International Journal of Horticultural Science 2008, 14 (4): 23–26
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Study on the emergence of the raspberry cane midge (*Resseliella theobaldi* Barnes) on the basis of temperature data and catches of sex pheromone traps

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Summary: Effective chemical protection against the raspberry cane midge (*Resseliella theobaldi*) should be based on the monitoring of the emergence of the pest. Before the application of sex pheromone traps, the results of several international studies carried out to determine the accumulated temperature needed by the larvae to become adults showed differences in the calculated data. The aim of this paper was to give information on the time of cane midge emergence by using sex pheromone traps and different methods of accumulated temperature calculations. On the basis of three years' results, the use of accumulated soil temperatures turned out to be reliable for the prediction of cane midge flight, and the relative standard deviation was the smallest in the case of 0 °C compared with other values applied as supposed biological zero points. According to our studies, 665 day °C are required for the development of one generation of the raspberry cane midge during the vegetation period. The emergence of the first generation was found at 451 day °C.

Key words: accumulated temperatures, air temperature, biological zero point, prediction, raspberry cane midge, soil temperature

Introduction

The raspberry cane midge (*Resseliella theobaldi*) was first described by Theobald in England, 1920. During the next decades, it was reported from several other European countries as well (*Woodford & Gordon*, 1978). In Hungary, the first observation of the damage caused by the raspberry cane midge was in Fertőd in 1958. The midge was found in 1962 and 1963 at Szigetcsép, Nagyréde, and near Győr, too (*Hódosy* et al., 1964).

The larvae of the pest feed on the periderm of the raspberry cane causing brown or violet necrosis spreading into the cambium (*Balázs*, 1966). Moreover, the damaged canes become susceptible to different fungal diseases like *Didymella applanata* and *Coniothyrium fuckelii* (*Hódosy*, 1965, *Williamson & Hargreaves*, 1979, *Gordon & Williamson*, 1991).

The basic requirement of the effective chemical protection against the raspberry cane midge is the identification of the time of midge emergence. Before the application of sex pheromone traps, experiments were carried out by *Gordon* et al. (1989) with the aim of determining the time of adult midge appearance by calculating accumulated soil temperatures. Based on their investigations in Scotland, the accumulated effective soil temperature above the basic 4 °C (339 day °C) can be used for the forecast of the flight of the first generation. Later on, these studies were continued in several other countries using the accumulated temperature calculation method so as to predict the time of the first flight of the adult midges. The calculated value was 360 day °C in Switzerland (*Schmid* et al., 2001), 260 day °C in Italy, 200 day °C in Finland (*Barrie* et al., 2000) and 312 day °C in France (*Gordon* et al., 2002). The remarkable differences in the results determined in different countries suggest further research in order to give more accurate data for the determination of the accumulated temperature needed by the first generation cane midge larvae to become adults. The aim of this work was to proceed in the topic described here by the use of sex pheromone traps and different calculation methods of accumulated temperature.

Materials and methods

Research was carried out in a raspberry plantation at Berkenye, Nógrád county, Hungary. For the monitoring of the flight of the raspberry cane midge, sex pheromone traps developed at the East Malling Research (*Cross & Hall*, 2006) were applied. These traps were tested in Hungary, too (*Cross* et al., 2007; *Sipos* et al., 2007). The sticky inserts in the traps were changed weekly from April until the beginning of October in 2006 and 2007, and from April to the end of August in 2008. The male midges caught in the traps were identified and the specimens were counted using a stereomicroscope. The lures were changed monthly. Eight traps in 2006, six in 2007 and two in 2008 were applied in the experimental area.

For the calculation of the accumulated temperature, an automatic soil and air thermometer (TGP-4510) was used inside the plantation, and the device recorded the data in every half hour. The soil thermometer was placed 10 cm under the surface of the ground, while the air thermometer in a paper box with ventilation splits was fixed to the supporting system of raspberry at the height of 50 cm. Using the data of the thermometer, the daily mean temperatures from 7 pm of each day to 7 pm of the next day were calculated. As the biological zero point of *R. theobaldi* is not known, different effective accumulated temperatures above different base temperatures were calculated using the formula:

$$T = \sum_{t_n > t_0} t_n - t_0$$

Where T is the effective accumulated temperature, t_n is the mean temperature of the n-th day, t_0 is the supposed biological zero point (the base temperature) and the summation is determined over the period between two consecutive peaks of emergence where the temperature was permanently over the base temperature. The effective accumulated temperature was calculated on the basis of both the soil and air temperature values because the pupae of the pest can be found in the soil, while the eggs, larvae and adults are on the canes. These data were compared with the trap catches.

Results

The numbers of midges trapped weekly during the three years is shown in *Fig. 1–3*. The number of passed weeks after the beginning of April is indicated on the time axis. In 2006, there were three distinguishable generations followed by an incomplete one (*Fig. 1*). For the calculation of the accumulated temperature, the periods between the peaks of the first and the second (5th–13th weeks), and the second and the third generations (13th–18th weeks) were used.

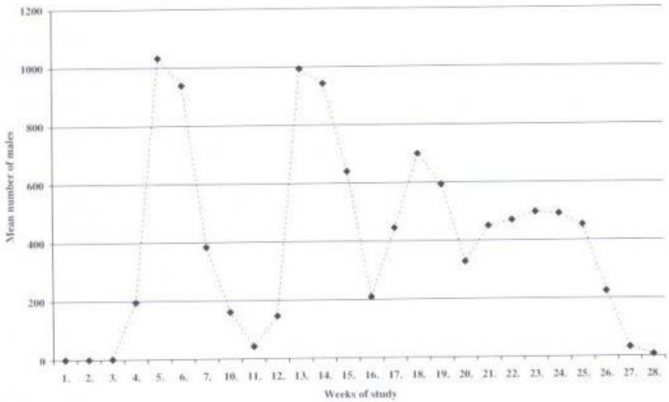

Figure 1. Mean number of trapped male raspberry cane midge (*R. theobaldi*) adults based on the catches of eight sex pheromone traps (*Berkenye*, 2006)

In 2007, there were only two distinguishable generations, so calculations were made only over the period between the 4th and the 11th week (Fig. 2).

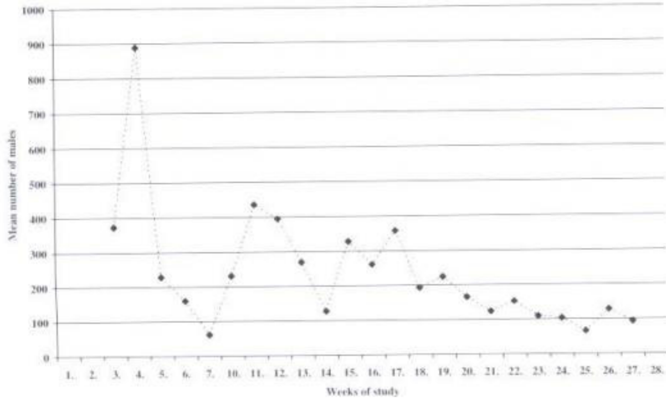

Figure 2. Mean number of trapped male raspberry cane midge (*R. theobaldi*) adults based on the catches of six sex pheromone traps (*Berkenye*, 2007)

In 2008, the first three generations were distinguishable, so the accumulated temperature was calculated between the 5th and 12th week and between the 12th and the 16th week.

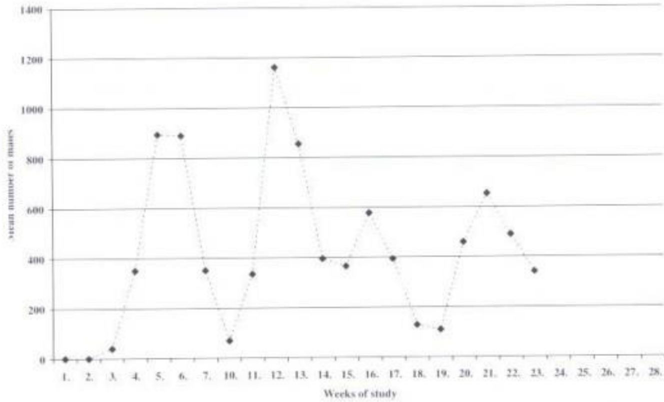

Figure 3. Mean number of trapped male raspberry cane midge (*R. theobaldi*) adults based on the catches of two sex pheromone traps (*Berkenye, 2008*)

The effective accumulated soil and air temperatures were calculated for each generation and with each supposed biological zero points. The mean of these data can be seen in

Table 1. The mean effective accumulated temperatures needed for the development of one generation of the raspberry cane midge (*R. theobaldi*)

Supposed biological zero point	Accumulated soil temperature (day °C)	Accumulated air temperature (day °C)
0°C	665	689
1°C	630	654
2°C	595	619
3°C	561	585
4°C	526	550
5°C	492	516
6°C	457	481
7°C	422	446
8°C	388	412

Table 1. The standard deviations and relative standard deviations of the accumulated temperatures belonging to a supposed base point can be seen in Fig. 4 and 5.

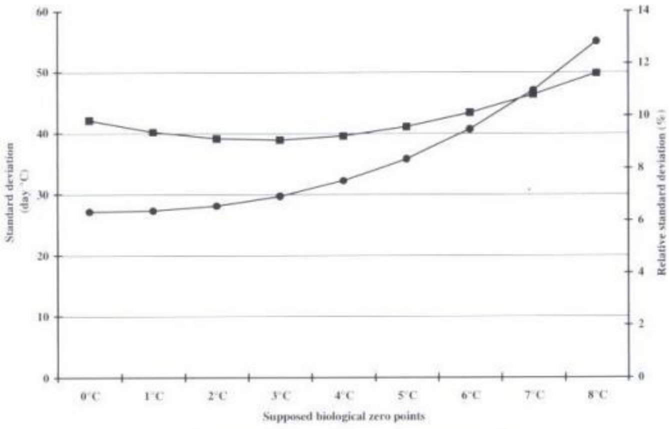

Figure 4. The standard deviation and relative standard deviation of the effective accumulated soil temperatures above different base temperatures (*Berkenye*, 2006, 2007, 2008)

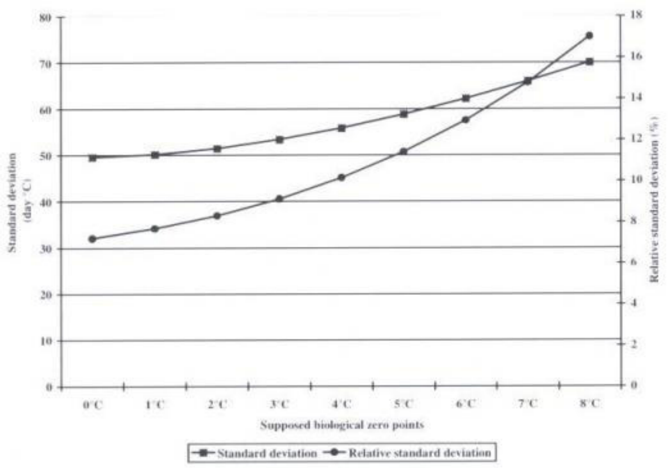

Figure 5. The standard deviation and relative standard deviation of the effective accumulated air temperatures above different base temperatures (*Berkenye*, 2006, 2007, 2008)

The relative standard deviation of the effective accumulated soil temperatures was the smallest (6.3%) above the 0 °C base temperature. The standard deviation between 39 and 50 day °C which means 1–3 days uncertainty in the prediction of midge emergence.

The smallest relative standard deviation of the effective accumulated air temperatures was above the 0 °C base temperature and this means 7.2%. The standard deviation between 50 and 70 day °C which means 3–5 days uncertainty in the prediction of midge emergence.

Discussion

Considering the data of the three-year study, the effective accumulated temperature calculated from soil temperatures is more suitable for the prediction of the emergence of each generation of *R. theobaldi*. On the basis of the smallest relative standard deviations, the 0 °C can be indicated as the best value for a biological zero point. The sex pheromone trap is suitable for the monitoring of raspberry cane midge male emergence. The calculation method of the effective accumulated soil temperatures gives us the possibility to study and analyse the effect of temperature on the development of midges, and helps to improve the prediction method. *Gordon* et al. (1989) also found the accumulated soil temperatures suitable for predicting the first oviposition of the midge. The relative standard deviation was found to be the smallest at the 2 °C base temperature (11.5%), while it was a bit higher (12.6%) when calculated with 4 °C. On the basis of their data, they estimated the appearance of the first eggs in previous years. The prediction turned out to be the most accurate using the 4 °C base temperature, the error was 2.6 days on an average. According to our studies, the relative standard deviation was the smallest when we used 0 °C as a base temperature. However, *Gordon* et al. (1989) did not calculate with base temperatures below 2 °C. If we do not take into consideration the 0 °C and 1 °C, our calculations will agree with those of the before-mentioned researchers in the respect that we also got the smallest relative standard deviation at 2 °C used as a base temperature.

On the basis of our investigations, 665 day °C are required for the development of one generation of the raspberry cane midge during the vegetation period. The emergence of the first generation can be expected at 451 day °C using 0 °C as a supposed biological zero point.

Our results show that it is necessary to calculate with temperature values to one decimal when determining the biological zero point with the smallest possible relative standard deviation, and it is also important to control the prediction as described by *Gordon* et al. (1989).

Acknowledgements

The authors would like to thank Jerry Cross for his cooperation. This research was funded by the GAK2005 Fkut1kol project.

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