



Efficacy of nanocapsules loaded with *Ectomyelois ceratoniae* (Zeller) (Lepidoptera: Pyralidae) sex pheromone as evaluated in wind tunnel and field trapping experiments

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Abstract

The carob moth, *Ectomyelois ceratoniae* (Zeller) (Lep.: Pyralidae), is a worldwide pest of pomegranate. Although synthetic sex pheromone has been used extensively for the management of this pest, the major component (*Z,E*)-9,11,13-tetradecatrienal (trienal) is unstable. We microencapsulated synthetic trienal and demonstrated that a nanocapsule gel formulation was superior to unformulated trienal and other formulations, including the pheromone analogue (*Z,E*)-7,9,11-dodecatrienyl formate, in wind tunnel and field trapping experiments. No significant effect was observed between the total times spent by males from the release site to dispensers in different treatments in wind tunnels. In the field, the trienal nanocapsule formulation provided superior attraction for up to 4 weeks, while no other formulation induced trap catches for longer than 3 weeks. According to our finding, microencapsulation of *E. ceratoniae* pheromone components may provide improved trap lures and may be suitable for application in mating disruption.

Keywords Carob moth · pheromone · Microencapsulation · Pomegranate · (*Z, E*)-9,11,13-tetradecatrienal

Introduction

Pomegranate, *Punica granatum* L., (Myrtales: Punicaceae) originated from central Asia (Holland et al. 2009) and is now a cultivated crop species in many tropical and subtropical regions of the world, particularly India, Iran and Turkey (Kahramanoglu and Usanmaz 2016). In Iran, > 80,000 hectares of pomegranate orchards produce about one million tons of pomegranates each year (Ahmadi et al. 2016).

Carob moth, *Ectomyelois ceratoniae* (Zeller) (Lepidoptera: Pyralidae), is the main pest of pomegranate (Karami et al. 2010), date (Nay et al. 2006), almond (Madge 2014) crops worldwide, and in the Middle East causes 30 – 80% annual crop loss (Shakeri 2004; Mamay et al. 2016). Carob moth females lay their eggs on stamens in the calyx and the

larvae feed on petals, pierce the fruit and enter it, creating brown spots on the peel, as well as hollow, cracked and rotten fruit that appears black and moldy and is unmarketable (Mamay et al. 2014). Once the larvae penetrate the fruit chemical pesticides are ineffective (Shakeri 2004). In Iran's Lorestan Province, carob moth is tri-voltine, with infestations persisting from the end of April to mid-November (Naserian et al. 2013).

Control tactics used against the carob moth in Iran include collection and removal of overwintering larvae in rotten pomegranates (Sheikh Ali et al. 2009), stamen removal, application of kaolin clay powder to disrupt oviposition (Mazhab et al. 2014), covering the crown with netting (Rafeie et al. 2011), release of the egg parasitoid *Trichogramma embryophagum* (Hartig) (Rezaei-Azqandi et al. 2015) and use of pheromone mediated mating disruption (Tamhankar et al. 2000; Cichón et al. 2004) or mass trapping (Pezhman and Saeidi 2018).

The main components of *E. ceratoniae* sex pheromone are (*Z,E*)-9,11,13-tetradecatrienal (trienal), (*Z,E*)-9,11-tetradecadienal and (*Z*)-9-tetradecenal (Noorbakhsh et al. 2017a; Varshovi et al. 2018). Instability of trienal leads to low efficiency of mating disruption (Baker et al. 1991). A pheromone analogue, (*Z, E*)-7,9,11-dodecatrienyl formate,

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