pest Management

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Abstract

Indiscriminate application of chemical pesticides to the crops is a major threat today to the environment. Chemical pesticides degrade the environmental quality and drastically affect human health. To address this issue, many studies have been conducted which recommend the use of biopesticides and highlighted the importance of entomopathogenic fungi as biocontrol agents. Application of *Beauveria bassiana* has been found to protect many crops from pests and prevent the dreadful impacts on environmental degradation. Biocontrol agents also play an important role in preventing environmental pollution and therefore used as a component of integrated pest management. Biocontrol agents help for sustainable agroecosystems mostly in tropical regions. It is found naturally, it is cost effective, eco-friendly with antimicrobial properties. The main aim of this review is to outline the importance of *Beauveria bassiana* and highlight its role in controlling the multiple pests and in minimizing the final yield losses.

Keywords: Biopesticide, *Beauveria bassiana*, Mycoinsecticides, Pest control

Introduction

Introducing chemical pesticides into agricultural ecosystems is a serious issue today. Synthetic pesticides are certainly detrimental to the biodiversity as well as environment. They may kill natural enemies of pests, which ultimately would result in the outbreak of pests. Pesticide residues on crops that are being exported are not permissible if they exceed the limits (1). Biopesticides are used to control pests and approximately 175 registered biopesticide ingredients and 700 products are present in the market. The biopesticide market is valued around $200 million in the United States and may increase further. Pesticides also affect predators and insect pollinators that are beneficial to the ecosystem. Insects and pathogens develop resistance to such chemical pesticides within no time by changing their genetic constitution (2). Pesticides contain harmful chemicals that may impact human and environmental health. Pesticide residues enter the foodchain and results in ecological imbalance. This has necessitated the use of biopesticides such as entomopathogenic fungi (EPF) for controlling the insect pests (3). In the tropical and subtropical regions, multiscale microbial diversity infects arthropods and other insects by acting as parasites (4,5). *Beauveria bassiana*, *Metarhizium anisopliae*, *Verticillum hirsutella, Lecanicillium, Isaria* are the commercially available genera which are being used on a wider scale to control insect pests (6,7). Many biopesticides were developed during the past few years that can concentrate on only target species and eliminate them. They are less toxic than conventional pesticides and thus help to increase the produce. The fungus infects sucking pests like white flies, aphids, thrips, weevils, mealy bugs, and leaf hopper. Many strains that have originated from this genus help in controlling a variety of insects. Toxic substances like bassianolide, beauverolides, bassianin, beauvericin, tenellin, oxalic acid and oosporein produced by these fungi kill the pests. Smallholder farmers cannot afford to buy chemical pesticides and at the same time, they need their food grains with minimum levels of toxicity. In this paper, *B. bassiana*, an entomopathogeneic fungus is reviewed.

Advantages of biopesticides

Microbial biopesticides are biologically toxic substances that come from microorganisms like bacteria and fungi. Global biopesticide production has crossed 3000 tonnes per year. Global market for biopesticides is valued at 3.0 billion US$. This accounts for nearly 5% of the total pesticide market (8,9). The market share of biopesticides may grow further by 2050 equal to that of chemical pesticides (10,11). Biopesticides are cheaper and can avoid resistance problems. Biopesticides kill a variety of pests like locusts, grass hoppers, white flies and termites. They replace the hazardous chemical substances and promote sustainable agriculture. *B. bassiana* is environmentally friendly mycoinsecticide that produces both enzymes and secondary metabolites that play an important role in the biological control of pests. There are thousands of fungal species that can kill insects, spiders and mites (9). Use of biopesticides does not lead to resistance build-up in target pests. *B. bassiana* is one of the best entomopathogenic fungi to control insect pests (12). Different strains of *B. bassiana* play a pivotal role in killing different types of pests. Biological metabolic compounds like tennelin, bassianin, pyridovericin, pyridomacrolidin non-peptide pigment oosporein, non-ribosomally synthesized cyclodepsipeptides (beauvercins and allobeauvercins, bassianolides), and BpL lectin) are being used in industrial, pharmaceutical and agricultural industries. Alkaloids like tennelin (II), bassianin (III) pyridovericin (IV) and pyridomacrolidin (V) are found in *B. bassiana* but their exact function is unknown till now (Table 1).

Brief history, taxonomy and morphology b. bassiana

B. bassiana belongs to the Kingdom Fungi, phylum Ascomycota, class Sordariomycetes, order hypocreales and family Clavicipitaceae (13,14). It was discovered by Bassi Agostino of Lodi, Italy, in 1835 and its role in killing pests (15), though others considered that it belongs to Cordycipitaceae or Ophiocordicipitaceae (16,17). The fungus is a saprophyte, and of terrigenous origin. It infects many insect orders like Lepidoptera, Hemiptera, Coleoptera, Hymenoptera, Homoptera, and Orthoptera (18,19). The spores of this fungus are called conidia which are white to yellowish in colour with septal filaments. Diverse types of conidia are produced by *B. bassiana* with different environmental conditions. The diameter of hyphae varies from 2.5 μm to 25 μm. Both conidiophores and blastophores are infectious organs (19,20,21).

Mode of action of the fungus

Mascarin and Jaronski (22) have studied in detail about the mode of infection of *B. bassiana*. Conidia are generally dispersed either by wind or rain or even by arthropod vectors which helps the asexual spores to colonize on the susceptible hosts (23). Infection of the fungus on the host is generally by adhesion, germination, differentiation, penetration and dissemination. Conidia first recognize the host cuticle cells by electrostatic and chemical forces which then produce mucilage and germinate (22,24,25). Under ideal conditions, conidia germinate, pegs penetrate into the cuticle. The germ tub now forms a structure called an enlarged cell or appressorium (24,25). Penetration peg secrets hydrolytic enzymes such as proteases, chitinases, lipases which then dissolve the cuticle for easy penetration into insect hemolymph. The fungus grows into a single-celled organism and starts destroying the host tissues. The conidia produced from the dead host are generally carried away with the air and are capable of infecting other hosts (26,27). The fungus also produces toxins like beauvericin, beauverolides, bassinolides and isarolides which can help in the invasion of the fungus (28). Once the insect dies, the fungus now starts producing a secondary metabolite called oosporein. Initially it was believed that it functions as an insect toxin. Now it appears that this compound functions after the death of the host to counter any bacterial competition on the host corpse. This permits the fungus to utilize the nutrients and also complete the life cycle (25). Production of oosporein is modulated by a cascade of transcription factors with BbSmr1 (putative methyltransferase) acting at the upstream as a negative regulator, but triggering other genes associated in the oosporein synthesis (29,30).

S. No		Strain	Effects
1		Bba 5653	Virulent to diamond back moth and kills cater pillars
		19, 1205, 1215	Controls F. oxysporum, f.ps lycopersici race 3 in tomato plants
		Bb GHA strain	Kills variety of insects and weakens insects outer coat and kill them
		CNPMF 407, CNPMF 218, and CNPMF 416	Play an important role in preventing pests. CNPMF 218 controls C. sordidus (banana weevil)
		Bb (202)	Kills plant sucking insects (31)
		PPRI 5339	Mortality of eggs and motile stages (valuation of two entomopathogenic fungi, *B. bassiana* and *Metarhizium anisopliae*, for the control of carmine spider mite, *Tetranychus cinnabarinus* (Boisduval) under greenhouse conditions.
		B. bassian a 146 strain	Effects eggs and larvae of Castniid Palm borer
		Native strain of B.bassian a NI8ARSEF8889	Shows effect on on green lace wigs, Chrysoperla rufilabris
		B. bassiana GHA (ARSEF3620, ATCC74250) GHA	Fungal biocontrol agents Effects insects and pests
		B.b -COO1	Infects T. infetants (32)
2	Bioactive metabolic compounds	N-decane,1-pentadecene, alkylbenzene derivatives and methyl -alkyl ketones (33) B. bassiana extracts of ethyl acetate and acetone	Shows antimicrobial,snailicidal and antioxidant activities

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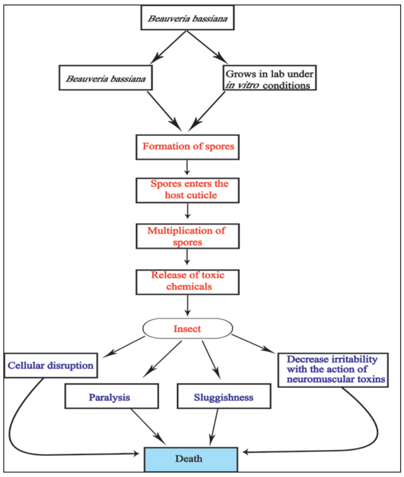
3	Biologically active metabolites	Tennelin, bassianin, pyridovericin, pyridomacrolidin Non-peptide pigment oosporein Non-ribosomally synthesized cyclodepsipeptides (beauvercins and allobeauvercins, bassianolides), and BpL lectin) Beauvericin A (2) and beauvericin A (3) two novel cyclodepsipepdide analogues (35) B. bassiana-22 B. bassiana- 28	Used in industrial, pharmaceutical and agriculture industries (34) Act against Gram positive bacteria and mycobacteria Effects different stages of larvae and targets several insects like root weevils, plant hoppers, spittle bugs, white grubs. Effective against CX. Quinquefasciatus pupae (36)
4	Volatile organic compounds	Diisopropyl naphthalenes Ethanol sesquiterpenes benzene acetal dehyde 1-pentadecene and methyl alkyl ketones (33)	Used as tool for detection of fungusbased on their characteristic capillary gas chromatography and mass spectrometry
5	Alkaloids	Alkaloids like tennelin (II), bassianin (III) pyridovericin (IV) and pyridomacrolidin (V) have been identified Tennelin (II), bassianin (III) (37), pyridovericin (IV) and pyridomacrolidin (V) have been found (38,39)	Exact role in fungal interaction with the host is unknown till now
6	Pigments	2-pyridone alkaloids tennelin (II) and bassianin (III), a red pigment-dibenzoquinone pigment oosporein (VI) (40)	They have antimicrobial and antiviral properties. They are yellow in colour.

Table 1. Beauveria bassiana compounds and their activities

Applications of beauveria bassiana

Spores of *B. bassiana* do not develop at high temperatures, and optimum is 18 and 29 ^{0}C. It can be used in association with other natural enemies, pathogens and pesticides (41,42,43). Spores produced by the fungus are applied to the affected crops in the form of emulsified suspension or wet powder. Fungal conidia treated with oosporein has been found highly effective against Aphididae, Cercopidae, Coleoptera, Delphaacidae, and Lepidoptera (44,45). Further, protein extract of the *B. bassiana* as granule can be mixed with inorganic material or emulsifiable concentrates.



Such formulations have been found effective against many insect pests (46).

Figure 1. Flow chart depicts the mechanism of action of Beauveria bassiana in killing the pests.

Genetic tinkering and fungal toxicity improvement

It is vital for us to improve the fungus genetically so that it can survive under harsh environments like heavy rain, photooxidative stress and ultraviolet light (47). Glare et al. (48) stressed the need for finding out the genes associated with virulence. Though genetic diversity among *B. bassiana* isolates is very high (49), finding target genes is still a challenge. It appears that protease-related genes and their transcription factors are crucial for improving the virulence of *B. bassiana*. Screening of the differentilly expressed genes has been carried out (50,51), which may help to scrutinize mutants and the associated virulence genes. It is now possible to obtain lines with better virulence by gene manipulation techniques such as CRISPR-Cas9 (52,53). Protein engineering can also be thought over for modulating the target proteins and to obtain strains with superior virulence to insect pests (54).

Conclusions

One of the most interesting integrated pest management practices is the use of *B. bassiana* entomopathogenic fungus which kills diverse types of insects in agricultural crops. It is found naturally in soil and can be cultured in the aboratory on a large scale. The insecticidal activity of *B. bassiana* is rapid compared to other fungi and an added advantage of this fungus is, conidia can be preserved for a long time. It is very simple to culture and strains of *B. bassiana* can be maintained in a laboratory conditions. It does not harm mammals, birds and human beings and other non-target organisms. So, the organism can be used effectively against a wide spectrum of insect pests for sustainable development. Its extract if sprayed on crop plants as an elicitor might help them to protect against insect pathogens. Bioactive compounds like oosporein, oxalic acid and tenellin must be exploited as emulsified wet powder. Further, strategies must be evolved to make genetically modified *B. bassiana* that is highly virulent to insects, but does not harm the environment.

Availability of data and materials The material used in this manuscript is available with the author.

Competing interest Authors declare no competing interest.

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