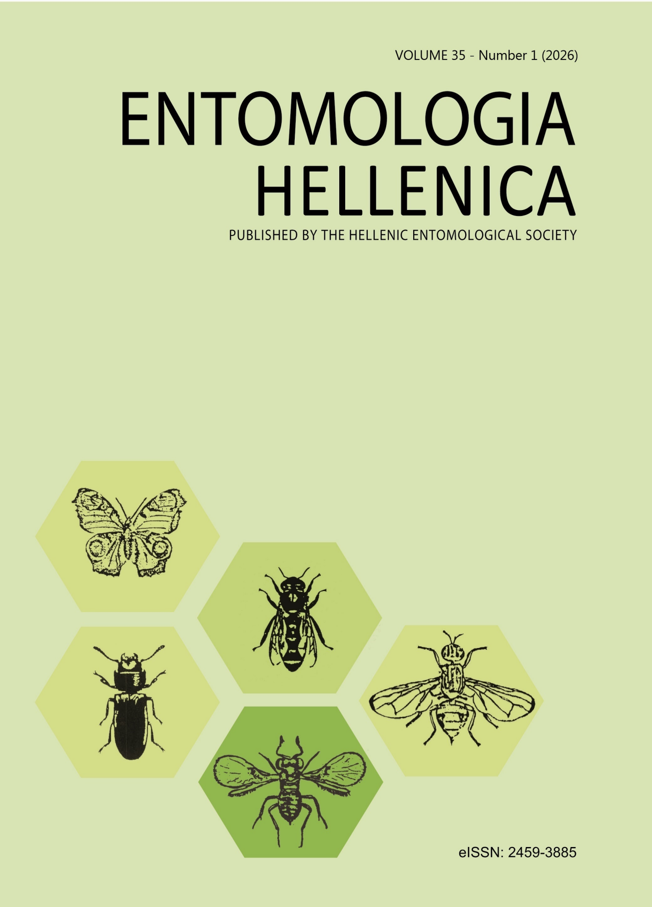
ENTOMOLOGIA HELLENICA

Vol 35, No 1 (2026)

Entomologia hellenica 35(1)



Species composition, biology, and phytosanitary status of Diptera damaging sweet cherry: overview and monitoring results in Central Southern Bulgaria

Plamen Ivanov

doi: 10.12681/eh.42433

ENTOMOLOGIA HELLENICA **35** (2026): 63-79

Received 17 August 2025 Accepted 05 December 2025 Available online 25 March 2026

Species composition, biology, and phytosanitary status of Diptera damaging sweet cherry: overview and monitoring results in Central Southern Bulgaria

P. I. IVANOV

Department of Orchard Management and Plant Protection, Fruit Growing Institute, Ostromila 12 str, Plovdiv, Agricultural Academy – Sofia, BULGARIA

ABSTRACT

Sweet cherry (*Prunus avium* L.) is one of the economically significant fruit crops in Bulgaria and Europe, subjected to notable phytosanitary pressure from fly species belonging to the families Tephritidae and Drosophilidae. This study provides both a literature-based overview and original field-monitoring data on Diptera species affecting cherries, collected during surveys conducted in southern Bulgaria from April to June 2025. Monitoring methods included yellow sticky traps and visual inspections of fruit. The results confirmed the presence of *Rhagoletis cerasi*, a univoltine species responsible for direct damage through oviposition in ripening fruits. Notably, no other species of *Rhagoletis* or *Drosophila suzukii* were detected, likely due to specific local climatic and phenological conditions. Possible reasons for non-detection, including trap type, host phenology, microclimatic conditions, and severe frost damage in 2025 (which reduced cherry fruit availability by 75–95% in some cultivars), are discussed. The study presents a binary morphological identification key and a diagnostic table of distinguishing traits for practical field identification. The findings highlight the importance of continuous monitoring and early warning systems, particularly under shifting climatic conditions and evolving pest pressures, underscoring the need for targeted and sustainable plant protection measures.

KEY WORDS: climate change, Diptera, invasive species, phytosanitary monitoring, plant protection, *Prunus avium*, *Rhagoletis cerasi*.

Introduction

The rapid growth of the global population demands diverse agricultural strategies to meet food needs, including expanding cultivation areas, adopting new technologies, and emphasizing sustainable practices (FAO, 2022). Recently, agricultural research has focused on the impacts of climate change—such as rising temperatures, increased CO_2 levels, and extreme weather events—which pose significant risks to crop yields and are crucial to minimizing production losses (Parry, 1990).

Pests are significant biotic stressors in fruit crop production, causing both direct and indirect damage. They reduce yield and quality through feeding and oviposition, and they can also transmit plant pathogens. Reports indicate that pest-related losses in fruit crops can reach up to 100%, with an average estimated loss of 7.8% of total production (Sharma et al., 2017).

Temperature has a significant impact on the development, survival, and reproduction of insects, particularly poikilothermic organisms such as Diptera. Warmer climates can accelerate pest reproductive cycles and ena-

**Corresponding author:* plamen280976@yahoo.com ORCID ID: 0000-0001-8980-9583

ble migration into new habitats, impacting population dynamics and ecological interactions (Kocmánková et al., 2010; Karuppaiah and Sujayanad, 2012; Prakash et al., 2014; Bhagarathi and Maharaj, 2023). As climate change opens up new ecological niches, pests are colonizing previously unsuitable areas, underscoring the need for adaptive surveillance and control systems (IPPC Secretariat, 2021).

Fruit flies (Diptera: Tephritidae) represent one of the most economically damaging pest groups in global fruit production and trade. Their significance is reflected in national and international quarantine protocols, as well as ongoing research in entomology and integrated pest management.

The family Tephritidae includes over 5,000 species across about 500 genera and six subfamilies, many of which are still poorly studied (Uchoa, 2012). Found in tropical, subtropical, and temperate regions (Hidayat et al., 2023), around one-third are frugivorous, with larvae feeding on host fruits and vegetables. If uncontrolled, fruit flies can cause damage ranging from minor to total crop loss, depending on the cultivar, location, and season (Dhillon et al., 2005; Tanga et al., 2018).

In temperate regions, three major fruit fly species have drawn particular attention: *Rhagoletis cerasi* (Linnaeus, 1758) (European cherry fruit fly), *Ceratitis capitata* (Wiedemann, 1824) (Mediterranean fruit fly), and *Bactrocera oleae* (Rossi, 1790) (Olive fruit fly). Documented damage includes up to 90% yield loss in late cherry varieties in the Upper Rhine, Bulgaria, and Romania, along with severe losses in peaches, apricots, and olives across Europe and the Middle East (Fischer-Colbrie and Busch-Petersen, 1989; Fimiani, 1991).

The EU's revised plant health legislation—Regulation (EU) 2016/2031—addresses concerns about the introduction and establishment of pests. EFSA is responsible for categorizing regulated pest species to support preventive measures, including 23 non-EU Tephritidae species due to their phytosanitary risk (EFSA PLH Panel, 2020).

Drosophila suzukii, the spotted-wing drosophila, has attracted increasing attention in recent years due to its ability to infest healthy fruits, causing yield losses of 30–50% in berry crops (Cini et al., 2014; Asplen et al., 2015; Savaris et al., 2016). In Bulgaria, the species was first recorded in 2014 in Blagoevgrad (Karadjova et al., 2016), with subsequent reports from Kyustendil and Central Bulgaria (Petrova et al., 2020; Minkov et al., 2017), and infestations on berry crops in the Troyan region (Minkov et al., 2018). Additional hosts such as mistletoe (*Viscum album* L.) have been documented (Zaemdzhikova et al., 2018). Recent studies further analyze the risk for raspberries and evaluate the effectiveness of different monitoring traps (Arabadzhiev and Palagacheva, 2023; 2025). Although *D. suzukii* was not detected in the present survey, its documented presence in Bulgaria underscores the importance of continuous monitoring and preparedness for potential outbreaks in cherry orchards.

In addition to *D. suzukii*, the American cherry fruit fly (*Rhagoletis cingulata*) has been reported in neighboring European regions, raising concerns about its potential introduction and hybridization with *R. cerasi* in Bulgaria. The species has been expanding its range in Europe over the past two decades, with established populations reported in Germany (EPPO, 2011; Vogt et al., 2012), Hungary (Kovács et al., 2013), and the Czech Republic (Máca, 2013). Its introduction is considered high-risk due to its ecological similarity to *R. cerasi* and its ability to infest both wild and cultivated cherries. Several studies have also documented natural hybridization between *R. cingulata* and *R. cerasi* in sympatric regions, raising concerns about potential genetic introgression and altered pest behavior (Doell et al., 2014; Johannesen et al., 2013). These findings highlight the importance of monitoring this species as a potential invasive threat to Bulgarian cherry production.

Despite increased attention, the biology, host range, and distribution of many Tephritidae species remain insufficiently characterized. In Bulgaria, developing resilient agriculture requires proactive monitoring, early warning systems, and species-specific studies to support phytosanitary decision-making.

The present study aims to:

- Analyze the biology and monitoring results of *R. cerasi* in sweet cherry orchards in southern Bulgaria
- Present the results of monitoring conducted in cherry orchards in southern Bulgaria
- Derive diagnostic morphological keys to aid practical identification
- Discuss emerging plant protection challenges in the context of climate change and increasing pest pressure, including the documented presence of *D. suzukii* in Bulgaria and the potential threat of *R. cingulata*.

By integrating theoretical knowledge and field data, this article contributes to the development of pest diagnostics, agronomic planning, and sustainable ecological management for temperate fruit crops.

Materials and Methods

The field study was conducted from May to June 2025 in four sweet cherry orchards in the Plovdiv region of Bulgaria (Fig. 1), an area characterized by intensive cultivation and high phytosanitary risks. All orchards were surveyed during full fruit ripening, with site selection based on representativeness of local cultivars and management practices.

The surveyed sites include:

- Novo Selo (Stamboliyski Municipality): 42.121200° N, 24.496846° E; elevation 189 m
- Karadzhovo (Sadovo Municipality): 42.094279° N, 24.891415° E; elevation 167 m
- Kuklen (Kuklen Municipality): 42.028596° N, 24.804415° E; elevation 332 m
- Fruit Growing Institute (Plovdiv Municipality): 42.105789° N, 24.723725° E; elevation 173 m.

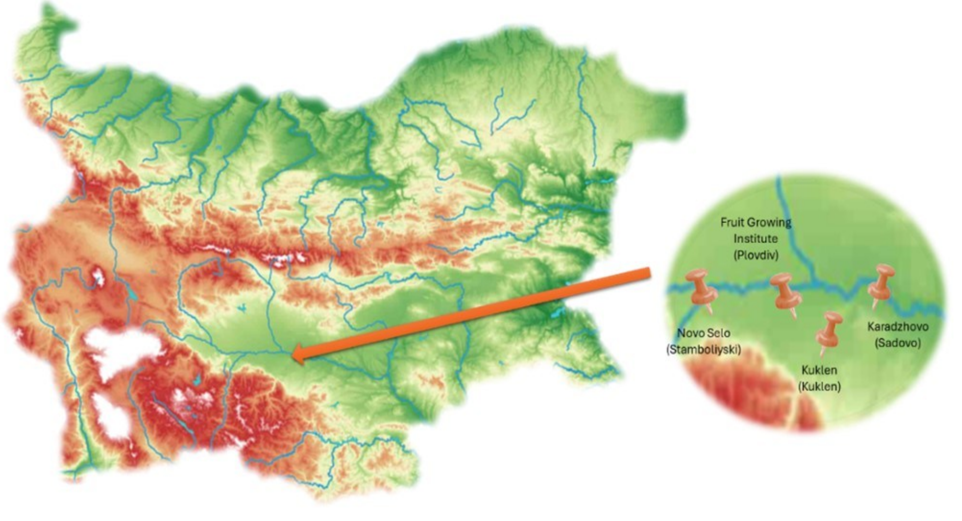


FIG. 1: Topographic map of the Plovdiv region showing the locations of the four surveyed sweet cherry orchards: Novo Selo (Stamboliyski), Karadzhovo (Sadovo), Kuklen (Kuklen), and the Fruit Growing Institute (Plovdiv). Elevation gradients and river systems are indicated. Red pushpins mark orchard sites; inset highlights their relative positions

Monitoring methods

Three complementary approaches were utilized for monitoring fruit fly activity:

Trap Deployment: Each orchard was equipped with 5–7 traps (total 25), serviced every 5–7 days, with sticky surfaces replaced and catches recorded systematically. Traps were installed in the tree canopy at 1.5–2.0 meters above ground level. Trap types included (Fig. 2):

- Csalomon® PALz trap, VARs+ funnel trap, and VARL trap (Plant Protection Institute, Centre for Agricultural Research, Budapest, Hungary)
- Rebell® yellow sticky traps (Andermatt Biocontrol AG, Switzerland). These traps are specifically designed for Tephritidae monitoring.

Visual Fruit Inspection: Mature fruits were examined for egg-laying scars and external damage typical of dipteran activity.

Specimen Collection and Preservation: Captured adult flies were preserved in 70% ethanol and transported for laboratory analysis.

FIG. 2: Representative examples of insect traps used during field monitoring. From left to right: (1) PALz trap – cylindrical container with mesh bottom and funnel top; (2) VARs+ funnel trap – green sticky surface with high capture density; (3) VARL trap – baited container with liquid attractant; (4) Rebell® yellow sticky trap – V-shaped panels designed for Tephritidae monitoring. All traps were suspended in the tree canopy at 1.5–2.0 m height and serviced every 5–7 days.

Table 1. Technical specifications of insect traps used during field monitoring.

Trap Type	Manufacturer/ Origin	Target Group	Trap Mechanism	Deployment Height	Notes
PALz trap	Csalomon®, Hungary	Tephritidae	Funnel + mesh container	1.5–2.0 m	Used with a pheromone attractant
VARs+ funnel trap	Csalomon®, Hungary	Tephritidae	Sticky surface + funnel	1.5–2.0 m	High capture efficiency
VARL trap	Csalomon®, Hungary	Tephritidae	Liquid bait container	1.5–2.0 m	Contains red liquid attractant
Rebell® yellow trap	Andermatt Biocontrol AG, Switzerland	Tephritidae	V-shaped sticky panels	1.5–2.0 m	Designed for visual attraction

Orchard management and climatic data

All surveyed orchards were conventional, managed according to national recommendations. Pest management included 2–3 insecticide applications per season with EU -approved active substances (deltamethrin, spinosad), applied according to phenological stage. Climatic data (temperature, humidity, precipitation) were obtained from the local meteorological station and are presented graphically in Figure 3, together with pest captures. Severe frost damage in March 2025 reduced cherry fruit availability by 75–95% in some cultivars, which was considered when interpreting pest population dynamics.

Identification protocols

Diptera specimens were identified using the following procedures:

Morphological Analysis: Adult flies were examined under a binocular microscope, with emphasis on wing venation and body coloration as diagnostic traits.

Taxonomic Key Development: A binary morphological key was constructed, adapting features from Uchoa (2012). For morphological identification of Rhagoletis cerasi, the descriptions of pupal stages published by Papanastasiou and Papadopoulos (2014) as well as profiles from Fruit Fly Identification Australia (n.d.) were used. The IPPC (2011, 2023) and USDA-APHIS (2017) diagnostic protocols were used to confirm species identity and quarantine status. Additional morphological keys for Diptera were consulted through online resources from ANSES (n.d.), Diptera.info (n.d.), University of Queensland (n.d.), National Museum Bloemfontein (2019), and North Carolina State University (n.d.).

Microscopy and Imaging: Suspect individuals were analyzed under ×40 magnification. Diagnostic photographs were archived for documentation and further verification. For identification and compliance with international phytosanitary requirements, regulatory documents and diagnostic protocols published by the IPPC (2011, 2023), USDA-APHIS (2017), EPPO (2011, 2013, n.d.), and EFSA (2020) were consulted. They provide standardized methods for morphological diagnosis, criteria for quarantine status, and recommendations for monitoring Rhagoletis spp. and other fruit flies.

Results

Species composition and biology of Diptera harmful to sweet cherry

The main phytosanitary threats to sweet cherry (*Prunus avium* L.) arise from fruit flies within the families Tephritidae and Drosophilidae. The dominant species detected was *R. cerasi*. Other species within the *Rhagoletis* genus and the invasive *D. suzukii* (Matsumura, 1931) pose potential risks, although they were not recorded during the study period.

Although *D. suzukii* has been documented in Bulgaria since 2014 (Karadjova et al., 2016; Minkov et al., 2017; Petrova et al., 2020; Minkov et al., 2018; Zaemdzhikova et al., 2018; Arabadzhiev and Palagacheva, 2023; 2025), it was not detected in the present survey, likely due to unfavorable climatic conditions and frost-induced fruit scarcity.

Major Diptera species affecting cherry crops

A binary morphological key was created for species-level identification and phytosanitary assessment, drawing from Uchoa (2012) and refined using morphological descriptions of *R. cerasi* pupal stages (Papanastasiou and Papadopoulos, 2014) and profiles from Fruit Fly Identification Australia. Diagnostic protocols from IPPC (2011, 2023) and USDA-APHIS (2017) were used to verify species identity and quarantine status.

To facilitate accurate field-level differentiation between *Rhagoletis cerasi* and other Diptera of phytosanitary concern, comparative morphological traits were compiled from literature and online identification tools, including ANSES (n.d.), Diptera.info (n.d.), University of Queensland (n.d.), National Museum Bloemfontein (2019), and

Table 2. Biological and phytosanitary characteristics of key Diptera species harmful to cherry.

Species	Family	Hosts (incl. cherry)	Origin	Status in Europe	Gen. /year	Activity Period	Damage Mechanism
Rhagoletis cerasi	Tephritidae	Sweet, sour cherry	Europe	Widespread, high economic impact (including Bulgaria)	1	May–June	Oviposition in ripening fruits, larval development
R. cingulata	Tephritidae	Cherry, other *Prunus* spp.	North America	Potentially invasive; not yet detected in Bulgaria	1	May–July	Similar to *R. cerasi, resource competition*
R. fausta	Tephritidae	Sweet cherry	North America	Under quarantine observation; absent in Bulgaria	1	May–June	Presumed to have a similar harmful mechanism
R. indifferens	Tephritidae	Cherry	West N. America	No phytosanitary concern; absent in Europe	1	Spring–summer	Larval development in fruit
R. completa	Tephritidae	Walnut, occasionally cherry	North America	Established in parts of Europe; not in Bulgaria	1	June–August	Primarily walnuts, possible impact on cherry
R. batava	Tephritidae	Sea buckthorn, possibly cherry	Eurasia	Biological interest, not regulated	1	July–August	Host shift potential
C. capitata	Tephritidae	>350 hosts incl. cherry	Africa	Invasive; present in southern Europe; sporadic in Bulgaria	>3	Spring–fall	Oviposition punctures + larval feeding → fruit decay, drop
D. suzukii	Drosophilidae	Cherry, berries, soft fruits	Asia	Invasive; permanently established; documented in Bulgaria since 2014	>10	Spring–fall	Eggs laid in healthy fruits → larval feeding causes rapid rot

North Carolina State University (n.d.). To ensure consistent and comparable identification, six diagnostic morphological characteristics were selected based on published taxonomic descriptions: (1) number of wing bands, (2) structure and completeness of the apical band, (3) adult body size, (4) abdominal coloration, (5) ovipositor morphology in females, and (6) competitive interaction with *R. cerasi* and other fruit-infesting Diptera. These traits form the basis of the comparative analysis presented in Table 3 and the binary identification key. To support practical field identification and to distinguish *R. cerasi* from other Diptera of phytosanitary concern, the species included in Table 3 were selected based on their relevance to cherry production in Europe and their potential for introduction into Bulgaria. The comparison includes native species, established invasive species, and high-risk quarantine pests with overlapping morphological traits or similar host preferences. *R. cingulata* was added because it has been documented in several Central European countries and has demonstrated the capacity to hybridize with *R. cerasi*, making it essential to include it in diagnostic differentiation.

Table 3. Comparative morphological characteristics of Diptera species potentially harmful to sweet cherry, including members of Rhagoletis and selected invasive taxa.

Characteristic	***Rhagoletis fausta***	***Rhagoletis indifferens***	***Rhagoletis completa***	***Rhagoletis batava***	***Ceratitis capitata***	***Drosophila suzukii***
Number of wing bands	4–5, with apical band	4–5, with apical band	5–6, with apical band	4–5, with apical band	Lots of spots, chaot-	No Stripes, Dark Spots
Apical band	Complete, wraps around the edge	Complete, wraps around the edge	Complete, wraps around the edge	Complete, wraps around the edge	Irregular, diffuse stains	Absent; only dark apical spot
Body size	3–4 mm	4–5 mm	4–6 mm	3.5–4 mm	3–5 mm	2.5–3.5 mm
Abdominal coloration	Black	Dark brown	Yellow-brown	Dark	Yellow-brown	Light with black stripes
Ovipositor (♀)	Black, sclerotized	Black, sclerotized	Black, long	Black, long	Short, yellowish	Strongly jagged, dark
Competitive interaction	Similar to *R. cerasi*	Competitor of *R. cerasi*	Competitor of *R. cerasi*	Competitor of *R. cerasi*	A competitor to *Rhagoletis* spp.	Competitor of all fruit flies

Morphological keys for distinguishing *Rhagoletis* species from other genera

To facilitate accurate field-level differentiation between *R. cerasi* and other Diptera of phytosanitary concern, comparative morphological traits were compiled from literature and online identification tools, including ANSES (n.d.), Diptera.info (n.d.), University of Queensland (n.d.), National Museum Bloemfontein (2019), and North Carolina State University (n.d.). To ensure consistent and comparable identification, six diagnostic morphological characteristics were selected based on published taxonomic descriptions: (1) number of wing bands, (2) structure and completeness of the apical band, (3) adult body size, (4) abdominal coloration, (5) ovipositor morphology in females, and (6) competitive

Table 4. Presence of species of the genus *Rhagoletis* and other Diptera on cherries in four settlements in the Plovdiv region .

Species	Novo Selo (Stamboliyski Municipality)	Karadzhovo (Sadovo Municipality)	Kuklen (Kuklen Municipality)	Fruit Growing Institute (Plovdiv Municipality)
Rhagoletis cerasi	+	+	+	+
Rhagoletis cingulata	-	-	-	-
Rhagoletis fausta	-	-	-	-
Rhagoletis indifferens	-	-	-	-
Rhagoletis completa	-	-	-	-
Rhagoletis batava	-	-	-	-
Ceratitis capitata	-	-	-	-
Drosophila suzukii	-	-	-	-

interaction with *R. cerasi* and other fruit-infesting Diptera. These traits form the basis of the comparative analysis presented in Table 3 and the binary identification key. To support practical field identification and to distinguish *R. cerasi* from other Diptera of phytosanitary concern, the species included in Table 3 were selected based on their relevance to cherry production in Europe and their potential for introduction into Bulgaria. The comparison includes native species, established invasive species, and high-risk quarantine pests with overlapping morphological traits or similar host preferences. *Rhagoletis cingulata* was added because it has been documented in several Central European countries and has demonstrated the capacity to hybridize with *R. cerasi*, making it essential to include it in diagnostic differentiation

Binary morphological key for distinguishing *Rhagoletis* species from similar Diptera

1a. Wings without transverse dark bands; only a dark apical spot present……… ……..…………… *Drosophila suzukii*
1b. Wings with 4–6 distinct dark transverse bands ………………………….. go to 2
2a. Wing pattern irregular, with numerous diffuse or chaotic spots…………………………………… ………………………*Ceratitis capitata*
2b. Wing pattern structured, with clearly defined transverse bands …….. go to 3
3a. Apical band incomplete or weakly developed…………………..……..…. ……………. ………*Rhagoletis fausta*
3b. Apical band complete, forming a continuous margin …..…………… go to 4
4a. Wing pattern forming the characteristic “F-shape”; abdomen black; ovipositor robust…………………………………..… ………………….. *Rhagoletis cerasi*
4b. Wing pattern not forming an “F-shape” ………………………………… go to 5
5a. Apical band broader and more contrasting; abdomen with clearer banding; ovipositor slender ……………….. ………………… *Rhagoletis cingulata*
5b. Apical band narrower; other traits variable …………………………… go to 6
6a. Body size 4–6 mm; abdomen yellow-brown ……………….…………... ……………. …...*Rhagoletis completa*
6b. Body size 3–4 mm; abdomen dark …… …………………..… *Rhagoletis batava*

Monitoring of Diptera

The identification was carried out through morphological analysis and comparison with key features described in the literature, including the characteristic wing pattern, ovipositor shape and structure, and the adult active period (May–June), which is consistent with the life cycle of *R. cerasi*. No other members of the genus *Rhagoletis* were found during the study, nor were any individuals of the invasive species *D. suzukii*, despite the confirmed presence of the latter in other parts of Europe.

Species presence was verified by morphological analysis at ×40 magnification, with diagnostic images archived for documentation. Identification was guided by international protocols (IPPC 2011, 2023; EPPO, 2011, 2013, n.d.; EFSA 2020), ensuring compliance with phytosanitary standards.

Climatic data

Meteorological records from the Plovdiv station indicated average daily temperatures of 18–24 °C, with maximum values occasionally exceeding 30 °C during late May. Relative humidity fluctuated between 45–60%, and total precipitation during May–June amounted to 42 mm. Severe frost events in late March 2025 reduced cherry fruit availability by 75–95% in some cultivars. These conditions favored the univoltine cycle of *R. cerasi* while limiting the establishment of other Diptera species, such as *D. suzukii*, which requires higher humidity and abundant fruit hosts (Fig. 3). Only *R. cerasi* was detected across all monitored sites, and no other Diptera pests were recorded during the study period.

Wing pattern variation in *Rhagoletis cerasi*

During the monitoring of *R. cerasi* during the active flight period, variations in the morphology of the wing pattern were documented, especially with regard to the presence, shape, and connectivity of the inter-

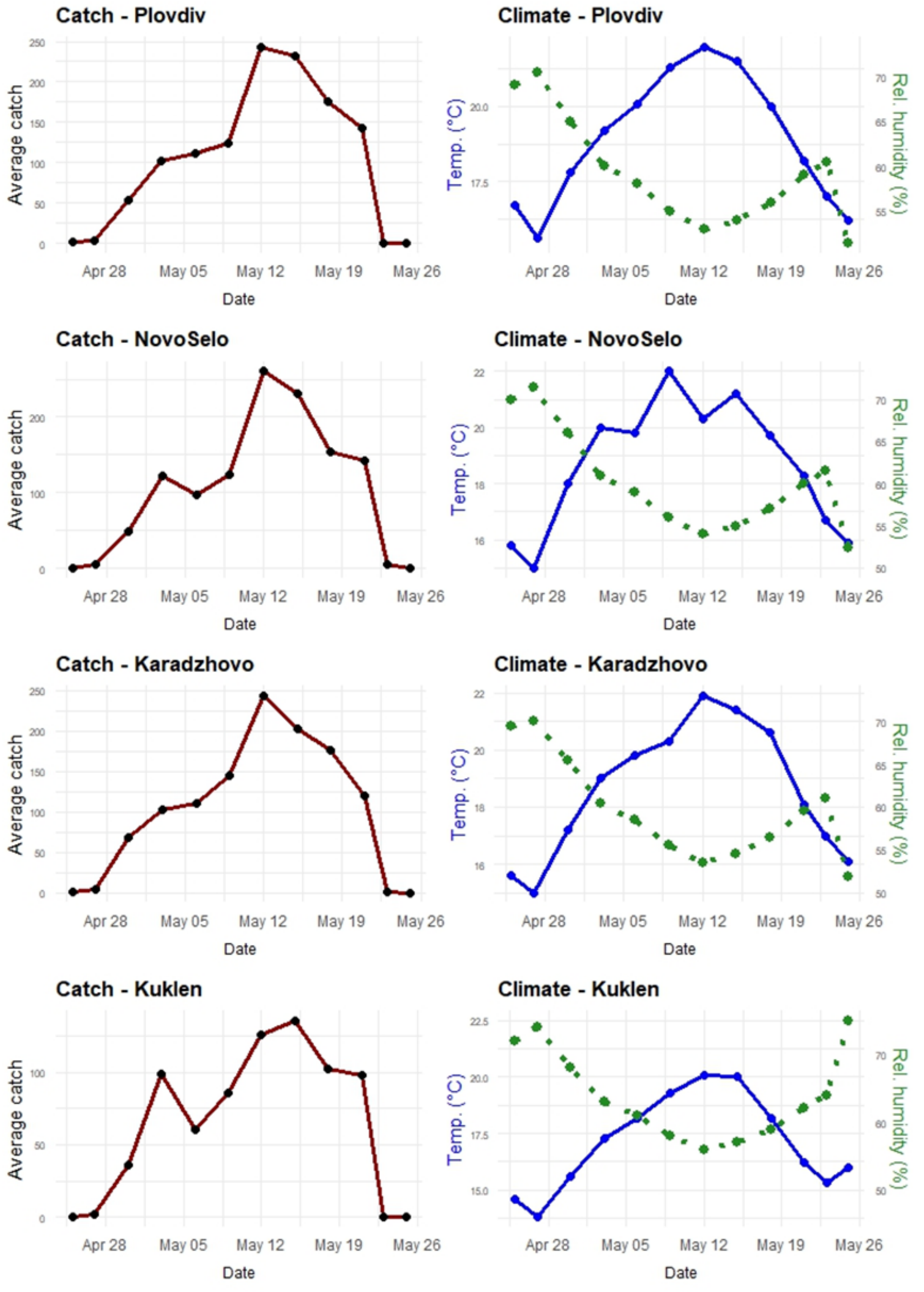


FIG 3: Monitoring of *Rhagoletis cerasi* catches and climatic conditions in four cherry orchards in the Plovdiv region (April–May 2025). Red solid line = average catch (individuals); blue dashed line = temperature (°C); green dotted line = humidity (% scaled by 0.5). Each subplot represents a separate orchard: Plovdiv, Novo Selo, Karadzhovo, and Kuklen.

mediate spot (Figure 4). These variations were manifested with varying degrees of clarity and structural connection to the anterior or posterior part of the wing. Such phenotypic variation may be due to phenotypic plasticity, determined by external environmental factors, or to age-related differentiation within individuals. The presence of morphological heterogeneity may also indicate intrapopulation genetic variation.

Similar observations have been reported in the literature, including the studies of Boller and Bush (1974), which demonstrated genetic differentiation in *R. cerasi*, as well as evidence for geographic races and cytoplasmic incompatibility (Schwarz et al., 2003; Katsoyannos, 2004; Kounatidis et al., 2008; Moraiti et al., 2012). The potential significance of the observed variations for the systematics and biology of the species warrants further morphometric and molecular studies. These phenotypic differences may reflect environmental influences, age-related variation, or underlying intrapopulation genetic diversity.

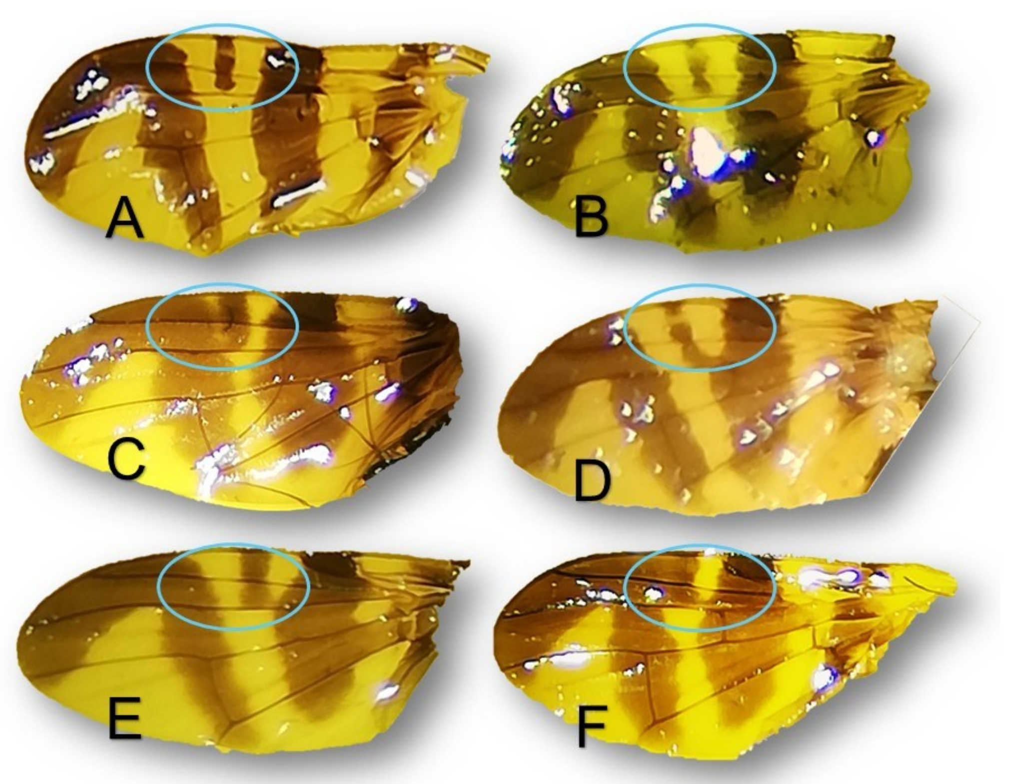


FIG 4: Variations in the intermediate spot on the wings of the cherry fly (*Rhagoletis cerasi*). The figure shows six variants of the cherry fly wing (A–F) observed during population monitoring. The intermediate spot (indicated by a green circle) is subject to variations related to shape, intensity, and location in relation to the other dark elements on the wing. A – The typical and most common form: the intermediate spot has well-defined borders, clearly connected to the apical and basal spots by venous structures. B–F – Deviations from the typical form are presented, including reduced pigmentation, asymmetrical outlines, unclear connection with other pigmented areas, or lack of a clear intermediate spot.

Regional pest dynamics

Rhagoletis cerasi remains the primary phytosanitary threat to sweet cherry cultivation throughout Europe (Daniel and Grunder, 2012; Būda et al., 2022). In Bulgaria, the species is particularly damaging to medium-early and late-ripening cultivars. Literature and historical data indicate that adult emergence typically begins early to mid-May in the Plovdiv region; however, the 2024 monitoring revealed an earlier flight onset (April 20) at the Fruit Growing Institute. Infestation was recorded even in early cultivars, and the extended flight period -early and late-ripening cultivars. Literature and historical data indicate that adult emergence typically begins early to mid-May in the Plovdiv region; however, the 2024 monitoring revealed an earlier flight onset (April 20) at the Fruit Growing Institute. Infestation was recorded even in early cultivars, and the extended flight period was accompanied by high larval densities—up to three larvae per fruit by late June—suggesting a potential shift in the species' biology.

In contrast, *D. suzukii*, a known invasive pest, was first documented in Spain and Italy in 2008 (Calabria et al., 2010) and rapidly colonized much of Western Europe by 2012 (Cini et al., 2014). Its demonstrated ability to migrate over 1,400 km within two years, aided by wind currents and ecological plasticity, highlights its high dispersal potential. Notable crop losses—up to 80% in France and 30–40% in northern Italy—underscore the severity of its impact (EPPO, 2010). Each generation of *D. suzukii* can disperse up to 45 km, reinforcing its potential threat to new regions.

The Mediterranean fruit fly, *C. capitata*, although heat-tolerant and widespread across the Mediterranean and adjacent regions, has historically failed to establish persistent populations in Bulgaria due to winter mortality (Szyniszewska and Tatem, 2014; Elqdhy et al., 2024). Despite sporadic detections since 2014 in districts such as Blagoevgrad, Kyustendil, and Plovdiv, as well as confirmed fruit damage between 2016 and 2018, the long-term establishment remains limited.

The exclusive detection of *R. cerasi* during this study confirms its dominant role in cherry pest dynamics in Bulgaria. The absence of other Diptera pests, including *D. suzukii*, suggests either localized ecological resistance or currently unfavorable conditions for their establishment. Factors such as cultivar phenology, microclimatic conditions, frost-induced fruit scarcity, and limited trade of propagation material may act as barriers to invasion.

Phytosanitary implications

From a phytosanitary standpoint, the presence of a single pest species is encouraging but calls for sustained vigilance. The potential introduction of *R. cingulata* or *D. suzukii* could disrupt current pest equilibria and significantly increase production losses, especially under scenarios of climate variability.

Moreover, the study supports the field applicability of the proposed binary morphological identification key. Effective differentiation between species enables rapid response and strengthens diagnostic capacity. The integration of field observations with literature-based tools exemplifies the importance of science-driven monitoring strategies.

In conclusion, the findings underscore the need for robust, adaptable phytosanitary programs that address both endemic and emerging pest threats in response to changing environmental conditions.

Discussion

Climatic influences and pest dynamics

The monitoring confirmed that *R. cerasi* remains the dominant phytosanitary threat to sweet cherry in Bulgaria. As shown in Figure 3, peak activity coincided with rising temperatures and declining humidity, while Kuklen's cooler and more humid conditions suppressed population levels. The absence of other Diptera pests, particularly *D. suzukii*, can be explained by several biotic and abiotic factors. Lower humidity during the study period, combined with severe frost damage in March 2025, reduced fruit availability and created unfavorable conditions for *D. suzukii*, which requires moist environments and abundant hosts. The synchrony between cherry phenology and the univoltine cycle of R. cerasi further limited opportunities for competing species to establish.

Comparison with European trends

In Western Europe, *D. suzukii* has become a major invasive pest, causing up to 80% yield losses in France and 30–40% in northern Italy. Its rapid dispersal capacity, aided by wind currents and ecological plasticity, has facilitated colonization across diverse regions. In contrast, Bulgaria's climatic conditions and limited trade in planting material appear to have delayed its establishment. Similarly, Ceratitis capitata has been detected sporadically in southern Bulgaria but has not formed stable populations due to winter mortality, unlike its persistence in Mediterranean countries.

Morphological variation in Rhagoletis cerasi

The wing pattern variations documented in Figure 4, particularly in the intermediate spot, highlight intrapopulation heterogeneity. Comparable observations have been reported by Boller and Bush (1974), who demonstrated genetic differentiation in R. cerasi, and subsequent studies have revealed geographic races and cytoplasmic incompatibility (Schwarz et al., 2003; Katsoyannos, 2004; Kounatidis et al., 2008; Moraiti et al., 2012). These findings suggest that the observed phenotypic diversity may reflect environmental influences, age-related variation, or underlying genetic differentiation—the potential significance of these traits for systematics and pest biology warrants further morphometric and molecular investigation.

Phytosanitary implications

The potential introduction of R. cingulata or the permanent establishment of *D. suzukii* would significantly alter pest dynamics and increase production losses. Continuous monitoring, combined with the application of morphological keys and diagnostic protocols, is essential for early detection and rapid response. These results highlight the importance of integrating monitoring data into Bulgaria's national phytosanitary programs.

The phytosanitary relevance of *R. cingulata* is further underscored by its rapid spread across Central Europe and its demonstrated capacity to establish in temperate climates similar to those in Bulgaria. Established populations in Germany, Hungary, and the Czech Republic indicate that the species can successfully overwinter and complete its life cycle under Central European conditions (Vogt et al., 2012; Kovács et al., 2013; Máca, 2013). Of particular concern is the documented hybridization between *R. cingulata* and *R. cerasi*, which has been confirmed through genetic analyses in regions where the two species co-occur (Johannesen et al., 2013; Doell et al., 2014). Hybridization may alter diapause traits, host preference, or phenology, potentially complicating monitoring and control strategies. Given Bulgaria's climatic suitability and increasing cross-border movement of plant material, the risk of introduction and establishment of *R. cingulata* should be considered significant.

Moreover, the study supports the field applicability of the proposed binary morphological identification key. Effective differentiation between species enables rapid response and strengthens diagnostic capacity. The integration of field observations with literature-based tools exemplifies the importance of science-driven monitoring strategies.

Future directions

Further research should focus on:

- Long-term monitoring of climatic factors and their influence on pest population dynamics.
- Morphometric and molecular studies to clarify the genetic basis of wing pattern variation in *R. cerasi*.

- Evaluation of trap efficiency under varying environmental conditions.
- Integration of monitoring data into national phytosanitary programs to strengthen diagnostic and management capacity.

Conclusions

This study provides an updated assessment of Diptera pests associated with sweet cherry in Bulgaria and demonstrates the continued dominance of *Rhagoletis cerasi* under current climatic conditions. By integrating field monitoring, morphological diagnostics, and comparative trait analysis, the research delivers practical tools for species identification, including a binary morphological key and a harmonized set of diagnostic characters relevant to both endemic and invasive taxa.

The inclusion of *R.cingulata* in the comparative framework strengthens preparedness for potential introductions, particularly given its expanding distribution in Central Europe and its capacity to hybridize with *R. cerasi*. The documented morphological variability within *R. cerasi* highlights the importance of ongoing morphometric and molecular investigations to understand population-level differentiation better.

Overall, the study contributes to the development of more robust phytosanitary practices by providing evidence-based diagnostic resources and emphasizing the need for continued surveillance. Future work should prioritize long-term monitoring, refinement of identification tools, and evaluation of environmental factors that may influence pest dynamics under changing climatic conditions.

Acknowledgements

This research was supported by the Bulgarian Ministry of Education and Science under the National Program "Young Scientists and Postdoctoral Students – 2".

References

ANSES. (n.d.). Online identification tools – Insects and mites. European Union Reference Laboratory for Insects and Mites. Retrieved July 22, 2025, from https://eurl-insects-mites.anses.fr/en/minisite/insects-and-mites/online-identification-tools

Arabadzhiev, I. and N. Palagacheva. 2023. Suzukii trap and traditional traps for monitoring *Drosophila suzukii* (Matsumura) – potentially dangerous pest by strawberries. *J. Biopestic*. 18 (1): 9–13. https://doi.org/10.57182/jbiopestic.18.1.09-13

Arabadzhiev, I. and N. Palagacheva. 2025. Field evaluation of *Suzukii* trap and traditional traps for monitoring *Drosophila suzukii* in strawberry plantations, Bulgaria. *J. Biopestic*. 20(2): 45–52.

Asplen, M.K., Anfora, G., Biondi, A. et al. 2015. Invasion biology of spotted wing Drosophila (*Drosophila suzukii*): a global perspective and future priorities. J. Pest Sci. 88: 469–494. https://doi.org/10.1007/s10340-015-0681-z

Benelli, G., A. Canale, A. Raspi and M. Fornaciari. 2020. Environmental effects on morphology and behavior of Tephritidae fruit flies: a review. Environmental Entomology, 49(2): 227–239. https://doi.org/10.1093/ee/nvz157

Bhagarathi, L.K. and G. Maharaj. 2023. Impact of climate change on insect biology, ecology, population dynamics, and pest management: A critical review. *World Journal of Advanced Research and Reviews* 19(3), 541-568. https://doi.org/10.30574/wjarr.2023.19.3.1843

Boller E.F. and G.L. Bush. 1974. Evidence for genetic variation in populations of the European cherry fruit fly, *Rhagoletis cerasi* (Diptera: Tephritidae) based on physiological parameters and hybridization experiments. *Entomologia Experimentalis et Ap-*

plicata 17(2), 279-293. https://doi.org/10.1111/j.1570-7458.1974.tb00345.x

Būda, V., A. Radžiutė, R. Stanevičienė, R. Žiogas and J. Blažytė-Čereškienė. 2022. The European cherry fruit fly *Rhagoletis cerasi* (Diptera: Tephritidae) in Lithuania: Distribution, host plants and parasitoids. *Agric. For. Entomol.* 24(4): 445–454. https://doi.org/10.1111/afe.12527

Calabria, G., J. Maca, G. Bächli, L. Serra and M. Pascual. 2010. First records of the potential pest species *Drosophila suzukii* in Europe. *J. Appl. Entomol.* 136(1–2), 139–147. https://doi.org/10.1111/j.1439-0418.2010.01583.x

Cini, A., C. Ioriatti and G. Anfora. 2014. Tracking the invasion of the alien fruit pest *Drosophila suzukii* in Europe. *J. Pest Sci*. 87, 559–566.

Daniel, C. and J. Grunder. 2012. Integrated management of European cherry fruit fly *Rhagoletis cerasi* (L.): situation in Switzerland and Europe. *Insects* 3(4), 956–988. https://doi.org/10.3390/insects3040956

Dhillon, M.K., R. Singh, J.S. Naresh and H.C. Sharma. 2005. The melon fruit fly, *Bactrocera cucurbitae*: a review of its biology and management. *Journal of Insect Science* 5(40), 1–16. https://doi.org/10.1093/jis/5.1.40

Diptera.info. (n.d.). Identification keys. Retrieved July 22, 2025, from https://diptera.info/downloads.php?cat_id=10

Doell, A., Johannesen, J. and Seitz, A. 2014. Genetic introgression between the European cherry fruit fly Rhagoletis cerasi and the American cherry fruit fly R. cingulata in sympatric populations. Journal of Evolutionary Biology, 27(3): 532–544. https://doi.org/10.1111/jeb.12320

EFSA Panel on Plant Health (PLH), Bragard, C., K. Dehnen-Schmutz, F. Di Serio, P. Gonthier, M.-A. Jacques, J.A. Jaques Miret, A.F. Justesen, C.S. Magnusson, P. Milonas, J.A. Navas-Cortes, S. Parnell, R. Potting, P.L. Reignault, H.-H. Thulke, W. Van der Werf, A. Vicent Civera, J. Yuen, L. Zappalà, E.M. Bali, N. Papadopoulos, S. Papanastassiou, E. Czwienczek and A. MacLeod. 2020. Pest categorisation of non-EU Tephritidae. *EFSA J.* 18(1): 5931. https://doi.org/10.2903/j.efsa.2020.5931

EFSA Panel on Plant Health. 2020. Pest survey card on *Rhagoletis fausta*. *EFSA Supporting Publications*, 17 (9), EN-1917. URL: https://doi.org/10.2903/sp.efsa.2020.EN-1917

Elqdhy, M., A.M. El-Sayed, G. El-Saadany, I.R. El-Gendy and W.M.Y. El-Sayed. 2024. Biology, ecology and control of the Mediterranean fruit fly, *Ceratitis capitata. J. Plant Dis. Prot*. 131: 365–402. https://doi.org/10.1007/s41348-023-00855-0

EPPO (n.d.) EPPO Global Database – *Rhagoletis* spp. European and Mediterranean Plant Protection Organization. URL: https://gd.eppo.int/taxon/RHAGFA/documents

EPPO. 2011. PM 7/104 (1) *Ceratitis capitata.* EPPO Bulletin. European and Mediterranean Plant Protection Organization. URL: https://gd.eppo.int/download/standard/228/pm7-104-1-en.pdf

EPPO. 2011. PM 7/107 (1) *Rhagoletis completa.* EPPO Bulletin. European and Mediterranean Plant Protection Organization. URL: https://gd.eppo.int/download/standard/231/pm7-107-1-en.pdf

EPPO 2011. *Rhagoletis cingulata* (Loew) – American cherry fruit fly. EPPO Reporting Service, 2011/180. Paris, France: European and Mediterranean Plant Protection Organization.

EPPO. 2013. PM 7/115 (1) *Drosophila suzukii.* EPPO Bulletin. European and Mediterranean Plant Protection Organization. URL: https://

gd.eppo.int/download/standard/239/pm7-115-1-en.pdf

European Food Safety Authority (EFSA), M. Schenk, E. Dijkstra, A. Loomans, A. Delbianco and S. Vos. 2020. Pest survey card on *Rhagoletis fausta*. EFSA Supporting Publ. 17(8): 1917E. https://doi.org/10.2903/sp.efsa.2020.EN-1917

FAO. 2022. The future of food and agriculture – Drivers and triggers for transformation. The Future of Food and Agriculture 3. Rome. 444 p. https://doi.org/10.4060/cc0959en

Fimiani, P. 1991. Mediterranean region. In: Fruit flies: their biology, natural enemies and control. Vol. 3B, Elsevier, pp. 39–50.

Fischer-Colbrie, R., and E. Busch-Petersen. 1989. Fruit flies in temperate zones. In: Robinson, A.S. & Hooper, G. (Eds.), World Crop Pests: *Fruit Flies* Vol. 3B, Elsevier, pp. 253–260.

Fruit Fly Identification Australia (n.d.). Species profile: *Rhagoletis cerasi.* Retrieved July 22, 2025, from https://www.fruitflyidentification.org.au/species/rhagoletis-cerasi/

Hidayat, P., N.B. Adilah and N. Maryana. 2023. Review of species, host plants, and distribution of fruit flies (Diptera: Tephritidae) in Indonesia. In: IOP Conf. Ser.: Earth Environ. Sci. 1208(1): 012018. https://doi.org/10.1088/1755-1315/1208/1/012018

IPPC 2011. National Fruit Fly Diagnostic Protocol. International Plant Protection Convention. URL: https://www.yumpu.com/en/document/view/14110398/national-fruit-fly-diagnostic-protocol-ippcint

IPPC 2023. Diagnostic Protocol DP 32: Genus Ceratitis. In: ISPM 27 – Diagnostic Protocols for Regulated Pests. International Plant Protection Convention. Retrieved July 22, 2025, from https://www.ippc.int/en/commission/standards-committee/technical-panels/technical-panel-diagnostic-protocols/

IPPC Secretariat. 2021. Scientific review of the impact of climate change on plant pests – A global challenge to prevent and mitigate plant pest risks in agriculture, forestry and ecosystems. Rome. FAO on behalf of the IPPC Secretariat. 88 p. https://doi.org/10.4060/cb4769en

Johannesen, J., Drüeke, M., Seitz, A. and Michalek, W. 2013. Interspecific hybridization, mitochondrial introgression and biogeographic patterns in *Rhagoletis cerasi* and *R. cingulata*. Biological Journal of the Linnean Society, 110(4): 749–764. https://doi.org/10.1111/bij.12163

Karadjova, O., Z. Ilieva, E. Petrova and M. Laginova. 2016. Predicted and actual distribution of the invasive species *Drosophila suzukii* (Diptera: Drosophilidae) in Bulgaria. *Agrar. Nauki* 19(7): 65–71. https://doi.org/10.22620/agrisci.2016.19.007

Karuppaiah, V. and G.K. Sujayanad. 2012. Impact of Climate Change on the Population Dynamics of Insect Pests. *World J. Agric. Sci*. 8(3), 240-246.

Katsoyannos, B. 2004. European cherry fruit fly *Rhagoletis cerasi* (L.) (Diptera: Tephritidae). In J. L. Capinera (Ed.) *Encyclopedia of Entomology*, pp. 808–810. Springer. https://doi.org/10.1007/0-306-48380-7_1513

Kocmánková, E., M. Trnka, J. Eitzinger, H. Formayer, M. Dubrovský, D. Semerádová and M. Možný. 2010. Estimating the impact of climate change on the occurrence of selected pests in the Central European region. *Clim. Res.* 44(1): 95–105. https://doi.org/10.3354/cr00905

Kounatidis, I., N. Papadopoulos, K. Bourtzis and P. Mavragani-Tsipidou. 2008. Genetic and cytogenetic analysis of the fruit fly *Rhagoletis cerasi* (Diptera: Tephritidae). *Genome* 51

(7): 479–491. https://doi.org/10.1139/G08-032

Kovács, T., Tóth, M. and Szabó, P. 2013. Occurrence and spread of the American cherry fruit fly, *Rhagoletis cingulata* (Loew), in Hungary. Növényvédelem, 49(6): 265–272.

Máca, J. 2013. Records of the American cherry fruit fly Rhagoletis cingulata (Loew, 1862) (Diptera: Tephritidae) in the Czech Republic. Acta Universitatis Carolinae Biologica, 57(1–2): 45–50. Minkov, P., D. Georgiev, N. Palagacheva and V. Dzhuvinov. 2017. *Drosophila suzukii* (Matsumura) – a new invasive insect pest on berry plants in the Central Balkan Mountains – first results. J. *Mt. Agric. Balkans* 20(6): 243–250.

Minkov, P., D. Georgiev, N. Palagacheva and V. Dzhuvinov. 2017. *Drosophila suzukii* (Matsumura) – a new invasive insect pest on berry plants in the Central Balkan Mountains – first results. J. Mt. Agric. Balkans 20(6): 243–250.

Minkov, P., D. Georgiev, N. Palagacheva and V. Dzhuvinov. 2018. Monitoring of spotted wing drosophila in raspberries and blackberries in Troyan region, Bulgaria. *Bulg. J. Agric. Sci.* 24(4): 670–673.

Moraiti, C.A., C.T. Nakas and N.T. Papadopoulos. 2012. Prolonged pupal diapause in the European cherry fruit fly: a mechanism for survival. Bulletin of Entomological Research, 102 (1): 79–86. https://doi.org/10.1017/S0007485311000380

Moraiti, C.A., C.T. Nakas, K. Koeppler and N.T. Papadopoulos. 2012. Geographical variation in adult life-history traits of the European cherry fruit fly, *Rhagoletis cerasi* (Diptera: Tephritidae). *Biol. J. Linn. Soc.* 107(1): 137–152. https://doi.org/10.1111/j.1095-8312.2012.01930.x

Moraiti, C.A., D.P. Papachristos, C.T. Nakas and N.T. Papadopoulos. 2014. Effect of temperature on pupal diapause termination and adult emergence of the European cherry fruit fly *Rhagoletis cerasi*. Journal of Applied Entomology, 138(5): 358–367. https://doi.org/10.1111/jen.12099

National Museum Bloemfontein. 2019. Key to Diptera families – adults (Suricata 4-12). Retrieved July 22, 2025, from https://nasmus.co.za/wp-content/uploads/2019/01/Suricata-4-12-KEY-TO-DIPTERA-FAMILIES-ADULTS-low-resolution_Part1.pdf

North Carolina State University. (n.d.). Order Diptera – ENT 425 General Entomology. Retrieved July 22, 2025, from https://genent.cals.ncsu.edu/insect-identification/order-diptera/

Papadopoulos, N.T. 2014. Fruit Fly Invasion: Historical, Biological, Economic Aspects and Management. In: Shelly, T., Epsky, N., Jang, E., Reyes-Flores, J., Vargas, R. (eds) *Trapping and the Detection, Control, and Regulation of Tephritid Fruit Flies*. Springer, Dordrecht., pp. 219–252. https://doi.org/10.1007/978-94-017-9193-9_7

Papanastasiou, S.A., N.T. Papadopoulos. 2014. Description of *Rhagoletis cerasi* (Diptera: Tephritidae) pupal developmental stages: indications of prolonged diapause. Journal *of Insect Science,* 14(1), 156. https://doi.org/10.1093/jisesa/ieu018

Parry, M.L. 1990. Effects on agricultural potential. In: Parry, M.L. (Ed.). Climate Change and World Agriculture. Routledge, London. pp. 27–52. https://doi.org/10.4324/9780429345104

Petrova, V., B. Katinova and E. Kadiyska. 2020. Monitoring of Drosophila suzukii (Matsumura), pest of fruit crops in Southwestern Bulgaria. *Rastenievad. Nauki* 57(4): 47–52.

Prakash, A., K.K. Sinha and R.C. Saxena. 2014. Climate change and insect pest dynamics: emerging patterns and future predictions. *Entomol. Res.* 44 (3): 99–106. https://doi.org/10.1111/1748-5967.12064

Rull, J., A. Birke, R. Ortega, P. Montoya and L. López. 2016. Phenotypic plasticity and climatic adaptation in Tephritidae: implications for pest management. Journal of Pest Science, 89(3): 689–700. https://doi.org/10.1007/s10340-015-0730-7

Savaris, M., A.L. Norrbom, L. Marinoni and L.C. Lampe. 2016. A review of economically important fruit fly species in South America. *Zootaxa* 4115(1): 1–91. https://doi.org/10.11646/zootaxa.4115.1.1

Schwarz, D., B.A. McPheron, G.B. Hartl, E.F. Boller and T.S. Hoffmeister. 2003. A second case of genetic host races in *Rhagoletis*? A population genetic comparison of sympatric host populations in the European cherry fruit fly, *Rhagoletis cerasi*. *Entomol. Exp. Appl.* 108(1): 11–17. https://doi.org/10.1046/j.1570-7458.2003.00065.x

Sharma, H.C., R. Ortiz and H. Ceballos. 2017. Plant productivity and pest management under climate change. *Crop Prot*. 97: 10–20. Available at CGIAR MEL Repository.

Szyniszewska, A.M. and A.J. Tatem. 2014. Global assessment of seasonal potential distribution of Mediterranean fruit fly, *Ceratitis capitata*. PLoS *ONE,* 9(11), e111582. https://doi.org/10.1371/journal.pone.0111582

Tanga, C.M., S. Ekesi and S.A. Mohamed. 2018. Host suitability and damage by *Ceratitis capitata* and *Bactrocera dorsalis* on commercial fruit crops. *J. Appl. Entomol.* 142(7): 671–682. https://doi.org/10.1111/jen.12527

Uchoa, M.A. 2012. Fruit flies (Diptera: Tephritidae): biology, taxonomy and pest status. In: *Insect Pests: Biology and Ecology*, Nova Science Publishers, pp. 189–210.

University of Queensland (n.d.). Adult Diptera identification key. Retrieved July 22, 2025, from https://shire.science.uq.edu.au/bb/parasitology/diptera/diptera-key1.html

USDA-APHIS. 2017. New Pest Response Guidelines: *Rhagoletis cerasi* (European cherry fruit fly). United States Department of Agriculture. URL: https://usbiotechnologyregulation.mrp.usda.gov/sites/default/files/rhagoletis-cerasi-nprg.pdf

Zaemdzhikova, G., P. Glogov, M. Bozhilova and M. Kechev. 2018. First record of *Drosophila suzukii* (Diptera: Drosophilidae) on the fruits of Viscum album ssp. album in Bulgaria. *Hist. Nat. Bulg.* 29: 137–144.

