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The efficacy of insecticides against eggs and nymphs of *Aleyrodes proletella* (Hemiptera: Aleyrodidae) under laboratory conditions

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A B S T R A C T

The importance of *Aleyrodes proletella* (L.) (Hemiptera: Aleyrodidae) as a pest of cruciferous crops is rising. Concurrently, there is insufficient know-how for successful and efficient control of this pest. The aim of this study was to compare the efficacies of 21 commonly used insecticides in order to search for the most suitable chemical control of this pest. Insecticides were sprayed on the leaves of *Brassica oleracea* var. *gongylodes* L. cv. Luna with laid eggs and nymphs of *A. proletella* at the concentrations recommended by the manufacturers. Treating eggs and nymphs with insecticides significantly increased their mortality compared to the control, but the effects of particular insecticides varied. The overall efficacy was lower in case of nymphs than for eggs. Many of the selected insecticides were effective against one stage only. Egg mortality was highest after treatment with spirotetramat, cyantraniliprole, spinosad, diflubenzuron, pyridaben, imidacloprid and thiacloprid. The most efficient active ingredients against nymphs were spirotetramat, cyantraniliprole, pyridaben and rapeseed oil. Thus, spirotetramat, cyantraniliprole and pyridaben were the most effective active ingredients against immature stages of *A. proletella* in this study, and so further confirmatory studies in the field are recommended.

1. Introduction

The European cabbage whitefly, *Aleyrodes proletella* (L.) (Hemiptera: Aleyrodidae), is a polyphagous species that feeds mostly on herbaceous host plants, with a preference for *Brassicaceae* and to a lesser extent also for *Asteraceae* (Martin et al., 2000). Feeding preferences differ even within brassica crops. Trdan and Papler (2002) observed higher susceptibility of kale than savoy cabbage or Bussels sprouts, whilst only individual specimen was found on cabbage. *Aleyrodes proletella* is widely distributed in the temperate Palearctic region and has spread to other parts of the world (De Barro and Carver, 1997).

Aleyrodes proletella has become a major pest in *Brassica* crops in Europe during the last two decades (Loomans et al., 2002; Muñiz and Nebreda, 2003; Trdan et al., 2003; van Rijn et al., 2008; Pajović, 2011; Saucke et al., 2011; Richter and Hirthe, 2014c). It is highly probable that *A. proletella* will become a serious pest also in new areas such as southern Sweden (Weimers, 2016). Large-scale rapeseed production near cabbage-growing areas supports the fast distribution of *A. proletella* by providing overwintering sites and a food source throughout the year (den Belder et al., 2008; Richter and Hirthe, 2014b). The abundance of this pest is also enhanced by high nitrogen content in leaves (Iheagwam, 1981) and mild winters (Richter and Hirthe, 2014b). Due to these circumstances it is essential to find a reliable solution for successful control of such a pest.

In the temperate zone of Europe, females of *A. proletella* overwinter on oilseed rape and other plants (Richter and Hirthe, 2014b). In spring, they usually lay 20–100 eggs during the daytime within a wax circle on the underside of leaves. The eggs hatch in a week, and the development to adults is completed within 3–4 weeks (Butler, 1938). On the other hand the development is temperature/season dependent and the duration of the first generation may be longer. According to Alonso et al. (2009) the mean generation time of *A. proletella* at 16 °C was 46–47 days. The phenology of this species in temperate Europe has been well-described by Richter and Hirthe (2014c). In their study in northern Germany, overwintered females started laying eggs in April. Adults that hatched in June left the

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rapeseed field and searched for new host plants. Thus, the invasion of whiteflies into vegetable crops normally started in the middle of June, and the first nymphs on vegetables could be found approximately three weeks later. During June and July, the infestation level remained low, but mass reproduction started in the middle of August, so up to 10,000 adult whiteflies, 1000 egg clutches and more than 50,000 larvae were found per plant during September. A decline in the abundance of eggs and adults was observed with falling temperatures in October. The number of generations of *A. proletella* varies from year to year. Generations overlap and it is very difficult to determine the precise number of generations in any one year (Butler, 1938). Generally, three to five generations per year can be completed in Europe; 3–4 generations per year were reported in Germany (Richter and Hirthe, 2014a), and 4–5 generations per year were observed in Great Britain (Butler, 1938). In southern Europe the number of generations is even higher. Pajović (2011) wrote that *A. proletella* can reach up to 10 generations per year in ideal conditions.

Most *Brassica* crops are tolerant to *A. proletella*, and even heavy infestations have little impact on plant growth (Ramsey and Ellis, 1996). On the other hand Trdan et al. (2003) observed significantly lower yield of Brussels sprouts under higher infestation of *A. proletella*, because the heads were consecutively removed due to intensive growth of sooty molds on the outer leaves. The feeding of *A. proletella* on plant fluids and release of sugar-rich excreta provide suitable conditions for the growth of sooty molds on the plants (Ramsey and Ellis, 1996). Thus, damage to plants caused by *A. proletella* is mainly cosmetic, nevertheless the marketability of the crop is strongly reduced (Broekgaarden et al., 2012).

Control of this pest is very difficult due to several factors, such as crop architecture and the waxy surface of the leaves as well as the hydrophobic waxy secretions of the adults and nymphs (Springate and Colvin, 2011). Control of this pest is also reduced by the fact that it usually develops on the underside of the leaves and because the puparia have an impermeable, tough cuticle (Leopold et al., 2008) that protects them against chemicals. Biocontrol attempts have also failed so far (van Rijn et al., 2008). Although the puparia can be parasitized by *Encarsia tricolor* (Förster) and *E. inaron* (Walker) (Hymenoptera: Aphelinidae) and the eggs and nymphs are attacked by the larvae of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), *Episyrphus balteatus* (DeGeer) and *Platycheirus peltatus* (Meigen) (both Diptera: Syrphidae), the population densities of these natural enemies are usually low in the field, so they are not able to compete with the fast population development of whiteflies and therefore do not make a notable impact on *A. proletella* populations (van Rijn et al., 2008).

Hence, control of this pest in *Brassica* crops relies largely on insecticides. Understanding how effective the particular insecticides are in controlling *A. proletella* is crucial, given that resistance to pyrethroids has already been documented in Great Britain (Springate and Colvin, 2011). The efficacy of some insecticides against *A. proletella* has been tested by Trdan et al. (2003), Richter and Hirthe (2014c), and Karanja et al. (2015). Unfortunately, each of the available studies included only a limited range of insecticides, which makes any comparison difficult due to the differences in experimental design, temperature conditions, and inter-population factors. A study comparing the efficacy of a range of insecticides for controlling this pest under the same conditions would contribute to formulation efficient control strategy of *A. proletella*, and is therefore needed. In this study we tested the efficacy of 21 insecticides against eggs and nymphs of *A. proletella*.

2. Materials and methods

2.1. Plant material

A potted culture of *Brassica oleracea* var. *gongylodes* L. cv. Luna was established in a greenhouse (experimental facilities of the Crop Research Institute, Prague – Ruzyně, Czech Republic) at the beginning of July 2015. In each of 440 pots, 1–2 plants with at least 2–3 leaves were grown. The conditions in the greenhouse were maintained at a temperature of 23 ± 3 °C, relative humidity of 40–80%, and a 16:8 h (L:D) photoperiod.

2.2. Insects

Eggs and one-week-old nymphs of *A. proletella* were obtained from a colony reared on the same host plant (*Brassica oleracea* var. *gongylodes* L. cv. Luna) in the greenhouse at 23 ± 3 °C, 40–80% relative humidity, and a 16:8 h (L:D) photoperiod. The colony was established from adults collected in the field (Litoměřice, Czech Republic, 50°30′58.732″N, 14°6′44.607″E, 149 m a.s.l.) from remnants of savoy cabbage after harvest in June 2015. The last application of insecticides at the site was more than 2 weeks before collection.

2.3. Chemicals

In total, 21 insecticides were tested against the eggs and nymphs of *A. proletella*. The products, active ingredients and concentrations used are listed in Table 1. Most of them have been approved for use on *Brassica* vegetables in the Czech Republic. The insecticides were diluted in water in concentrations recommended on the product label, and the Break-Thru surfactant (polyether-polymethylsiloxane-copolymer 80% and polyether 20%, concentration 0.05%) was added when appropriate (Table 1). The *Quassia amara* L. extract was prepared 2–4 h before application by boiling *Quassia* wood chips (100 g) in 2 l of water for one hour (Psota et al., 2010).

2.4. Bioassay

2.4.1. Eggs

To obtain eggs for the bioassay ≈ 200 *A. proletella* adults were released in each of 22 replicate observation cages (35 × 35 × 60 cm, BioQuip; USA). Each cage contained 20 pots of host plants (*Brassica oleracea* var. *gongylodes* L. cv. Luna). After two days, adults were removed by airflow (blown out with no special equipment), and the number of eggs per pot was counted. The solutions of insecticides and Break-Thru were applied to the plants with eggs using a SG e1 hand sprayer (Biostep; Germany), so that the upper and lower leaf surface were sprayed to run-off. We estimate the sprayed volume as ca 1 ml per plant. The plants in the control group were treated only with water plus Break-Thru. For each insecticide and control treatment, ten replicates, each containing at least 30 eggs per pot, were used. The treated eggs were then kept in the cages in a greenhouse at 23 ± 3 °C, 40–80% relative humidity, and a 16:8 h (L:D) photoperiod. Host plants with at least 3 egg loads (11 eggs per 1 load on average) of *A. proletella* were used. Mortality was assessed after five to seven days, which reflects the natural duration of egg development under these conditions (Butler, 1938).

2.4.2. Nymphs

This experiment was conducted at the beginning of August 2015 in a similar set-up and under the same conditions as described above. Adults of *A. proletella* were removed from the cages two days after oviposition, and the number of eggs per pot was recorded. Host plants with at least 2 egg loads (11 eggs per 1 load on average)