Persistence of augmented *Metarhizium anisopliae* and *Beauveria bassiana* in Finnish agricultural soils

Irene VÄNNINEN1, Johanna TYNI-JUSLIN1 and Heikki HOKKANEN2
1Agricultural Research Centre, Plant Protection, Jokioinen, Finland; 2University of Helsinki, Department of Applied Zoology, Helsinki University, Finland

Received 21 October 1998; accepted in revised from 27 March 2000

**Abstract.** The persistence and penetration into soil of surface-applied unformulated conidia of two isolates of *Metarhizium anisopliae* and one of *Beauveria bassiana* at sites with clay, peat and two kinds of sand as their soil types and at depths of from 0 to 20 cm was studied in 1988–1991 under conditions characterized by permanent snow cover and frozen soil in the winter time. At 0–5 cm depth, *M. anisopliae* persisted throughout the experiment at all sites, clay being the most and peat the least favourable soil for persistence. Clay and one of the sandy soils were the least and peat the most conducive soil to penetration of *M. anisopliae* from the surface to deeper soil layers and persistence therein. Differences in persistence were evident between the two *M. anisopliae* isolates in the sandy and peat sites, but not in the clay site. Three years post-application there were still enough infectious propagules of *M. anisopliae* in soil of all sites to infect over 80% of the *Tenebrio molitor* larvae used as baits in samples taken from the cylinders of all soils. All the augmented propagules of *B. bassiana* disappeared during the first winter after application in clay and one of the two sandy sites, but some persistence one year post-inoculation was evident at 0–5 depth in one of the sand soils and at 0–5 and 5–10 cm depths in peat.

**Key words:** biological control, ecology, entomogenous fungi, Finland, persistence, Deuteromycetes

**Introduction**

The persistence in soil of the inoculum of fungal entomopathogens is a prerequisite for successful control efficacy when the fungus is applied to the soil before the crop is sown. Presowing application in which the fungus is mixed with the soil before the crop is sown is desirable when the pest does not appear until later in the growing season. This application method has been shown to give better persistence than spraying the inoculum onto the soil surface (Gaugler et al., 1989; but for contradictory results obtained in Brazil, see Quintela et al., 1992). Persistence is also necessary when the soil-
dwell stage of the pest is long, or control for several years is required, as in pastures (Rath et al., 1995).

The many laboratory studies conducted with *Beauveria bassiana* (Bals.) Vuill. have shed light on the manner in which persistence, percolation and long-term efficacy of fungal propagules are affected by different factors in the soil environment: by soil type (Storey and Gardner, 1987, 1988; Studdert et al., 1990), moisture conditions (Studdert et al., 1990), temperature (Lingg and Donaldson, 1981; Studdert et al., 1990), pH, organic matter content and level of conductivity (Lingg and Donaldson, 1981) and antagonistic organisms (Fargues et al., 1983; Fargues and Robert, 1985). Long-term semi-field or field studies are not as numerous (Muller-Kögler and Stein, 1970; Muller-Kögler and Zimmermann, 1986; Gaugler et al., 1989; Storey et al., 1989; Quintela et al., 1992), and only few experiments have been conducted in climates with permanent snow cover and frozen soil in winter (Wojciechowska et al., 1977; Bajan and Fedorko, 1982). The persistence of *Metarhizium anisopliae* (Metsch.) Sorok. in soil appears to have attracted little attention (Muller-Kögler, 1976; Fargues and Robert, 1985; Zimmermann, 1992; Li and Holdom, 1993), even though it is well able to tolerate the conditions in the soil (Fargues and Robert, 1985). It appears also to be more tolerant than *B. bassiana* to disturbance by cultivation, at least in a boreal climate (Vänninen, 1996).

In the context of examining the natural occurrence, ecology and use of entomopathogenic fungi in agricultural and forest soils in Finland (Vänninen et al., 1989; Vänninen, 1996; Vänninen and Hokkanen, 1997), we studied the persistence of unformulated conidia applied to field soil in a 3-year experiment (1988–1991) designed to show whether *M. anisopliae* and *B. bassiana* would have sufficient persistence under northern conditions to be used for the long-term control of soil-dwelling pests. At the same time, the study provides information on the safety aspects (Zimmermann, 1992) of applying large quantities of these fungal species to the soil under conditions where freezing of soil in winter is likely to slow down the speed of degradation of the inoculum (cf. Lingg and Donaldson, 1981).

**Material and methods**

**Experimental sites**

All experimental sites were located in fields that had long been under cultivation of various types of crops (cabbage, oil seed rape, cereals). Three of the sites, the Agricultural Research Centre (MTT), Rehtijärvi and Kuuma, are located within a 10-km radius of each other in the municipality of Jokioinen (120 km north-west of Helsinki). The fourth site is located 60 km north-west