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Original article

The seasonal wing-length variation and bionomy of *Tinearia alternata* (Diptera: Psychodidae)

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Abstract
Tinearia alternata (Say, 1824) is one of the most common cosmopolitan species of the family Psychodidae and is widespread throughout the world wherever it has suitable living and reproduction conditions. Due to its neutral relationship (whether positive or direct) to humans, this species is often overlooked and therefore insufficiently studied. This work provides a detailed analysis of the one-year life cycle of this species and also analyses the seasonal variability of wing length in both sexes of this species. From environmental variables, temperature positively correlates with abundance of both males and females of *T. alternata*, while precipitation showed negative correlations only with female abundance. *T. alternata* has two significant population maxima. The first large maximum, which consists of three mutually overlapping generations, was recorded in May–June. The second maximum was recorded at the end of August. The last indication of third maximum, represented by only a few specimens, was recorded at the turn of October and November. The data suggest a correlation between abundance (or activity) of both sexes with precipitation, with an inverse trend in values visible. Though we did not confirm a statistically significant correlation between precipitation and activity (abundance), we concluded that during periods of more intense precipitation, the activity (abundance) decreased to very low values. By analysing results of wing length of both sexes of *T. alternata*, we found out that the largest wing length for both sexes was recorded at beginning and end of the season, while shortest wing length for both sexes was recorded between June and August.

Keywords: moth flies, trickling filter fly, environmental factors, life cycle, wing length

Introduction

Research in the dipterous insects is not just about describing new species and creating checklists for specific countries or regions. Diptera also represent an important object of research in the field of biology, epidemiology, phytopathology, etc. Depending on the amount and quality of information, various ecological studies can then be created (e.g., Oosterbroek 2006). Both in the world and in Slovakia, a great deal of attention is devoted primarily to those groups of Diptera, or generally insects, that pose a direct or indirect threat to humans, or insects that are "aesthetic", interesting or "special". Common species that live in close proximity to our dwellings, especially synanthropic species, but also those that have no impact on humans, are usually given only marginal attention. Diptera generally represent a very diverse and variable group of insects with diverse biology (e.g., Manko 2015). An example of a relatively well-studied Diptera family is the family Psychodidae, a relatively large family with more than 3,000 described species, with the greatest biodiversity occurring mainly in tropical and humid climates (Curler & Moulton 2012; Ježek & Barták 2000). Altogether, 119 species of this family are listed in the present checklist in Slovakia (Ježek et al. 2021).

Adults have a short and chaotic flight and often occur in shady places near water, wetlands or directly near larval habitats (Ježek 1972). *Tinearia alternata* (Say, 1824) or the trickling filter fly (known also under the synonym *Psychoda alternata* Say, 1824; see Ježek (1997)) is one of the most common species of this cosmopolite family and is widespread throughout the world wherever it has suitable living and reproduction conditions. Adult individuals occur from April to September, sometimes until October, where the maximum number of flies peaks in mid-summer. This species is often present in damp places, such as cesspit walls, livestock farms, sites with excrement and other organic materials, as well as on the shores of swamps, etc. (Yabe et al. 1970; Szabó 1972–1973; Rozkošný 1971; Vaillant 1971–1983; Ježek 1972; Semelbauer et al. 2020).

The main objective is to describe the population dynamics and seasonal wing-length variation of *T. alternata* in a cow shed and to evaluate what environmental variables are affecting it.

Material and methods

Samples were collected at a bovine farm (Poľnohospodárske družstvo Šenkvice), which is located in the village of Šenkvice (48°18‘09.2“N 17°21‘34.6“E, altitude 175 m a.s.l.). Airstrike wall traps (which operate on a similar principle to Malaise‘s traps, see Semelbauer et al. 2020) were designed and used for collection. Sampling took place at regular weekly intervals from April 2016 to April 2017. Subsequently, the material from each trap was placed in a separate collection container, fixed with alcohol and

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transferred to a laboratory for further processing. In the laboratory, whole material was first sorted to the family level, and selected families were subsequently processed. Family Psychodidae (Figure 1) was first identified under a stereomicroscope to the species level using the determination literature (Satchell 1947; Ježek 1977, 1990; Wagner 1997) (only complete or minimally damaged samples were identified). A macroscopically easily identifiable taxon – *T. alternata* – was measured using a stereomicroscope with a measuring eyepiece. Since the family Psychodidae does not have a strongly sclerotized body, size is variable; thus, the length of the wing was measured – from the base to the wing to is apex (see Figure 2).

Figure 1. A sample of sorted Psychodidae material ready for identification.

Figure 2. A female of *T. alternata* with the wing-length measurement scheme.

In addition to the collection of biological material, data on external temperature and precipitation were also obtained from the nearest weather station from the Slovak Hydrometeorological Institute (SHMU) for the collection period.

General linear models (GLM) with Poisson distribution and Log link function were used to predict the *T. alternata* activity as a response (dependent variable) to temperature (independent variable).

The Past software (version 4.09; Hammer et al. 2001) was used to provide the analyses.

Results

Overall, 3,009 specimens of *Tinearia alternata* (Say, 1824) (664 males, 2,345 females) were obtained from all the traps throughout the collection period.

The data indicate an association of abundance (or activity) of both sexes with precipitation. An inverse trend in values is visible. GLM plots in Figures 3 and 4 show, that during periods of intense rainfall activity, the abundance dropped to very low values.

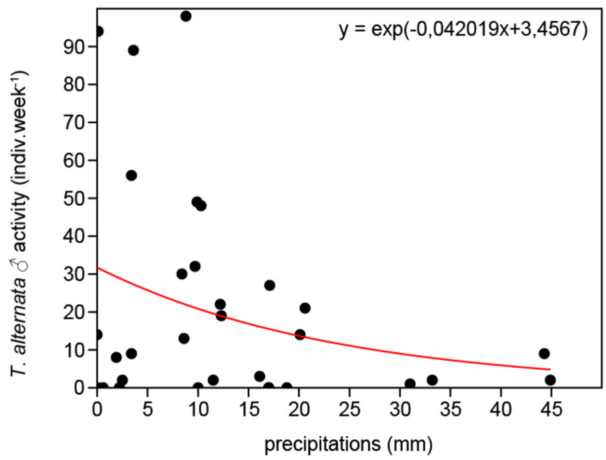

Figure 3. Negative relationship between the activity of *T. alternata* males and precipitations - Generalized linear model plot (Poisson distribution, log link; Slope a: -0.042019; Std. err. a: 0.005; Intercept b: 3.457; Std. err. b: 0.054; Log likelihood: -472.48; G: 107.61; p<0.0001).

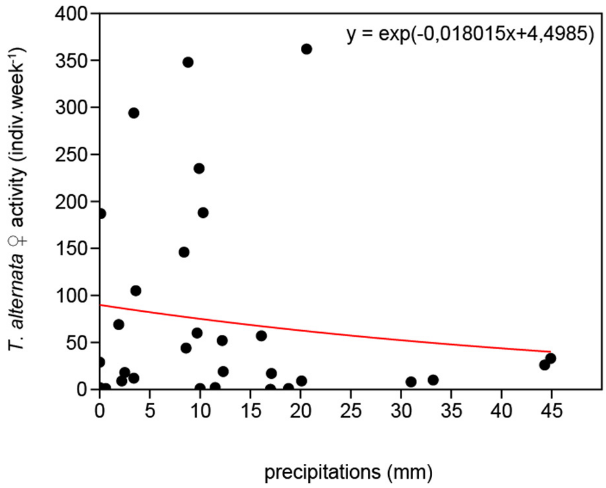

Figure 4. Weak negative relationship between the activity of *T. alternata* females and precipitations - Generalized linear model plot (Poisson distribution, log link; Slope a: -0.018015; Std. err. a: 0.002; Intercept b: 4.499; Std. err. b: 0.029; Log likelihood: -1893.8; G: 88.458; p<0.0001).

Contrary to precipitation, the activity of both sexes increased with temperature, mainly higher than 13 °C (Figures 5 and 6).

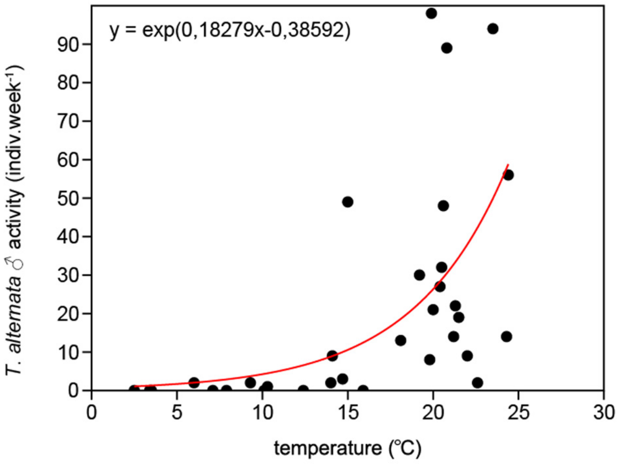

Figure 5. Positive relationship between the activity of *T. alternata* males and temperature - Generalized linear model plot (Poisson distribution, log link; Slope a: 0.18279; Std. err. a: 0.011; Intercept b: -0.386; Std. err. b: 0.226; Log likelihood: -292.91; G: 466.75; p<0.0001).

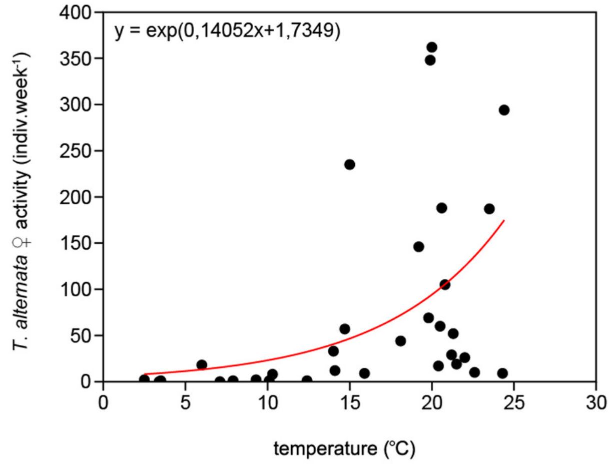

Figure 6. Positive relationship between the activity of *T. alternata* females and temperature - Generalized linear model plot (Poisson distribution, log link; Slope a: 0.14052; Std. err. a: 0.005; Intercept b: 1.735; Std. err. b: 0.101; Log likelihood: -1354.3; G: 1167.4; p<0.0001.

It is clear that the activity of males and females is very similar and the abundance of individuals of both sexes not only regarding to precipitations and temperature but also in terms of seasonal dynamics (Figure 7). For a better overview, average temperature and precipitation amounts are also projected on the secondary axis. The graph shows that the species *T. alternata* has two significant population maxima. The first large maximum, consisting of three overlapping generations, was recorded in May–June. The second maximum was recorded at the end of August. The last hint of the least significant third maximum, represented by only a few specimens, was recorded at the turn of October and November.

Upon analysing the results of measurements of the wing length of both sexes of the species *T. alternata* we found that the highest wing length for both sexes was recorded at the beginning (May) and end (November) of the season (8 – 8.5 mm for ♂ and 11 – 12 mm for ♀). While shortest wing length (4 – 5 mm) for both sexes was recorded between June and August. Changes in wing length during the season due to the relatively large dispersion of values in individual collections as well as fluctuations over time better reflect the trend curves in the figures (Figures 8 and 9).

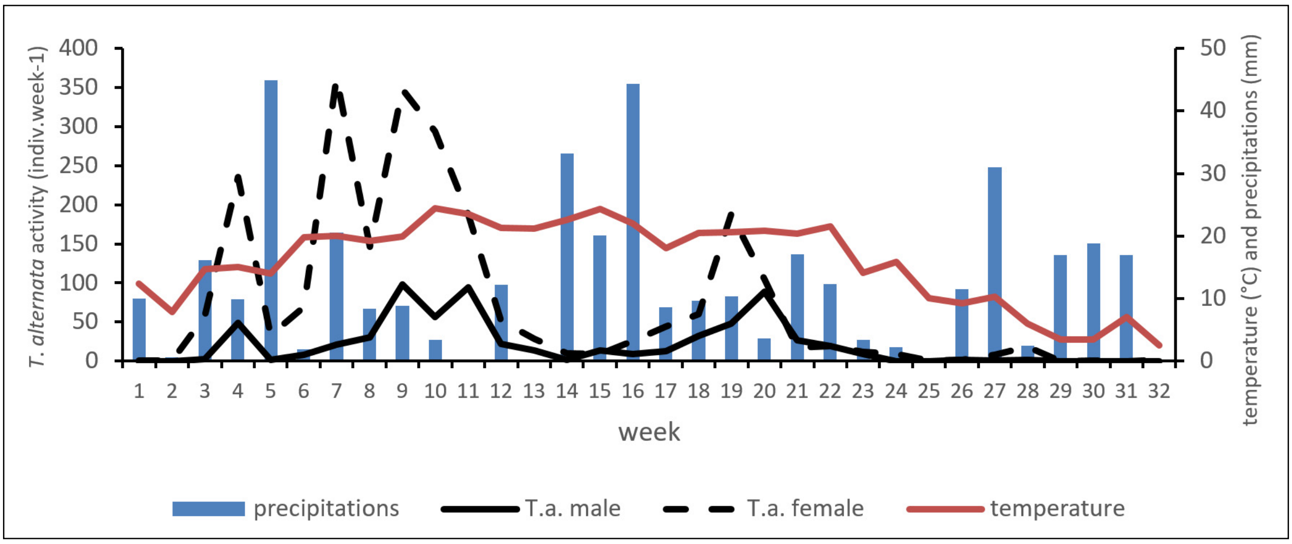

Figure 7. Seasonal dynamics of male and female abundance of *T. alternata*; the secondary axis shows average temperature and precipitation, including the moving average of precipitation values over the reference period (data from 21 Nov 2016 to 23 Mar 2017 are not shown on the graph because *T. alternata* was not present in the samples).

Discussion

According to Satchel (1947), the species *T. alternata* breeds only in very humid and organic-enriched environments but does not constitute a specialist for farms and their environment. Satchel further states that adults can get here, for example, from wastewater and, if they find suitable habitat, are able to multiply rapidly. This also corresponds to our results, as no specimen of this species was recorded in traps during winter. *T. alternata* is a cosmopolitan species (e.g., Quate 1955; Satchel 1947; Vaillant 1971–1983; Rozkošný 1971; Ježek 1972; Halgoš 1973; Ježek 1984; Kroča & Ježek 2015, 2019, 2022; Ježek et al., 2017, 2018a,b, 2020, 2021; Morelli & Biscaccianti 2021; etc.). Adults occur in the wild from April to September quite frequently. The maximum occurrence is usually dated at the beginning of summer, especially in the vicinity of sewage, sewerage, near wet manure, sewage treatment plants, rotting vegetation and the like. It is also often found near human dwellings (Ježek 1977). Similarly, in this work we recorded two significant population maxima. The first large maximum was recorded in months of May to June. The second maximum was recorded at end of August. The last hint of the least significant third maximum, represented by only a few specimens, was recorded at the turn of October and November.

Most species of the family Psychodidae have a relatively short life cycle, especially in favourable environmental conditions (Vaillant 1971–1983). Ameen & Huq (1973) indicate the length of development as follows: in summer 7–9 days, in winter 13–15 days (in Bangladesh); Quate (1955) indicates larval development time up to 21–27 days. According Solbé et al. (1974), development depends mainly on the temperature, and temperature also affects the longevity of adults. Vaillant (1971) noted that at 4°C adults live for about one month, and at 25°C for about 10 days. For these reasons, we believe that individual peaks at the first population maximum could have been formed by three separate generations, and throughout the research, *T. alternata* could have up to five generations (see Figure 4) (the first three generations were present at the first population maximum, followed by one generation at the second population maximum (end of August) and the last generation (probably wintering with the longest wings) at the end of October).

Lloyd et al. (1940) investigated the seasonal occurrence of *T. alternata* and concluded that the incidence of this species outdoors is gradually increasing from spring to autumn. According to the authors, the decrease in occurrence during the summer may be related to an increase in the presence of other species, i.e., competition. According to our results, the most important factors that influenced the abundance of *T. alternata* were season, precipitation and temperature. The results show that the abundance of this species dropped sharply after more intense precipitation (e.g., 20.5.2016 or 20.7.2016). Klueken et al. (2009) argue that increased precipitation activity shortens the flight time and thereby reduces the species dispersion distance. This may also be due to the fact that insects largely avoid flying in the rain.

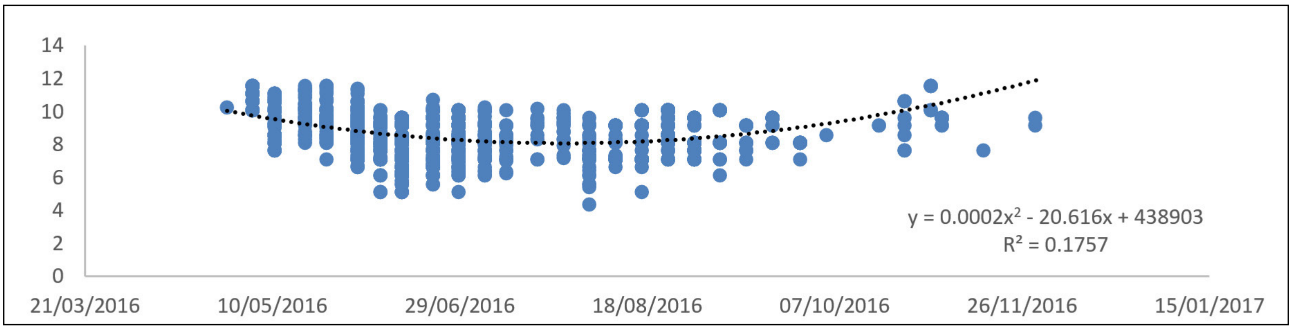

Figure 8. Graphical representation of measured wing lengths of females obtained at individual sampling dates (the dashed line represents a polynomial trend curve, in the blue box are the curve equation and the r^2 value).

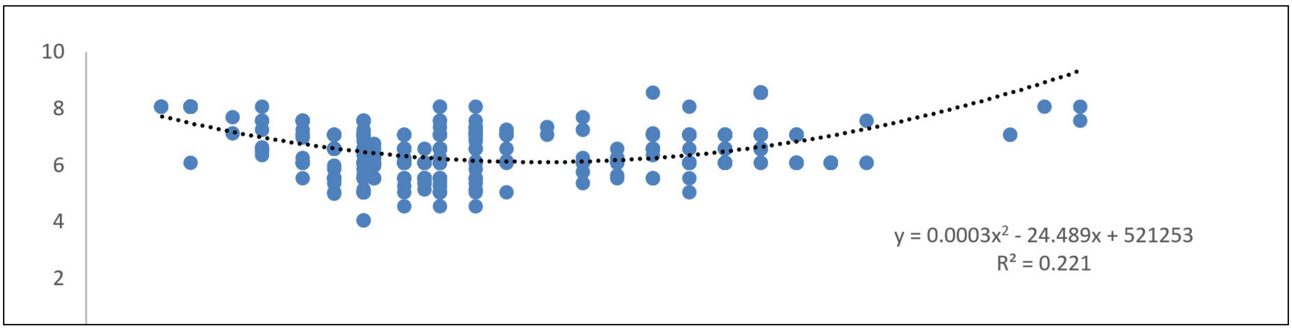

Figure 9. Graphical representation of measured wing lengths of males obtained at individual sampling dates (the dashed line represents a polynomial trend curve, in the blue box are the curve equation and the value r^2).

By analysing the results of the wing length of *T. alternata*, we found that the longest wing length for both sexes was recorded at the beginning and the end of the season, while the shortest wing length for both sexes was recorded in the months of June to August. Oboňa et al. (2016), who measured the length of wing of species *Clogmia albipunctata* (Williston, 1893), achieved similar results. We assume that greater wing length at the beginning and the end of the season may be due to the fact that both species (*C. albipunctata* and *T. alternata*) migrate during this period, while smaller individuals in the middle of season are only meant to reproduce and do not migrate significantly.

Research on the Psychodidae family can also be important from an epidemiological point of view, as flies of this family can directly or indirectly spread pathogens. Bovien (1937) in his work indicates that many species of the family Psychodidae carry larval stages of *Rhabditis* (Nematoda: Rhabditidae). The worms wrap around the abdomen of adults in grooves between body segments and often occur on flies harvested in fields near manure. In laboratory experiments, these worms were able to be carried by almost all species of the family Psychodidae (Goodey 1943). Flies of this family also have a number of internal parasitic nematodes that almost fill body cavity with their eggs. They are also capable of transmitting various medical and veterinary protozoa, e.g., genus *Glaucoma* (Watson 1946). Myiasis is also known in this family (see e.g., Okada 1927; Tokunaga 1953; Önder et al. 2018; Sarkar et al. 2018). It is very important that we continue to draw our attention to such often overlooked species in order to contribute to the overall knowledge of organisms that live in close proximity to our homes.

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