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RESEARCH ARTICLE

Sub-lethal effects of *Beauveria bassiana* (Balsamo) on field populations of the potato tuberworm *Phthorimaea operculella* Zeller in China

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Abstract

The potato tuberworm *Phthorimaea operculella* Zeller, is one of the most important potato pests worldwide including China. Several reports indicate that *P. operculella* could be controlled biologically by the use of beneficial fungus such as *Beauveria bassiana* (Bals.-Criv) Vuill. However, limited information is available under growing conditions in China. Thus, this study evaluated the sub-lethal effects of *B. bassiana* on the offspring of *P. operculella* by the age-stage, two-sex life table. First instar larva of *P. operculella* were treated with 1×10^7 conidia mL^{-1} of the fungus, and several biological parameters were evaluated. The fecundity, duration of the egg stage, all larval stages, pre-adult stage, and total pre-oviposition period, were significantly shorter than the control treatment. Offspring of treated parents, presented a net reproductive rate and mean generation time of 17.43 per day and 24.98 days, respectively, compared to 65.79 per day and 26.51 days for the untreated ones. This study provides basic information to help understanding the potential long-term effects of entomopathogenic fungi on *P. operculella*.

Keywords: potato tubermoth, sub-lethal effects, biological control, management

1. Introduction

The potato tuberworm, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae), is considered to be one of the most important potato (*Solanum tuberosum* L.) pests worldwide including China. In recent years, China has been boosting potato production to make potato the fourth major crop produced in the country following rice, wheat and maize (Zhang *et al*. 2017). *Phthorimaea operculella* has a close evolutionary relationship with *Solanaceous* crops that is enhanced by the insect high adaptability to daily and seasonal changes, high reproductive potential, and high survival rate even under extreme temperatures (Dogramaci *et al*. 2008). The pest can thrive under field and storage conditions (Bacon 1960; Foot 1974b; Haines 1977; Shelton and Wyman 1979a, b; Briese 1986; Herman *et al*. 2005). In China, *P. operculella* was first reported in Guangxi in 1937 (Li and Zhang 2005); at present, *P. operculella* is widely distributed in China and mainly occurs in Yunnan, Guizhou and Sichuan (Xu 1985). All these regions are key

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potato production areas. The pest is difficult to control, and over the years insecticides have been used extensively (Foot 1974a; Trivedi and Rajagopal 1992), however, no resistance to pesticides has been reported yet, but basic line information to determine pesticide susceptibility has already been collected (Dobie 2010).

P. *operculella* adults deposit eggs in potato foliage or close to tubers, while the larvae mine leaves, stems, and petioles and excavate tunnels through potato tubers (Rondon *et al*. 2007; Yuan *et al*. 2017). This wider niche ability makes this insect difficult to control. In the U.S. Pacific Northwest, there are many pesticides registered to control *P*. *operculella* (Rondon *et al*. 2007), while in China, there are several products that effectively control the pest (Du *et al*. 2006); however, El-kady (2011) reported that continuous use of pesticides promoted pesticide resistance in *P*. *operculella* and better management program are needed.

Under low pesticide input conditions, *P*. *operculella* can be controlled effectively by the use of natural enemies (Kroschel and Koch 1996; Coll *et al*. 2000). *Beauveria bassiana* (Bals.-Criv) Vuill has proved to be an effective biological control agent of *P*. *operculella* in the laboratory (Li and Zhang 2005). The advantages of using natural products such as *B*. *bassiana* are numerous, including being safe to the environment when compared to chemical insecticides, relatively easy to handle and safer to handlers. However, *B*. *bassiana* depends on favorable environmental conditions during application and they are heavily humidity dependable (Shah and Pell 2003). Microbial control is not yet developed for massive commercial production and more information is still needed to prove the effectiveness of this method (Kroschel and Koch 1996; Sporleder *et al*. 2001). In high pesticide input systems, the effect of pesticides on natural enemies of *P*. *operculella* is unknown (Koss 2003). Most researches of pesticides have focused on their lethal effects on *P*. *operculella* developmental stages (Desneux *et al*. 2007); however, data concerning sub-lethal effects are limited. In general, besides the direct mortality induced by any given pesticide, the sub-lethal effect must be considered for a completely assessment of pesticide impact and effectiveness (Desneux *et al*. 2007).

Entomopathogens are a good alternative to pesticides since they contribute to the natural regulation of arthropod populations (Evans 2008). Seyed-Talebi *et al*. (2012) studied the sub-lethal effect of *B*. *bassiana* on the life table parameters of two-spotted spider mite *Tetranychus urticae* Koch. They found that the duration of the immature stage was significantly longer on female when compared to male longevity, while oviposition period and fecundity were significantly lower on fungus-treated mites. Hafez *et al*. (1997) indicated that *B*. *bassiana* influence the longevity of *P*. *operculella* larvae and adults, however, sub-lethal effects were not thoroughly studied. In potatoes, early studies by Arthurs *et al*. (2008) determined the effects of granulovirus and *B*. *thuringensis* for season-long control of *P*. *operculella* with mixed results. Quesada-Moraga *et al*. (2004), Latifian *et al*. (2010), and Seyed-Talebi *et al*. (2012) suggested that entomopathogenic fungi should be evaluated further to determine its influence in offsprings' life-history, including growth, development and reproduction. Thus, this study was designed to evaluate the sub-lethal effects of *B*. *bassiana* on different biological parameters of *P*. *operculella*. Information will provide valuable insight regarding the effects of this fungus in *P*. *operculella* that could potentially be used in pest management programs.

2. Materials and methods

2.1. Insect colony

Following modifications of Gui and Li (2003) and Rondon *et al*. (2009) protocols, a colony of *P*. *operculella* was established by collecting over 500 adults in the Yunnan Province, China (103.79´E, 25.51´N). Potato tuberworm adults were reared on potato tubers placed in cylindrical food containers (14 cm diameter×3.5 cm depth) which were covered with a fine cheesecloth adjusted with a rubber band. Adults were fed with a 5% sugar suspension which was applied using a small brush applied in a small cotton wick. Also, a round filter paper (5 cm diameter) was placed on top of the cheese cloth to be used as oviposition substrate. Eggs were collected daily, and filter paper with eggs was transferred to an empty container until hatching. After hatching, a (6±1) cm-diameter-hemispherical tuber was added as a feeding substrate; tubers were changed every other day. Also, a layer of fine sand was added at the bottom of the container to be used as a pupation substrate. Colony was kept in an environmental chamber (MLR-351H, SANYO Electric Co., Ltd., Moriguchi City, Osaka, Japan) at (27±2)°C, 12 h L:12 h D, and 80–90% (RH). About every two months, *P*. *operculella* adults were added to the colony to prevent introgression and to increase genetic diversity in the confined population. Insects from the colony were used in all bioassays.

2.2. Fungal strain

A strain of *B*. *bassiana* JLGZL-14, derived from *Ostrinia furnacalis* (Guenee), was collected in Gongzhuling, Jilin Province, China in 2011. The strain was maintained, and conidia were produced on Sabouraud dextrose agar (SDA) at (26±1)°C under continuous darkness. Conidia were then harvested from one- to three-week-old cultures. Conidial concentrations were determined with a haemocytometer and