Enhancing the efficacy of the entomopathogenic fungus *Metarhizium anisopliae* for the control of black vine weevil larvae in food and non-food crops

T.M. Butt, F.A. Shah and M.A. Ansari

Department of Pure and Applied Ecology, Swansea University, SA2 8PP, Swansea, UK

Introduction

The black vine weevil (BVW), *Otiorhynchus sulcatus,* is considered one of the most important pests of hardy nursery stock and soft fruit causing annual losses of ca. £30 million. Adult BVW feed on the aerial parts of plants and leave characteristic notches in leaves (Fig. 1). Eggs are laid around the base of host plants. The subterranean larvae feed on plant roots and crown (Fig. 2). Feeding damage can result in stunted growth, reduced crop yields and even plant death. Larval control still heavily depends on the use of chemical pesticides but many chemicals have been withdrawn (e.g. Fipronil) or are under threat of being withdrawn (e.g. chlorpyrifos). A strain of the entomopathogenic fungus *Metarhizium anisopliae (*V275) has been identified which is highly pathogenic to BVW (Fig. 3). It offers a benign alternative to chemical pesticides but is slow acting especially at low temperatures. Recent studies show that *M. anisopliae* works synergistically with chemical insecticides and entomopathogenic nematodes (EPN) allowing each agent to be used at lower application rates without a decline in efficacy even at relatively low temperatures (Shah *et al*., 2007; Ansarai *et al.,* 2008, 2010). Exploiting synergies between these agents reduces or eliminates chemical inputs and offers potential savings for growers. Furthermore, this strategy is in accord with EU Directive 2009/128EC which makes it obligatory on EU Member States to implement the "*principles of integrated pest management, with* ***priority given wherever possible to non-chemical methods*** *of plant protection and pest and crop management".*

Fig 1. Adult BVW feeding results in characteristic irregular-shaped notches in leaf margins.

Fig 2. *Euonymus* plant treated (A) and untreated (B) with *M. anisopliae* and exposed to BVW larvae. Treated plants are protected against BVW damage.

Synergy between *M. anisopliae* and low rates of chemical insecticide

- *M. anisopliae* was efficacious in a wide range of growing media (peat, coir, bark, peat blended with 10% or 20% composted green waste) whether premixed or applied a drench.
- Chemical insecticides (e.g. chlorpyrifos, thiacloprid, imidacloprid, fipronil) used at 1% or 10% the recommended rate enhanced the efficacy of *M. anisopliae* resulting in control of BVW similar to the recommended rate of the pesticide (Fig. 4).
- Insecticides stopped insects from feeding giving immediate plant protection and gave the fungus more time to kill its host.
- This strategy reduced pesticide inputs and operator exposure to harmful chemicals
- Since there are no residue issues it allows for continuous cropping of fruit (e.g. strawberries).

Synergy between *M. anisopliae* and entomopathogenic nematodes

- *M. anisopliae* is compatible with commercial strains of the EPN *Steinernema kraussei* (cold tolerant), *S. feltaei*, *Heterorhabditis megidis* and the Swansea University isolate of *H. bacteriophora*
- *M. anisopliae* and EPN work synergistically in controlling BVW larvae (Figs. 5, 6).
- It allows *M. anisopliae*, *H. bacteriophora* and *S. kraussei* to be used at 10%, 6% and 50% the recommended rate, respectively (Figs. 5, 6).
- Strong synergy was observed when the EPN was applied simultaneously with *M. anisopliae* or two weeks after applying the fungus.
- The synergy provide the potential for eradicating BVW larvae at significantly lower costs to growers compared with using either EPN or *M. anisopliae* alone. Furthermore, since *S. kraussei* works well at low temperatures the synergistic combination offers a solution to controlling overwintering BVW larvae (Fig. 6).
- The strategy offers a pesticide free solution for organic growers.

Abbreviations: Ma = *M. anisopliae,* Im = Imidacloprid, Fip = Fipronil, PM = Premixed, DR = Drench, RD/FC = Recommended dose, SLD = Sublethal dose, IJ= infective juvenile, Hb = *Heterorhabditis bacteriophora,* Sk = *Steinernema kraussei*

References.

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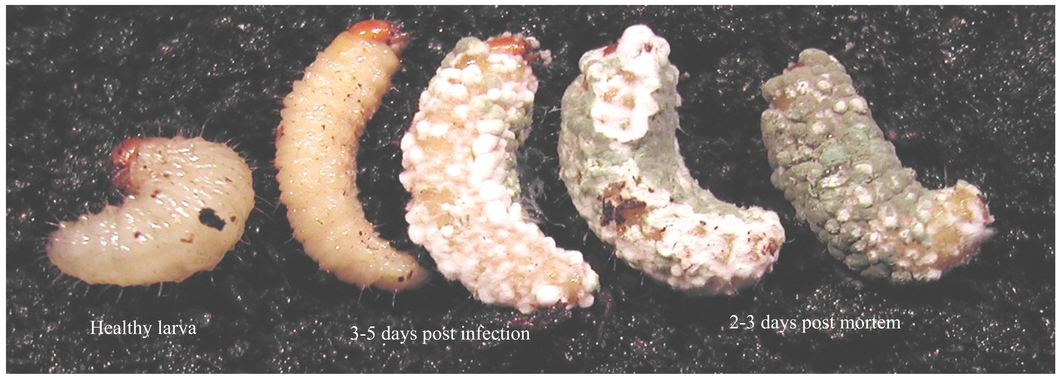

Fig 3. BVW larvae at different stages of infection with *M. anisopliae*

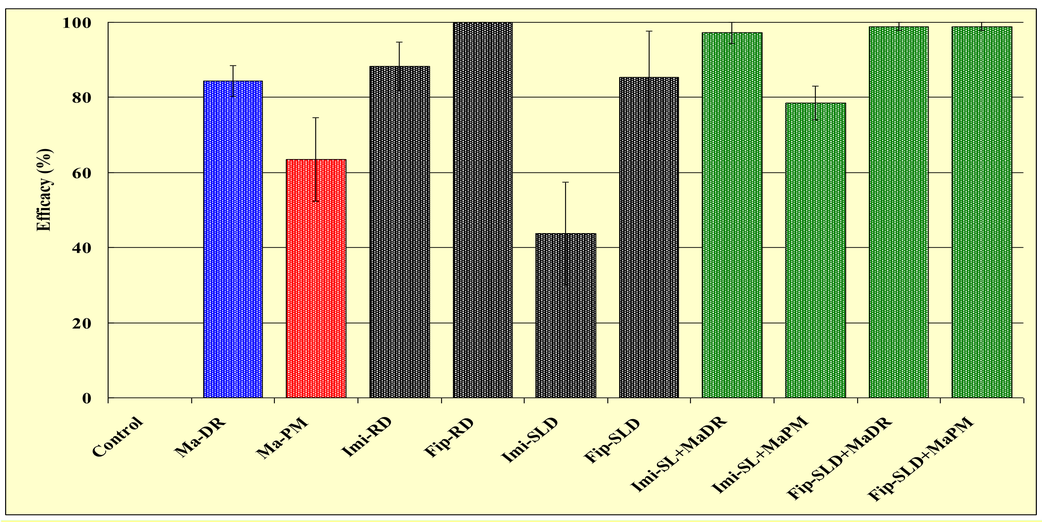

Fig 4. Efficacy of *M. anisopliae* (Ma) and chemical insecticides against BVW larvae in peat.

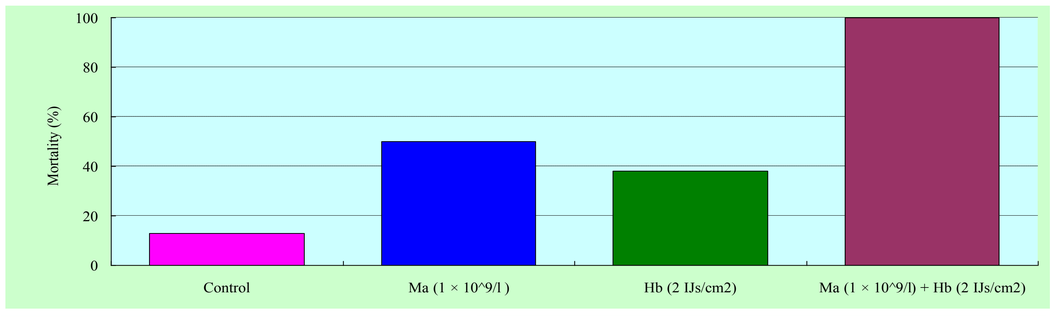

Fig 5. Efficacy of *M. anisopliae* and *H. bacteriophora* against BVW larvae in *Euonymus*.

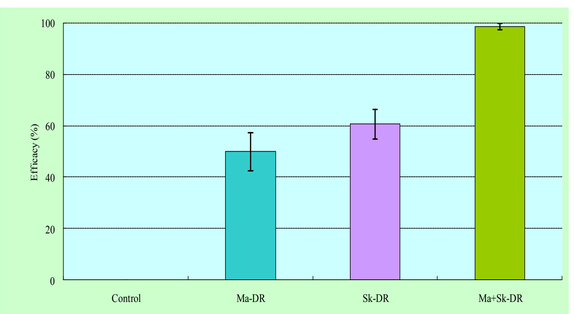

Fig. 6 (right) Efficacy of *M. anisopliae* and *S. kraussei* against overwintering BVW larvae in strawberry growbags.