Journal of Plant Diseases and Protection
https://doi.org/10.1007/s41348-021-00462-x

SHORT COMMUNICATION

Monoterpenes-induced toxicity in nymphal stages of *Halyomorpha halys*

Luca Finetti[1] · **Stefano Civolani**[1,2] · **Giovanni Bernacchia**[1]

Received: 5 February 2021 / Accepted: 30 March 2021

Abstract
In this work, the toxic activity by fumigation of 10 monoterpenes was evaluated on *Halyomorpha halys* 2nd instar nymphs. The results showed that (±)-limonene was the monoterpene with the highest insecticidal activity (LC_{50} 0.48 µl l^{-1} air), followed by two phenolic monoterpenes eugenol and isoeugenol (LC_{50} 0.41 and 0.55 µl l^{-1} air, respectively). In addition, the alcoholic monoterpenes α-terpineol and L-(−)-menthol and the ketonic monoterpene (+)-pulegone exhibited strong efficacy on *H. halys* 2nd instar nymphs (LC_{50} values 0.84, 1.15 and 0.48 µl l^{-1} air, respectively). These preliminary data indicate that essential oils and the individual terpenic components could be used as fumigants for the control of *H. halys* nymphs.

Keywords Brown marmorated stink bug · Essential oils · Insecticides · Pest control · Fumigant assay

Introduction

As defined in the European Pharmacopoeia, essential oils (EOs) are the products obtained from hydro-distillation, steam distillation, dry distillation or mechanical cold pressing of plants. EOs are composed by several elements with different biosynthetic origins, including terpenes (Bakkali et al. 2008). Among the compounds produced by plants, terpenes represent the most diversified chemical class (Regnault-Roger et al. 2012). These molecules consist of a combination of several 5-carbon-base (C5) units called isoprene. Monoterpenes, composed by one isoprene unit only, are usually the most abundant terpenes accounting up to the 90% of EOs (Croteau et al. 2000).

Monoterpenes are widely used in cosmetic, sanitary, pharmaceutical, agricultural and food industries for their bactericidal and insecticidal features (Isman 2006). In particular, the use of monoterpenes in pest control is an important tool known and applied already in agriculture. In fact, they have traditionally been used to protect stored agriculture products, such as grain and legumes, by repelling flying insects (Sarac and Tunc 1995; Shaaya and Kostjukovsky 1998; Isman 2020). Furthermore, several terpenes hold also fumigant and contact insecticidal actions against pests, including pentatomidae (Werdin Gonzalez et al. 2010, 2011; Brügger et al. 2019).

Halyomorpha. halys (Stål) (Hemiptera; Pentatomidae) is native of the Eastern Asia (China, Japan, Taiwan and Korea) (Haye et al. 2015) but has spread first in USA (1998) then in Europe (2004, Switzerland) where it has become a stable presence (Hoebeke and Carter 2003; Rice et al. 2014; Cesari et al. 2018). *H. halys* is responsible for major damages to many economically relevant crops, including apple and pear (Leskey and Nielsen 2018). The most common synthetic insecticides are not particularly effective against *H. halys*, thus making very difficult its control and elimination (Bergmann and Raupp 2014). Insecticides that have been most effective toward *H. halys* include pyrethroids and neonicotinoids. However, these molecules are broad-spectrum insecticides that might be also potentially disruptive to pollinators (Kuhar and Kamminga 2017). Furthermore, *H. halys* also showed a higher ability to recover from a moribund state after insecticides exposure (Leskey et al. 2012). *H. halys* nymphs are typically more susceptible to insecticides than adults (Nielsen et al. 2008). Furthermore, unlike other Pentatomidae, the nymphal stages of *H. halys* cause just as many fruit injuries as adults (Stahl et al. 2020). For these reasons, identifying alternatives to current chemical control approaches targeting *H. halys* nymphs results important in

✉ Giovanni Bernacchia
bhg@unife.it

[1] Department of Life Sciences and Biotechnology, University of Ferrara, Via Borsari 46, Ferrara 44121, Italy

[2] InnovaRicerca S.R.L. Monestirolo, Via Pastorella 17, Ferrara 44124, Italy

Published online: 16 April 2021