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Variation in damage levels by codling moth to ten apple cultivars in an organic orchard in Poland

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Abstract: This study was conducted in an experimental ecological orchard in central Poland in 2011–2013. The experiment assessed the variation in damage to the fruit of ten apple cultivars by the codling moth *Cydia pomonella* (L.) under an organic system of apple cultivation. The cultivars were divided into two groups according to their susceptibility to apple scab *Venturia inaequalis* (Cooke) Wint. The first group of apple trees (A) consisted of cultivars resistant to scab (Enterprise, Gold Milenium, Rajka, Rewena, and Topaz), while the second group (B) consisted of cultivars with reduced susceptibility to scab (Delbard Jubile, Ligolina, Pinova, Piros, and Szampion). All of the trees of the evaluated cultivars were protected against the codling moth by applying treatments containing the codling moth granulosis virus (CpGV). Codling moth adults were monitored using pheromone traps during the study period. Each year, an assessment of fruit damage was made for all apple cultivars. The 3-year average percentage of damaged fruit for group A ranged from 1.0% (Gold Milenium) to 4.1% (Topaz), and in group B from 1.3% (Piros) to 3.3% (Pinova). Overall, the highest percentage of damaged fruit was recorded in 2013.

Key words: Apple cultivars, organic orchard, fruit damage, *Cydia pomonella* (L.), Poland

1. Introduction

The increase in ecological awareness among consumers and producers with regard to the need for environmental protection is one of the most important factors for the development of plant protection (Pruszyński and Nawrot, 1999). In ecological fruit production systems, total production and quality of yield are lower than in conventional systems. In spite of this, the demand for ecological food among consumers has been rising continuously (Łuczka-Bakuła and Smoluk-Sikorska, 2010; Kazimierczak and Zgiep, 2013). New solutions allowing a reduction in the use of pesticides in plant protection are still needed together with the simultaneous aim to minimize the losses in the quantity and quality of crops (Balázs et al., 1997; Badowska-Czubik and Kruczyńska, 2010).

The codling moth is one of the most prevalent pests in apple orchards all over the world (Arthurs and Lacey, 2004). Every year, it causes huge losses of the crop (Lacey et al., 2007). In Poland, this key pest is also regarded as one of the most important factors reducing the quality and amount of crops produced (Olszak and Płuciennik, 2001; Płuciennik and Olszak, 2006). The females of the codling moth lay their eggs on the surface of leaves or fruits. After hatching, the larvae penetrate the fruit and feed on the fruit flesh (parenchyma). Affected fruits usually drop prematurely and those that survive on trees infested by caterpillars are not suitable for trade, consumption, or storage (Arthurs and Lacey, 2004; Gorzka et al., 2010; Badowska-Czubik et al., 2011; Bryk et al., 2013, 2014).

Commercial apple plantings are composed of a mixture of varieties, affecting the attraction of codling moth adults as well as the efficacy of control against codling moth (Sutherland et al., 1977; Kovanci et al., 2010). For example, Sutherland et al. (1977) found that apple cultivar Dunn's Favourite, Granny Smith, Golden Delicious, and Delicious are more preferred by the codling moth during the first generation and the apple cultivars Granny Smith, Sturmer, and Jonathan are preferred in the second generation. The percentage of damaged fruit by codling moth in Poland varied from 3.7% in 2012 to 4.1% in 2011, the long-period average damage being 5.4% (Walczak et al., 2012, 2013). Relating the percentage of damaged fruit to the statistical data regarding the crops, it can be concluded that the codling moth damaged 102,200 t and 106,500 t of apples in 2011 and in 2012, respectively (Witkowski and Dmochowska, 2013). In Poland, the demand for ecological fruit has been increasing over the years, which stimulates the development of ecological horticulture.

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The aim of this study was the assessment of fruit damage levels caused by codling moth in an ecological production system using a viral plant protection product. Commercial crops from 10 cultivars of apples recommended for cultivation in ecological orchards in Poland were evaluated. Additionally, the influence of the reduced number of protection treatments on the percentage of damaged fruits was assessed.

2. Materials and methods

The research was conducted in the ecological experimental orchard (EEO) in Nowy Dwór-Parcela, Poland, in 2011–2013. In order to determine the flight dynamics of codling moth adults, delta-style pheromone traps were used. This type of trap is the most effective one for catching the codling moth, as was concluded in a comparative experiment carried out at the Research Institute of Horticulture (Gorzka et al., 2010). Two traps were used per hectare as recommended by Thomson et al. (2001), and pheromone capsules were changed three times during the season. The control of the catch was carried out at weekly intervals in the course of the vegetation season. The weather conditions were determined by the automatic meteorological station Metos Compact, installed at the experimental site. In order to decrease the population of codling moth and to minimize fruit damage, biological plant protection has been used since 2011 on the basis of research conducted at the EEO in 2009 and 2010 (Badowska-Czubik et al., 2011). This formula contains an entomopathogenic virus of the family *Baculoviridae* (codling moth granulosis virus, CpGV), which causes granulosis in the codling moth. It is registered for use in ecological agriculture in Poland (Ciesielska et al., 2011; Szulc et al., 2015). The treatments were performed twice in the season and were aimed at combating the first generation of codling moth. The times of the treatments were scheduled according to the monitoring of adult flights. The first treatment was performed in the 'black head' phase, and the second was applied 10 days later. The treatments were performed with the use of a tractor sprayer containing 750 L of working liquid per hectare with the addition of 250 mL of Madex SC and 250 g of dry skimmed milk. The air temperature during the treatments varied: 21.7 °C and 24.8 °C in 2011 (Figure 1), 22.9 °C and 25.1 °C in 2012 (Figure 2), and 23.6 °C and

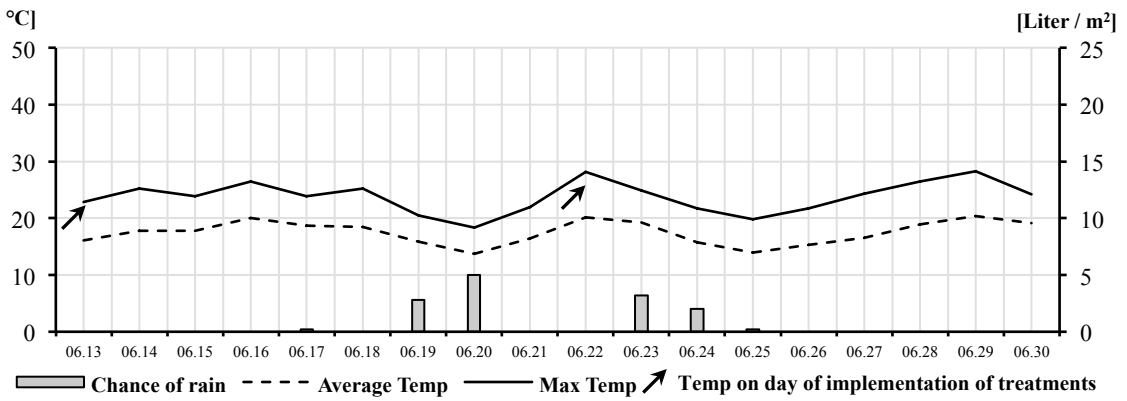

Figure 1. Meteorological conditions during codling moth granulovirus treatments in 2011.

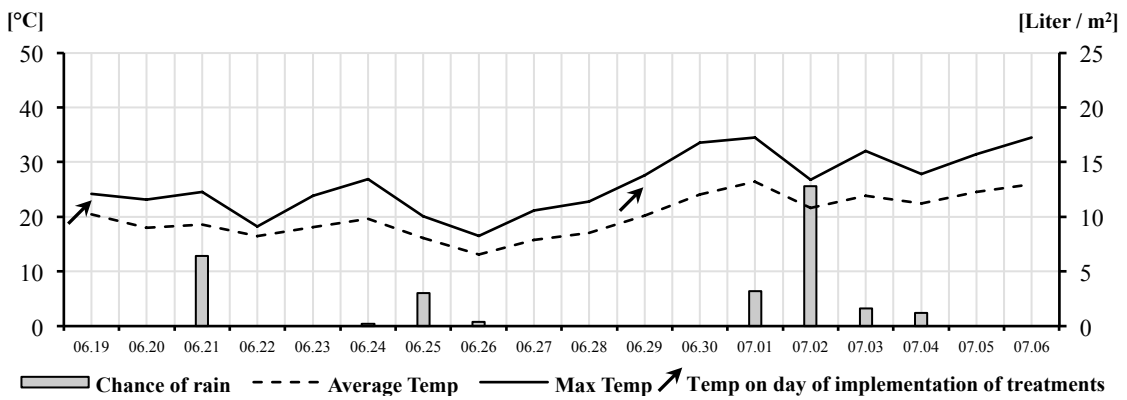

Figure 2. Meteorological conditions during codling moth granulovirus treatments in 2012.

17.1 °C in 2013 (Figure 3), while the mean wind velocity varied from 0.2 to 1.0 m/s. Fruit damage control was carried out during the harvest. The assessment contained 10 varieties, among which 5 varieties were resistant to scab (group A): Enterprise, Gold Milenium, Rajka, Rewena. and Topaz. The other 5 varieties had reduced susceptibility to scab (group B): Delbard Jubile, Ligolina, Pinova, Piros, and Champion. Samples of fruits were taken randomly in four replications with a minimum of 400 fruits from each variety (combination). The results were analyzed using one-way ANOVA followed by Duncan's test and P = 0.05 was used to separate means in STATISTICA version 10. Percentage results were transformed using the Bliss transformation ($\arcsin\sqrt{x}$) before statistical analysis.

3. Results and discussion

In the course of this research, flights of the codling moth were noted in the second part of May. During the whole period of observation the number of moths caught in periods of peak flights exceeded the economic threshold established for this pest (Płuciennik et al., 2014). The maximum trap captures of the first generation of codling moth were observed in the last 10 days of May 2011, at the end of May and beginning of June 2012, and the beginning of June 2013. The maximum captures for the second generation of codling moth were noted in the second part of August 2011, in the first 10 days of August 2012, and at the beginning of August 2013 (Figure 4). The occurrence of a high-density first generation in 2013 was directly connected to the high number of moths of the second generation in 2012, and also with good wintering conditions in the winter of 2012/2013. The minimum monthly temperature in the period between October 2012 and April 2013 varied from –4.2 °C to –16.9 °C. The mean air temperature for that period was 1.3 °C, and the mean monthly soil temperature varied from –0.3 °C to 6.2 °C.

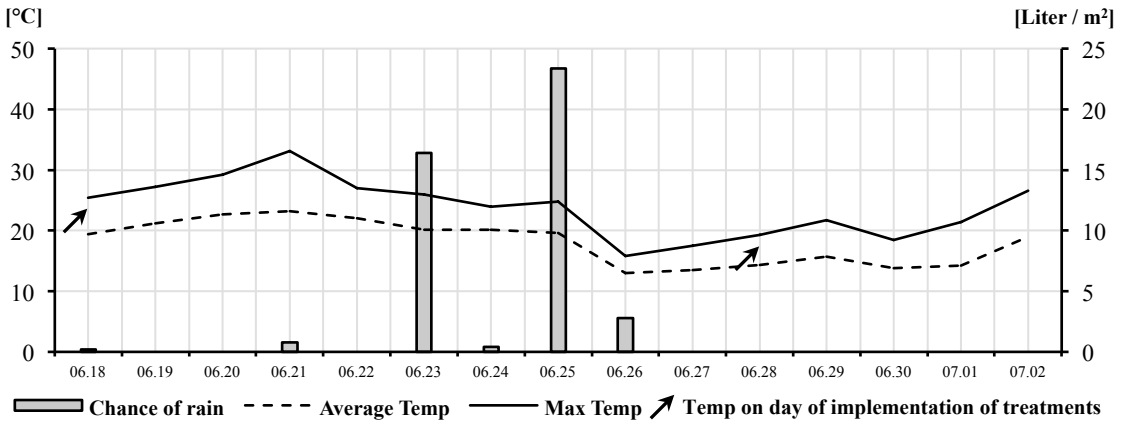

Figure 3. Meteorological conditions during codling moth granulovirus treatments in 2013.

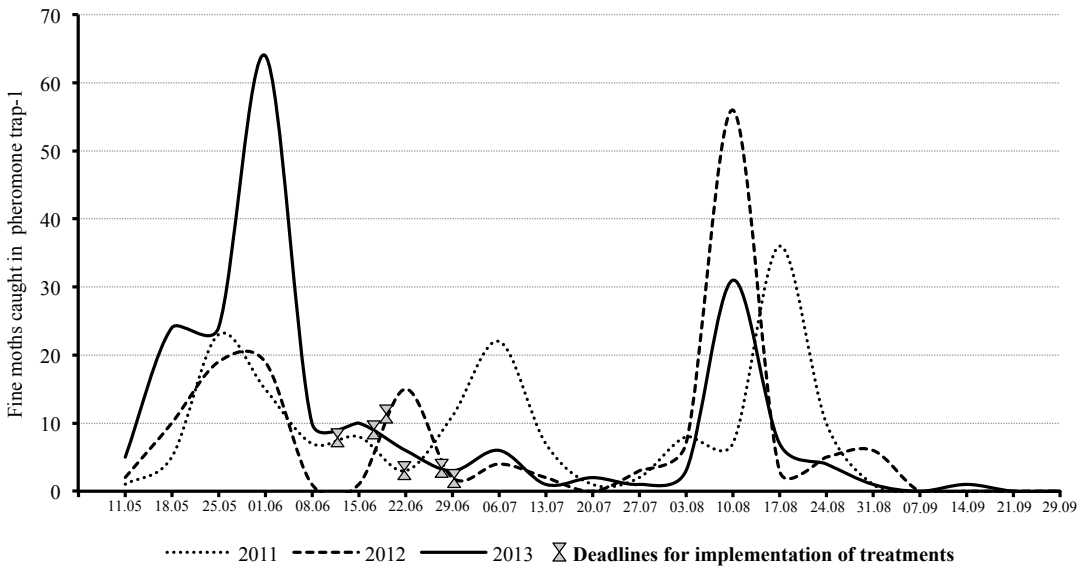

Figure 4. Flight dynamics of the codling moth adults between 2011 and 2013.

The occurrence of a high number of moths of the second generation in 2012 was also connected with an increase in temperature directly after the second treatment (Figure 2). Ciesielska et al. (2011) reported that the granulosis virus undergoes rapid biodegradation at high temperatures. The increase in temperature on the days directly after the treatment contributed to the reduced effectiveness. A similar situation was observed in 2013 after the first treatment (Figure 3).

The lowest number of damaged fruits in the group of scab-resistant varieties (group A) was found in the crops of cultivars Gold Milenium and Rewena, whereas the highest was found in the crops of Enterprise and Topaz (Figure 5). The mean triennial percentage of damaged fruit for group A was as follows: 1.0% – Gold Milenium, 1.4% – Rewena, 1.9% – Rajka, 3.0% – Enterprise, 4.1% – Topaz. The mean percentage of damaged fruit for all varieties in group A was 2.3%

In the group with reduced susceptibility to scab (group B), fruits of cultivars Ligolina and Piros were the least damaged by the caterpillars of the codling moth, whereas fruits of Delbard Jubile and Pinova had the highest percentage of codling moth damage (Figure 6). The mean triennial percentage of damaged fruit for group B was as follows: 1.3% – Piros, 1.5% – Ligolina, 2.6% – Szampion, 3.0% – Delbard Jubile, 3.3% – Pinova. The mean percentage of damaged fruit for this group was 2.3%.

In 2013, a great increase of damaged fruit was observed for all varieties. The reason for this was the occurrence of an abundant second generation of the codling moth in 2012 in comparison to the previous years (2011–2012), and an even more numerous first generation in 2013 (Figure 4). Moreover, an important factor influencing the increase of damaged fruit was clearly a lower yield of all varieties in 2013. In comparison to the years 2011 and 2012, the decrease was about 60%.

The meteorological conditions during the research in 2013 also had a negative influence on the effectiveness of granulovirus treatments against the codling moth. High temperatures and heavy rainfall between the treatments

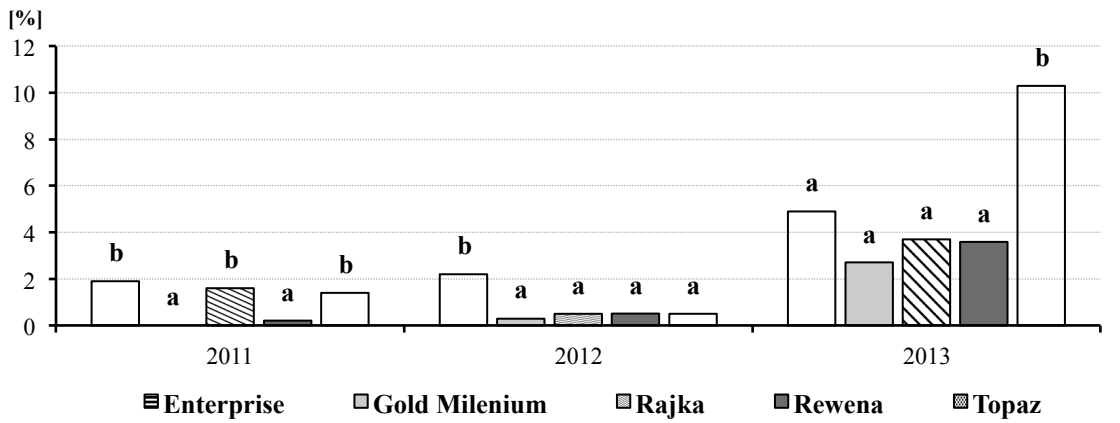

Figure 5. The mean percentage of damaged fruit for scab-resistant varieties (group A) in the years 2011–2013.

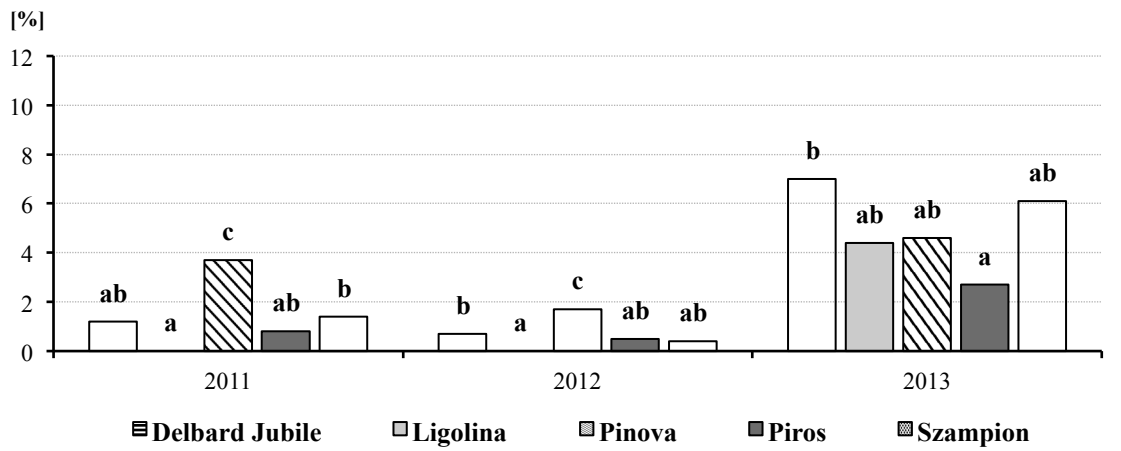

Figure 6. The mean percentage of damaged fruit for the varieties with reduced susceptibility to scab (group B) in the years 2011–2013.

contributed to a lower effectiveness of the protective formula Madex SC (Figure 3). As stated previously, the triennial percentage of fruit damage for all varieties was 2.3%.

In earlier studies (Badowska-Czubik and Kruczyńska, 2010), the percentage of damaged fruit was evaluated for a few varieties in a young ecological apple orchard. It was concluded that the mean percentage of damaged fruit varied from 0.0% to 2.9%. In 2008 and 2009, the lowest damage was observed for the varieties Rajka (0.0%) and Rewena (0.4%), whereas the highest damage occurred on the varieties Enterprise (2.4%) and Delbard Jubile (2.9%) (Badowska-Czubik and Kruczyńska, 2010). The present study shows that the variety Rewena belonged to the group with the lowest mean percentage of damaged fruit (1.4%), whereas the varieties Enterprise and Delbard Jubile belonged to the group with the highest percentage of damaged fruit (3.0%).

Studies on the usefulness of formulas containing CpGV have been conducted for many years (Niemczyk et al., 1998; Arthurs and Lacey, 2004). In these experiments, formulas with different technical parameters were applied (Arthurs et al., 2005, 2007; Badowska-Czubik et al., 2011) with the use of additional elements enhancing the effectiveness, e.g., dispensers (Kutinkova et al., 2008). These numerous studies showed varied effectiveness of applied formulas (Niemczyk et al., 1998; Olszak and Płuciennik, 2001; Lombarkia et al., 2005; Arthurs et al., 2007; Płuciennik, 2012). Olszak and Płuciennik (2001) proved the effectiveness of a viral formula after it was used 5 times at 71.4% in 1998 and at 92.9% in 1999 with the damage at respectively 3.5% and 3.2%. Kutinkova et al. (2008) applied granulovirus treatments 11 times with dispensers and observed 0.9% of damaged fruits. Arthurs et al. (2007) applied their formula less intensely without any dispensers and obtained 3.5% of damaged fruits. Płuciennik (2012) proved varied effectiveness of combating the codling moth with a viral formula, from 35.9% to 75.5%, establishing the percentage of damaged fruit at levels between 3.2% in 2005 and 8.7% in 2006. Badowska-Czubik et al. (2011), after using biological formulas to combat the codling moth, obtained the percentage of damaged fruit at the level of 1.5% (2009) and 7.6% (2010) for Pinova and 4.8% (2009) and 8.8% (2010) for Topaz. In their experiments, the formula was applied twice in the course of the study against the first generation of the codling moth, as opposed to other experiments, where treatments were repeated several times in the season (Kutinkova et al., 2008; Płuciennik, 2012).

Yearly application of the codling moth granulovirus has led to a significant reduction in the damage caused by *C. pomonella*. The level of damaged fruit was lowered by 57.4% on average in comparison to the nationwide level (Walczak et al., 2013). In the case of the occurrence of a very numerous second generation of the moth, it is necessary to apply an additional cycle of protective treatments.

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