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Fungal Based Biopesticide Formulations Used Against Insect Pests

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Putting together the components in appropriate relationship or structure, according to a formula are referred as **Formulations.** Biopesticides are the formulated form of active ingredients based on micro organisms or its metabolites or natural products. Biopesticide formulation is required to stabilise the active metabolite or microbe, optimise transport to the target, protect the biopesticide during storage and in the field, improve efficacy, and facilitate application.

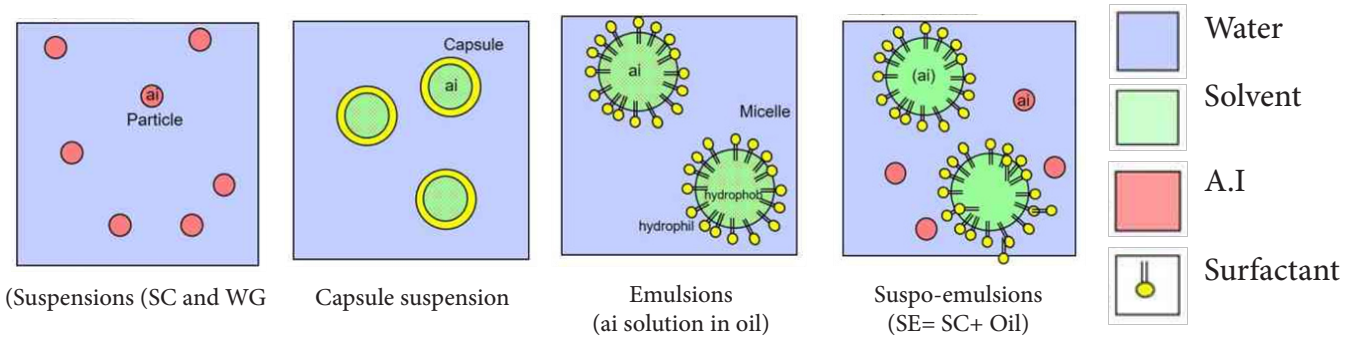
Formulation types

Because of variances in environmental conditions, biopesticides may be synthesised in several forms, each customised to a specific market. The majority of biopesticides are dry (solid) formulations.

Dry formulations of inactive fungal spores are likely to have an extended shelf life in contrast to most liquid formulations. However, dry formulations may have a number of drawbacks, including poor field performance and the danger of nozzle obstruction.

Liquid biopesticide formulations often contain biopesticide metabolites or microorganisms suspended in a medium comprising adjuvants, protectants, and nutrients. Liquid biopesticide formulations address the shelf life and field efficacy concerns while also being easily applied with existing field equipment.

Dry formulations	Liquid formulations
1. Dusts (DP)	1.Water-based:
2. Seed dressing formulations – Powders for seed dressing (DS)	• Suspension concentrate (SC) • Suspo-emulsions (SE)
3. Granules (GR)	• Capsule suspension (CS)
4. Micro granules (MG)	2. Oil-based
5. Water dispersible granules (WG)	3. Polymer- based
6. Wettable powders (WP)	4. Ultra low volume liquids (UL)
	5. Combinations.



(Suspensions (SC and WG | Capsule suspension | Emulsions (ai solution in oil) | Suspo-emulsions (SE= SC+ Oil)

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Inert Ingredients: Formulation components other than the active ingredient or microorganism are called inerts. Inert ingredients may contribute to improve product performance by optimising contact to leaf, soil or insect surfaces, have low toxicity, reduce desiccation, increases shelf life, increases solubility, increases suspensibility in water, increases survival and viability and storage stability. Activators help in distribution, retention and uptake of biopesticides whwere as modifiers help in handling, safety and application of biopesticides.

Adjuvants are of three types.

1. Activator adjuvants:
    a) Wetters
    b) Spreaders
    c) Penetrants/translocants
2. Spray modifier adjuvants:
    a) Stickers
    b) Drift retardants (thickeners, typically polymers)
    c) Humectants
3. Utility modifier adjuvants:
    a) AMS (ammonium salts)
    b) Antifoam agents
    c) Suspension agents

For biopesticides, formulation inerts must be low toxicity, both in terms of the environment and health, as well as the survivability of the microorganism being formulated. Chitosan is frequently used in biopesticide formulations (for example, hydrogel production), and its potential antibacterial properties must be considered when developing microbial biopesticides.

Fungi pathogenic to insect pests of crops

Fungus	Target pest	Crop
Beauveria bassiana PDRL1187.	*Lipaphis erysimi*, *Aphis craccivora*	Canola
Beauveria bassiana BB-01	*Schizaphis graminum*, *Rhopalosiphum padi*, *Brevicoryne brassicae* and *Lipaphis erysimi*	In Laboratory
Beauvaria bassiana	Whiteflies	Melon
Verticillium lecanii V17, PDRL922	*Myzus persicae*	Cabbage
Verticillium lecanii	*Myzus persicae*, *Lipaphis erysimi*	Cabbage, Canola

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Paecilomyces fumosoroseus n32	*Lipaphis erysimi*, *Plutella xylostella*	Chili
Metarhizium anisopliae L6, M440. PDRL711, PDRL526	*Lipaphis erysımı*, *Aphis gossypii*. *Aphis craccivora*	Cabbage, Canola
Peacilomices lilcinus PDRL812	*Lipaphis erysimi*	Cabbage, Canola
Hirsutella thompsonii	*Aphis craccivora*	Cowpea
Cladossporium oxysporium	*Aphis craccivora*	Cowpea

Commercially available mycoinsecticides with their target pest and producer

Fungus	Brand Name	Target Pest	Producer
Beauveria bassiana	Mycotrol WP	Whiteflies/Aphids/Thrips	Emerald BioAgriculture Corp. (Previously Mycotech Corp.)
	Myco-Jaal	Diamondback moth	Pest Control India (Pvt) Ltd.
	Conidia	Coffee berry borer	AgrEvo
	Naturalis L	Whiteflies/Aphids/Thrips/White grubs	Troy Biosciences Inc.
Metarhizium flavoviride	Biogreen	Scarab larvae	Bio-Care Technology
Metarhizium anisopliae	Bioblast	Termites	Ecoscience
	DeepGreen	White grub	Live System Technology S.A.
Isaria fumosoroseus	PFR-97	Whitefly	Eco-tek
	Pae-Sin	Whitefly	Agrobionsa
Metarhizium anisopliae var. acridum	Green Muscle	Locust, Grasshoppers	Biological Control Products SA (Pty) Ltd (under licence from CABI, UK)
Lagenidium giganteum	Laginex	Mosquitoes	Agra Quest
Beauveria brongniartii	Betel	Scarab beetle larvae	NPP (calioppe)
Nomuraea rileyi	Numoraea 50	Lepidoptera	Ago Biocontrol
Hirsutella thompsonii	Mycohit	Acari	Plantrich Chemicals & Biofertilizer Ltd
Conidiobolus thromboides	Vektor 25SL	Aphids/Thrips/ Whiteflies	Mycolab
Lecanicillium longisporum	Vertalec	Aphids	Kopper Biological System.
L. muscarium	Mycotal	Whiteflies/Thrips	Kopper Biological System.
B. bassiana+ *M. anisopliae*+ *Ifumosoroseu*	Tri-Sin	Psyllid	Agrobiologicos del Noroeste S.A. de C.V. (Agrobionsa)

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Challenges for Biopesticide Formulations

The key difference between the conventional (chemical) pesticide and biopesticide formulation is the living nature of the biopesticide, and their biological viability which is sensitive to storage conditions and environment. Presence of additional fermenting materials besides the microbes themselves that reacts with formulation ingredients is a major challenge for the formulation of microbial biopesticides.

a) Shelf life (storage stability)

An additional challenge in biopesticide formulation is that biopesticides have a shorter shelf life (in weeks) than conventional pesticides (in years). Shelf life and viability can be enhanced by lowering the storage temperature through freezing or refrigeration. Microorganisms can be stored frozen or refrigerated in culture broth or a suitable buffer. Aside from storage, greater shelf life can be achieved by increasing the number of microorganisms in the product, ensuring viability despite a subsequent reduction in their population. Formulations should include carbon sources (nutrients) such as molasses or peptone, as well as moisture-retaining polymers, to ensure microbial survival and efficacy after delivery.

b) Delivery

Since most biopesticides are particulate, agitation of the spray suspension is critical to avoid precipitation in the spray tank. Biopesticides are applied using regular application equipment, and further filtering and straining, as well as the use of large-orifice nozzles, are recommended to avoid clogging. When biopesticides are administered in the field, they are subjected to adverse environmental circumstances such as sunshine (UV), variable moisture conditions, plant physiological and biochemical reactions, and competition from microorganisms already present on leaf surfaces. These conditions may result in reduced persistence once the biopesticide is applied to crops. UV-stability can be addressed by adding protectants (sunscreens like oxybenzone and light blockers like lignin), including antioxidant-rich natural ingredients,

Since many biopesticides take time to control the insect or pathogen, farmers may believe that the treatment is ineffective and reapply unnecessary amounts. For optimal application of these products, growers must read labels carefully, understand how the product works, and conduct appropriate scouting. This allows them to reap the full benefits of biopesticides and achieve consistent results. Hydrogels can be utilised in slow-release biopesticide formulations to promote nutrient and moisture retention, additionally minimising degradation, which increases biopesticide viability and efficacy. Hydrogels are composed of a network of hydrophilic polymer chains that can contain a high amount of water.

The trend in formulating conventional pesticides and biopesticides is to move away from dusts, wettable powders and suspension concentrates to water dispersible granules. Controlled release formulations are being created to improve efficacy, while nanotechnology is expected to yield new forms of formulations such as nanoemulsions, nanosuspensions, and nanocapsules. Another area of focus is selecting adequate adjuvants for maximum biopesticidal efficacy. Collaboration between biologists and chemists is enabling the development and introduction of new formulations and uses, minimising field inconsistency, and encouraging producers to adopt this new technology. Attention is also being paid to distribution and application strategies, specifically the impact of plant defence induction kinetics on application, timing and location.

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