Scientific Papers. Series B, Horticulture. Vol. LXV, No. 1, 2021
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

MANAGEMENT AND CONTROL OF *RESSELIELLA THEOBALDI* (DIPTERA: CECIDOMYIIDAE) IN BIOLOGICAL RASPBERRY PRODUCTION

Lilyana KOLEVA[1], Elena TSOLOVA[2]

[1]University of Forestry, Faculty of Agronomy, Kliment Ohridski 10, 1797, Sofia, Bulgaria
[2]Institute of Agriculture - Kyustendil, Sofjisko shose Str., 2500, Kyustendil, Bulgaria

Corresponding author email: liljanamarkova@abv.bg

Abstract

This study was carried out in a raspberry plantation (2017-2019) in the experimental field of the Institute of Agriculture - Kyustendil, Bulgaria. The purpose of the study was to investigate the effect of organic fertilizer application on the larvae density of Resseliella theobaldi (Barnes) and population management, using biological plant protection products. Our results indicate that the use of organic fertilizers has a negative effect on the survival of R. theobaldi larvae but has no effect on the larval endoparasitoid Aprostocetus epicharmus (Walker) in the cultivars 'Willamette' and 'Lyulin'. The interrelationship between R. theobaldi and A. epicharmus in organic raspberry production has also been studied. The assessed rate of parasitism by A. epicharmus (24.94-36.11%). is considered to be enough to reduce the population of R. theobaldi in cv. 'Lyulin' effectively without chemical control. Two treatments with bioinsecticides have been carried out for the protection of cv. 'Willamette' due to a significantly lower rate of parasitism in this cultivar (11.68-20.05%). The most effective insecticides for the control of adults of R. theobaldi have been identified as follows: Pyrethrum FS EC - conc. 0.05% and NeemAzal®-T/S - conc. 0.3%.

Key words: *organic fertilizers, biological control, raspberry cane midge.*

INTRODUCTION

In many European countries (Germany, Poland, United Kingdom, other Nordic Southeast Europe countries) raspberry production is very important for the agricultural sector (Wollbold & Behr, 2020). According to statistics, in the last 15 years the number of organic raspberry producers in Bulgaria and the interest in organically grown fruits has significantly increased (Bioregister, 2021).

It is known that the organic fertilization system can influence and change the cane characteristics, productivity and berry quality, including the fruit aroma, of red raspberry (Xiu-yan, 2011; Stojanov et al., 2019; Estrada-Beltran et al., 2020). However, the fertilization system could lead to changes in pest management practices (MacConnell et al., 2001; Altieri & Nicholls, 2003; Barzman et al., 2015) which has not yet been studied in detail. According to the results of earlier study by Tsolova and Koleva (2019), it was proved that fertilizing with organic fertilizers Humustim-100, Haemosim bio N5 + Haemofol H4 and Biohumax® has a reductive effect on the survival of the *Agrilus aurichalceus* population and does not affect the population of the larval endoparasitoid *Trastichus heeringi* in the cultivars 'Willamette' and 'Lyulin'.

The raspberry cane midge, *Resseliella theobaldi* (Barnes, 1927) (Diptera: Cecidomyiidae) is a major pest of raspberry in Europe (Mitchell et al., 2018). By feeding and developing under the rind of canes, the larvae cause direct damage to the plants.

Moreover, in the wounds, several fungal pathogens can occur, which together with the pest cause a syndrome known as midge blight (Pitcher & Webb, 1952).

Control of *R. theobaldi* is difficult because larvae are protected under the epidermis of first-year canes (Nilsson, 2008). Effective insecticide treatments are appropriate against the first generation, at the peak of adult emergence, because adults of the further generations are on the wing during the flowering and harvest of raspberry (Sipos, 2012). Timing of insecticides application and the population density are very important to consider in raspberry cane midge management not only in the conventional, but also in organic production.

The objective of this study was to evaluate the larvae density of *R. theobaldi* in different variants of organic fertilization and the effect of the application of botanical insecticides for control.

MATERIALS AND METHODS

This study was carried out during 2017-2019 at the Institute of Agriculture in Kyustendil (N 42°81'68.18", E 23°22'48.50"), Bulgaria. The organic raspberry plantation was established in 2010 with ′Willamette′ and ′Lyulin′ cultivars. The research was conducted as part of a project entitled ‘Development of technology for organic raspberry production’, which includes research on the stem insect pests of raspberry (*Rubus idaeus* L.) in organic production of raspberries. The investigations of three intrastem pests: rose stem girdler (*Agrilus aurichalceus* Redtenbacher 1849) raspberry cane midge (*R. theobaldi*) raspberry gall midge (*Lasioptera rubi* (Schrank, 1803)) were performed according to a standardized methodology described by Tsolova & Koleva (2019). The meteorological characteristics of the study region based on the derived data since 2015–2017 were mostly in line with previous studies, although an increase in rainfall was observed (Tsolova & Koleva, 2019). Also, during the research period no significant deviations from the meteorological conditions specific to the region were observed. Usually, the flowering period of cv. ′Willamette′ was over 20 days, and in the cv. ′Lyulin′ it was over 60 days. The BBCH-scale was used to identify the phenological development stages of each cultivar. The experimental plants were grown by using authorized fertilizers and plant protection products according to Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products regarding organic production, labelling and control. The liquid organic fertilizers Humustim-100, Haemosim bio N5, Haemofol H4 and Biohumax® were tested, applied three times by foliar treatment to the plants during inflorescence emergence (BBCH 51-57), the beginning of flowering (BBCH 60-61), and the formation of the development of fruit (BBCH 71-73), in following four fertilisation variants: V0 (untreated); V1 (Humustim - 1 L ha^{-1}); V2 (Haemosim bio N5 - 5 L ha^{-1} + Haemofol H4 - 4 L ha^{-1}) and V3 (Biohumax® - 10 L ha^{-1}). The rows in between were maintained by mowing and mulching. The experiment was arranged by block method with four variants and four replicates each. Drip irrigation was applied at 80% evapotranspiration.

The level of infestation by *R. theobaldi* was determined 1 time a month (from June to end of September). The test canes (10 canes in the case of each fertilisation variant and treatment) were collected by cutting to the soil surface and processed in laboratory conditions. The canes were cut lengthwise and all larvae were removed, divided into groups: live and parasitized.

Under field conditions in cv. ′Willamette′, two treatments with botanical insecticides pyrethrum and azadirachtin were carried out: pyrethrum in three concentrations 0.05, 0.06, and 0.08% and azadirachtin in 0.25, 0.30 and 0.35%; in four replications (4×5 m^2), with an area of 20 m^2 for each variant. The applications were targeted against the adults of the second generation. The timing of treatment was determined by standard pheromone white delta traps. The first treatment was carried out during the peak of flight activity, whereas the second after 7 days. The survival data on adult’s population were transformed into percent mortality by Abbott (1925) and Henderson and Tilton (1955). The results were statistically evaluated by dispersion analysis (ANOVA).

RESULTS AND DISCUSSIONS

The survival of the population of *R. theobaldi* larvae in cv. ′Willamette′ and cv. ′Lyulin′ during 2017-2019 and between fertilization variants is shown in Figure 1 and 2.

The highest survival rate of larvae in cv. ′Willamette was characterized in 2019 (84 larvae/fertilization variant or 39.25% in variant Haemosim bio N5 + Haemofol H4/V2) and the lowest in 2017 (10 larvae/fertilisation variant or 13.25% in variant with Humustim/V1).

In the parasitism by the larvae of *Aprostocetus epicharmus* (Hymenoptera: Eulophidae), the opposite trend was observed from total 11.68% (2019) to 21.15% (2017).
Though the highest value of parasitism between variants 11 larvae/variant or 7.89% was reported for fertilization with Biohumax® (V3) during 2019.
It is notable that during three years of the study the population of live larvae in the cultivar ′Lyulin′ had the total highest values (99–55.56%) when fertilized with Biohumax® (V3), while the total lowest values (2–1.04%) when fertilized with Humustim (V1) (Figure 2).
During the three years of the study, the number of live larvae in the cultivar ′Lyulin′ was the highest in 2018 and the lowest in 2019 (Figure 2).
The infestation of the larvae of the raspberry cane midge by *A. epicharmus* was as follows: total 27.07% (2017); 24.94% (2018) and 36.11% (2019). The carried out partial studies on the relationship of *R. theobaldi* to *A. epicharmus* showed that the obtained values of parasitism in the range of over 35% were sufficient to regulate and maintain the raspberry cane midge population under threshold of economic harm.
The high rate of parasitism could lead to a reduction of the number of insecticide treatments during the growing season for the cultivar ′Willamette′, our data and observations were not enough to make even preliminary recommendations. Population monitoring show *A. epicharmus* have at least three generations for a year under average continental climatic conditions. The parasitoid conspicuously emerges in late May and can be characterized by the same number of generations as its host, the raspberry cane midge (Stoyanov, 1963). According to Vétek et al. (2006), the primocane splitting during the vegetation periods influenced the population dynamics of the host and the parasitoid. It also concerned the interrelationship between the raspberry cane midge and their parasitoid *A. epicharmus.*
The statistical processing of the obtained data was performed by two-factor analysis of variance (ANOVA) for the effect of the impact of organic fertilizer variants on the *R. theobaldi* larvae in the cultivars ′Willamette′ and ′Lyulin′ in 2017-2019 (Tables 1, 2).

Table 1. Two-factor dispersion analysis (ANOVA) of the effect of the fertilization variants on the density of *R. theobaldi* larvae in cv. ′Willamette′ in 2017-2019

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Fertilization	200.9167	3	66.97222	2.833137	0.128516	4.757063
Years	112.1667	2	56.08333	2.372503	0.174114	5.143253
Error	141.8333	6	23.63889			
Total	454.9167	11				

The two factors fertilization and research period had no influence on the number of *R. theobaldi* larvae in cultivar Willamette during 2017–2019. The reported low population of raspberry cane midge probably depends on adult's treatments and the degree of parasitism by the endoparasitoid *A. epicharmus*.

Table 2. Two-factor dispersion analysis (ANOVA) of the effect of the fertilization variants on the density of *R. theobaldi* larvae in cultivar ′Lyulin′ in 2017-2019

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Fertilization	300.9167	3	100.3056	0.381189	0.770534	4.757063
Years	5181.167	2	2590.583	9.844928	0.01274	5.143253
Error	1578.833	6	263.1389			
Total	7060.917	11				

The research period also affected the larvae of *R. theobaldi* in the cultivar ′Lyulin′ during 2017-2019. Differences between fertilization variants were significant between the years. There were no significant differences between the variants for a given year. Further research should be focused on examining the long-term effects of the use of tested organic fertilizers in direct relation to the biochemical parameters of the soil in organic raspberry production.
Based on the data on density of *R. theobaldi* larvae, treatments with the biopesticides Pyrethrum FS EC® and NeemAzal® T/S were carried out in 2018 and 2019. The test results of botanical insecticides against adults of the second generation of raspberry cane midge in field conditions were characterized by low values, which ranged from 60.6% to 69.8%. Double treatment against second generation showed very good efficacy of Pyrethrum FS

EC® (0.05%), which ranged from 90.1% to 90.8%. Similar results were obtained with NeemAzal® T/C, where the efficiency was in the range of 90.4-92.3% for the study years (Figure 3). Mohamedova (2017) also reports for lowest number of larvae in raspberry canes was observed after application of NeemAzal® T/C and *B. subtilis* in raspberry fields near Samokov, Bulgaria. Both products demonstrated highest efficacy, when the number of larvae per splits was 67.1-82.5% for NeemAzal® T/C, and 75.1-81.2% for *B. subtilis* lower compared with the control.

The results show that the organic production of raspberry poses risks associated with the occurrence of certain biotic stress factors which could cause damage of the production. The control against cane midge is very important in the biological management of raspberry in many raspberry growing regions.

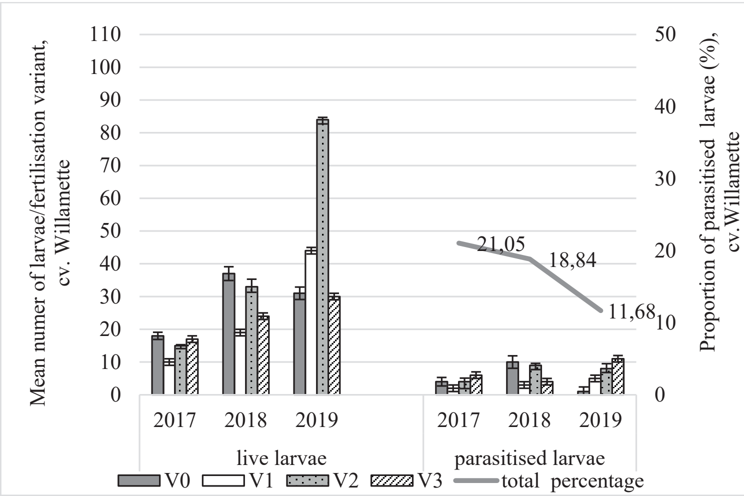

Figure 1. Number of *R. theobaldi* larvae by different fertilization treatments in cultivar ′Willamette′

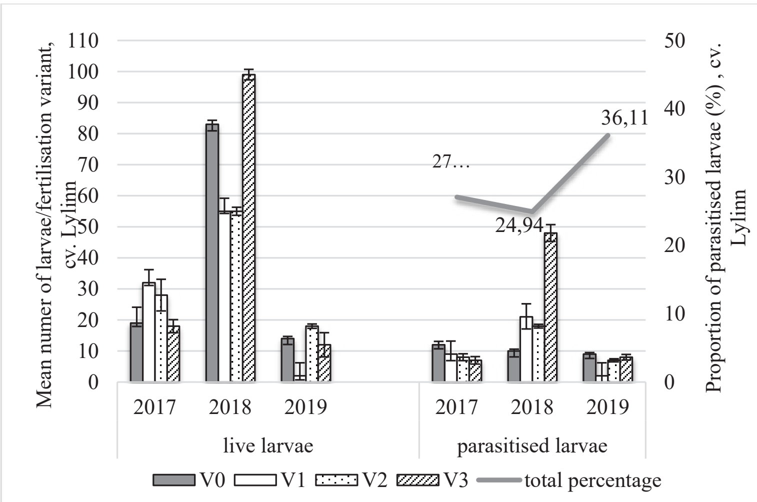

Figure 2. Number of *R. theobaldi* larvae by different fertilization treatments in cultivar ′Lyulin′

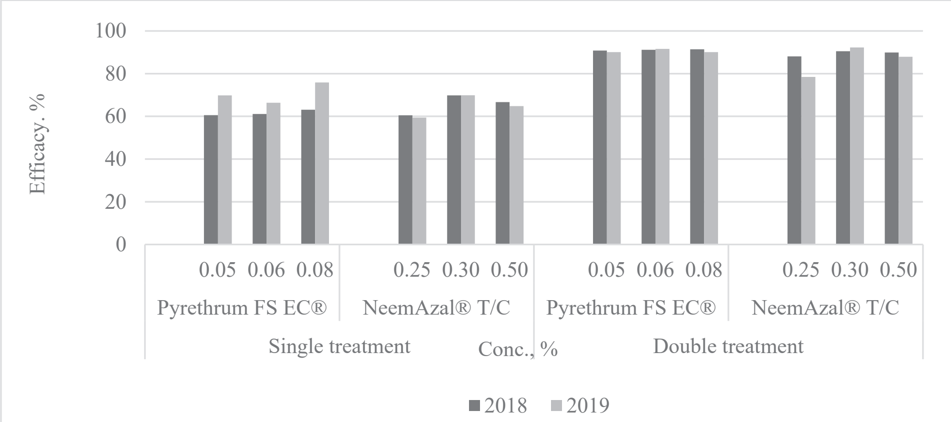

Figure 3. Efficacy of botanical insecticides against *R. theobaldi* adults under field conditions in 2017-2019

CONCLUSIONS

The duration of fertilization with various organic fertilizers does not had a direct influence on over-wintering stock of *R. theobaldi* larvae in the cultivars ′Willamette′ and ′Lyulin′.

A higher degree of parasitism from the endoparasitoid *A. epicharmus* was observed in the larvae of the cultivar ′Lyulin′ (36.11%) than in the cultivar ′Willamette′(21.05%).

The double treatment against adults of the second-generation raspberry cane midge with Pyrethrum FS EC® - 0.05% and NeemAzal® T/S - 0.3% showed very good efficacy up to 90.8% resp. 92.3%.

REFERENCES

Abbott, W.S. (1925). A method of computing the effectiveness of an insecticide. *J. econ. Entomol*, *18*(2), 265-267.

Altieri M.A., Nicholls C.L. (2003) Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystems. *Soil Tillage Res 72*, 203-211.

Barzman, M., Bàrberi, P., Birch, A. N. E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., ... & Lamichhane, J. R. (2015). Eight principles of integrated pest management. *Agronomy for sustainable development, 35*(4), 1199-1215.

Estrada-Beltran, A., Salas-Salazar, N. A., Parra-Quezada, R.A., Gonzalez-Franco, A.C., Soto-Caballero, M.C., Rodriguez-Roque, M. J., ... & Chavez-Martinez, A. (2020). Effect of conventional and organic fertilizers on volatile compounds of raspberry fruit. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *48*(2), 862-870.

Henderson, C.F. & Tilton, E.W. (1955). Tests with acaricides against the brow wheat mite. *Journal of Economic Entomology*, *48*,157-161.

MacConnell, C.B., Menzies, G.W., & Murray, T.A. (2001). Integrated pest management for raspberries. *In VIII International Rubus and Ribes Symposium*, 585, 299-302.

Mitchell, C., Hawes, C., Iannetta, P., Birch, A.N.E., Begg, G., & Karley, A.J. (2018). An Agroecological Approach for Weed, Pest and Disease Management in Rubus Plantations. *In Raspberry. Springer, Cham*, 63-81.

Mohamedova, M. (2017). Field evaluation of three biopesticides for control of the raspberry cane midge, Resseliella thobaldi (Barnes) in Bulgaria. *Advances in Horticultural Science*, *31*(3), 183-189.

Nilsson, T. (2008). Raspberry cane midge (Resseliella theobaldi (Barnes)), biology, control methods and monitoring. *PhD Thesis, Sveriges Lantbruks-universitet*, 28 pp.

Pitcher, R.S., & Webb, P.C.R. (1952). Observations on the Raspberry Cane Midge (Thomasiniana Theobaldi Barnes): II.“Midge Blight”, A Fungal Invasion of the Raspberry Cane Following Injury by T. Theobaldi. *Journal of horticultural Science*, *27*(2), 95-100.

Sipos, K. (2012). The monitoring, daily activity, and development of forecasting methods of raspberry cane midge (*Resseliella theobaldi* (Barnes)). *PhD Thesis, Budapesti Corvinus Egyetem*, 16 pp.

Stojanov, D., Milošević, T., Mašković, P., Milošević, N., Glišić, I., & Paunović, G. (2019). Influence of organic, organo-mineral and mineral fertilisers on cane traits, productivity and berry quality of red raspberry (*Rubus idaeus* L.). *Scientia Horticulturae*, *252*, 370-378.

Stoyanov D. (1963). Investigations on the raspberry cane midge *Thomassiniana thebaldi* Barnes in Bulgaria. *Izvestija na Instituta za Zastita na Rastenijata*, *Gara Kostinbrod, 4*, 41-46 (in Bulgarian).

Tsolova, E & Koleva, L. (2019). Control of *Agrilus aurichalceus* Redt. (Coleoptera: Buprestidae) in

biological raspberry production. *Rastenievadni nauki*, 56(4), 26-3.
Vétek, G., Thuróczy, C., & Pénzes, B. (2006). Interrelationship between the raspberry cane midge, *Resseliella theobaldi* (Diptera: Cecidomyiidae) and its parasitoid, *Aprostocetus epicharmus* (Hymenoptera: Eulophidae). *Bulletin of entomological research*, *96*(4), 367.
Xiu-yan, B.U. (2011). Effect of Different Kinds and Dosages of Organic Fertilizer on Raspberry Yield in Autumn. *Journal Horticulture & Seed*, 6.