**Table 3. Commercial products of the six species of hypocrealean fungi.**

| *Species Name* | *Product Name* | *Product Features* | *Registered Uses* |
|---|---|---|---|
| *Beauveria bassiana* | BotaniGard 22WP; Mycotrol | Not harmful to bees. | Vegetables, fruits, berries, ornamentals, herbs, spices and turf. |
| *Cordyceps fumosorosea* | PRF-97; Ancora; No Fly | Both OMRI (Organic Materials Review Institute) and NOP (National Organic Program) approved. Can be used in both organic and non-organic farming. Has limited effects on beneficial nematodes, mite predators, lady beetles, etc. Has excellent compatibility with other IPM tools such as beneficial arthropods, chemical pesticides, herbicides and most fertilizers. Can be mixed with copper-based fungicides. | **PRF-97:** vegetables, fruits, tobacco and other food crops. **Ancora:** vegetables, fruits, ornamental plants grown in greenhouses or other protected environments or in nurseries. **No Fly:** vegetables, ornamentals, herbs and medicinal plants in the greenhouse or other indoor growing facilities. |
| *Akanthomyces muscarius* | Mycotal | Successful performance depends on suitable temperature and relative humidity and the timing of application. | Greenhouse crops including tomato, cucumber, pepper, chili, ornamentals, aubergine (eggplant), runner bean, broad bean, French bean, lettuce, squash, gherkin, melon, pumpkin and courgetti. |
| *Metarhizium anisopliae* species complex | Met52; Tick-Ex EC | This product is more persistent when incorporated in the soil than when applied to foliage. | Onions, celery, lettuce, spinach, peppers, tomatoes, grape, strawberry, cranberry, raspberry, blackberry, ornamentals and turf. |
| *Purpureocillium lilacinum* | Melocon; BioAct WG; NemOut WG | The primary function of this product is to target nematodes. | Vegetables, fruits, tobacco, ornamentals, cotton, peanut, tree nuts and turf. |
| *Trichoderma harzianum* | RootShield WP | This product will aid in the prevention of plant diseases. Best used as a fungicide. It is useful in both field and greenhouse settings. | Forage crops, cereal grains, fruits, vegetables, oilseeds, peanut, shade house/ nursery crops, ornamentals, tobacco, tree nuts, turfgrass and seed treatments. |

Note: Always refer to the product label for specifics before applying any pesticide product.
Refer to the label for a full list of crops for which each product is registered.

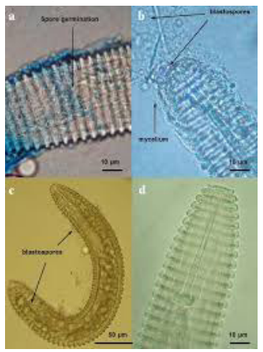


**Figure 6. The infection process of *Purpureocillium lilacinum* on *Criconemoides* sp. a. spores germinating on the nematode cuticle at 24 hours after inoculation (1,000 x), b. mycelium and blastospores emerging from the body 72 hours after inoculation (1,000 x), c. nematode completely degraded by the fungus at 120 hours after inoculation (400x), d. control specimen at 120 hours after inoculation (1000x).** (Lopez-Lima et al., 2014)



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EXTENSION

# Fungi Used for Pest Management in Crop Production

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Bizhen Hu
Extension Small Farm Horticulturist

Che Deer
Graduate Student

Eric Rebek
State Extension Specialist, Horticultural Entomology

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Entomopathogenic fungi are organisms that infect and parasitize arthropod pests. These fungi are used in integrated pest management (IPM) programs to kill, disable or manage target pests. These fungi belong to the order Hypocreales and the most common species of these hypocrealean fungi used in IPM programs targeting arthropod pests are *Beauveria bassiana, Cordyceps fumosorosea* (formerly *Isaria fumosorosea*), *Akanthomyces muscarius* (formerly *Lecanicillium muscarium*), *Purpureocillium lilacinum* and the *Metarhizium anisopliae* species complex (including *M. robertsii* and *M. brunneum*). In addition, *P. lilacinum* and *Trichoderma harzianum*, are used to control plant-parasitic nematodes and fungal plant pathogens, respectively. These species are known to kill pests at high rates in nature. Unlike many chemical insecticides, entomopathogenic fungi specifically target pests in crop production and pose little threat to beneficial organisms, including pollinators. As biological control agents, these fungi provide an effective, environmentally friendly alternative to conventional pesticides for managing key agricultural pests.

This fact sheet provides background information on these fungi used for pest management in crop production, including their target pests and commercial products that contain spores of these fungal agents.

**Figure 1. Western tarnished plant bug (*Lygus hesperus*) killed by the entomopathogenic fungus, *Beauveria bassiana*.** (Photo by Surendra Dara; Dara, 2017)

**Figure 2. Infected *Diaphorina citri* adult that was dusted with *Cordyceps fumosorosea* blastospores and incubated for seven days.** (Chow et al., 2018)

**Table 1. Six hypocrealean fungi used for pest control and their modes of action.**

| *Species Name* | *Background* | *Mode of action* |
|---|---|---|
| *Beauveria bassiana* | This species is widespread and primarily found in the soil. The strain GHA is commonly used in integrated pest management. | This species causes what is known as "white muscardine disease," which appears as a white mold-like growth on infected hosts. The fungi infiltrate the host and attack the digestive system. Ultimately, the fungi shut down the host's internal organs and form a white mycelial mass on the host cadaver. Spores are formed and released into the air to infect nearby hosts. |
| *Cordyceps fumosorosea* | This species has been used to control grayscale mealybug populations in Hawaii to improve pineapple production. A related species, *Cordyceps javanica*, helps stop powdery mildew infections of crop foliage. | This fungus enters the host through the cuticle. The cuticle acts as a barrier to infection for most insects, but it is ineffective in safeguarding against *Cordyceps fumosorosea*. Like other entomopathogenic fungi, this species secretes enzymes that degrade the host's cuticle and provide an entry point for host penetration. Ultimately, the fungi spread throughout the host, consuming tissues and eventually forming spores that cover the host cadaver and spread to nearby hosts. |
| *Akanthomyces muscarius* | Temperature and relative humidity are the major environmental factors that determine optimal performance of this fungus under greenhouse and field conditions. The ideal temperature range is 18 C to 30 C, and ideal relative humidity is 70%. | This species infects a host by directly penetrating the cuticle like *Cordyceps* and *Beauveria* spp. or by growing on the exterior of the host. This fungus is highly infectious and will spread throughout a dense pest population in a matter of days. The fungus rapidly consumes vital tissues and nutrients, and host death occurs within two to three days. |
| *Metarhizium anisopliae* species complex | This common fungus is a generalist that infects insects belonging to more than seven orders. | This species causes "green muscardine disease" of insect hosts. Upon encountering a host, spores adhere to the body and then penetrate the cuticle, allowing the fungus to infiltrate the host and take over vital organs. Ultimately, green spores form on the surface of cadavers and are released into the environment, spreading to other hosts. |
| *Purpureocillium lilacinum* | This species is hardy within a wide range of temperatures (20 C to 35 C) and pH (4 to 9) and can grow in many substrates. | This fungus has an affinity for nematode eggs. It has been useful in reducing populations of the root-knot nematode and cyst nematode. |
| *Trichoderma harzianum* | This fungus is found in nearly all soils. It parasitizes and kills other fungi and can colonize the roots of some plants. The optimal temperature range is 15 C to 2 C, and the optimal pH range is 2 to 6. | This fungus can form symbiotic relationships with different living organisms. Seed treatment promotes seed germination, seedling growth and protection against pathogens. This fungus is excellent at killing both pathogens and parasitic nematodes. |



**Table 2. Target pests of the six species of hypocrealean fungi.**

| *Species Name* | *Target Pests* |
|---|---|
| *Beauveria bassiana* | Aphids, whiteflies, mealybugs, psyllids, chinch bugs, lygus bugs, grasshoppers, stink bugs, thrips, termites, fire ants, flies, stem borers, fungus gnats, shoreflies, bark beetles, black vine weevil, boll weevil, cereal leaf beetle, Colorado potato beetle, Japanese beetle, Mexican bean beetle, red palm weevil, strawberry root weevil, coffee borer, emerald ash borer, caterpillars and mites. |
| *Cordyceps fumosorosea* | Aphids, citrus leaf miner, beetle larvae, weevils, leafminers, caterpillars, mealybugs, phorid flies, psyllids, root worms, sciarid flies, European red mite, brown mite, apple rust mite, spider mites, broad mites, thrips, whiteflies and wireworms. |
| *Akanthomyces muscarius* | Aphids, whiteflies, scales, mealybugs and thrips. |
| *Metarhizium anisopliae* species complex | Ticks, root weevils, flies, gnats, thrips, locusts, grasshoppers, cockchafers, spittlebugs, various grubs, borers and mosquitoes. |
| *Purpureocillium lilacinum* | Root-knot and cyst nematodes, thrips, whiteflies, aphids, various beetles and mosquitoes. |
| *Trichoderma harzianum* | Pythium, rhizoctonia, fusarium, thielaviopsis and cylindrocladium. |

Note: Effectiveness against each target pest listed depends on the specific fungal strain used and the growing environment. Sourced from University of Michigan, University of Connecticut, Cornell Extension services, Hunter et al. (2011), Toledo-Hernández et al. (2019), the PRF-97 label, the Mycotal label and the RootShield-WP label.

**Figure 3. *Akanthomyces muscarius* (formerly *Lecanicillium muscarium*) sporulation on pest.** (Koppert Biological Systems product Mycotal)

**Figure 5. Close up image showing *Trichoderma harzianum* culture.** (Koppert Biological Systems)

**Figure 4. Cockroach killed by *Metarhizium anisopliae*.** (Image Credit: Chengshu Wang and Yuxian Xia, 2011 PLoS Genetics Issue Image)