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First record of African fig fly, *Zaprionus indianus* Gupta, 1970 (Diptera, Drosophilidae) in Hungary

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Abstract

Our study reports the first occurrence of *Zaprionus indianus* Gupta, 1970 (Diptera: Drosophilidae) in Hungary, representing the northernmost European record of this thermophilic species. Specimens were captured in October 2023 during a large-scale *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) monitoring program conducted in sweet cherry orchards in north-central Hungary. A total of five individuals (one female and four males) were caught at two different orchards 1 km apart, using modified pan and bottle traps baited with apple cider vinegar-based lures. No specimens were detected in the previous year (2022) or the following year (2024), which may indicate a transient population, though further monitoring would be required to confirm the lack of establishment. Although the overwintering of the species appears unlikely in Hungary, climate change may facilitate its future range expansion. Our findings highlight the importance of continuous monitoring of invasive drosophilids in Central Europe for better understanding their establishment potential and agricultural risks.

Key Words

Central Europe, cherry orchard, drosophilids, fruit pest, invasive species

Introduction

Invasive species pose a significant threat to biodiversity, often altering ecosystems and outcompeting native species, with substantial implications for agriculture, forestry, and human health (Messing and Wright 2006; Calabria et al. 2012). Since the emergence of the spotted-wing drosophila *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) in Europe and North America in 2008, faunistic research on drosophilids has intensified worldwide, leading to the detection of Drosophilidae species previously known only from subtropical regions, particularly in cooler parts of Europe (Georges et al. 2024). As part of a large-scale *D. suzukii* monitoring program, we report the first record of *Zaprionus indianus* Gupta, 1970 (Diptera: Drosophilidae) in Hungary, which represents the northernmost European occurrence of this thermophilic species to date.

This invasive pest is a secondary invader capable of colonizing pre-damaged fruits (van der Linde et al. 2006). It is highly polyphagous and has been reported as a significant economic pest, affecting both cultivated and wild fruit species (De Toni et al. 2001; Castrezana 2011; Biddinger et al. 2012; Alawamleh et al. 2016). This species was initially identified in India (Gupta 1970) but is broadly considered to have an African origin (Chassagnard and Kraaijveld 1991; Yassin and David 2010; Commar et al. 2012). Additionally, it has spread rapidly across Central and South America (Vilela 1999; Tidon et al. 2003; David et al. 2006; Commar et al. 2012) and has also been documented in France, Spain, Italy, and Türkiye (Raspi et al. 2014; Kremmer et al. 2017; Çatal et al. 2019; Molina-Rodríguez and Pérez-Guerrero 2019).

The genus *Zaprionus* is characterized by two longitudinal silvery-white stripes bordered by black lines on the thorax, a yellowish body (approximately 3 mm in length)

and red eyes (Yassin and David 2010). The global spread of *Z. indianus* has been facilitated by climate change, increasing its presence in previously unsuitable habitats. Monitoring invasive species at early stages of colonization is crucial for understanding their establishment potential and ecological impacts (van der Linde et al. 2006). In the present study, we document the first detection of *Z. indianus* in Hungary, providing insight into its potential distributional limits in Europe.

Materials and methods

Study area

A large-scale research program aiming to test trapping methods for monitoring *D. suzukii* was conducted between 2022 and 2024 in two sweet cherry orchards: one hosting genetic resources and another containing pre-selected accessions from the local breeding program at the experimental area of the Hungarian University of Agricultural and Life Sciences, Institute of Horticultural Sciences, in Érd, Pest County, Hungary. More than 100 traps were operated throughout the vegetation seasons to compare the effectiveness of different lures and trap designs in capturing *D. suzukii* and other drosophilid species. Specimens of *Z. indianus* were recorded at both monitoring sites, situated approximately 1 km apart, at an elevation of 120 m a.s.l. The first site was located at 47°20'28"N, 18°51'45"E, and the second at 47°20'53"N, 18°51'15"E (Fig. 1).

Site 1: The first orchard was an old sweet cherry gene bank approximately 1 hectare in size and was planted between 1999 and 2004 (depending on the row). The orchard consisted of 8 rows of 62 sweet cherry trees from different cultivars (2 trees per cultivar planted in pairs). The rows were spaced 6 m apart and trees were spaced 2 m apart within cultivar pairs and 4 m apart between cultivar pairs. The tree strips were treated with herbicides for weed control, while the row spacings were left grassy and mown regularly. The orchard was surrounded by other sweet cherry, sour cherry, plum, apple and pear orchards, as well as arable fields. During the experimental period, the focal orchard received only fungicide treatments, but insecticide treatments were not used. The surrounding orchards were managed conventionally, including regular pesticide applications and general horticultural practices (Fig. 1).

Site 2: The second orchard was an old sweet cherry hybrid plot approximately 2 hectares in size and was planted between 2002 and 2012 (depending on the row). The orchard comprised 19 rows, each containing 60 sweet cherry trees, representing 264 hybrids. The trees were planted in structured groups, with four trees per hybrid, organized into blocks of four-tree units for each hybrid cultivar. The rows were spaced 6 m apart and trees were spaced 4 m apart. The tree strips were treated with herbicides for weed control, while the row spacings were left grassy and mown regularly. The orchard was surrounded by other sweet and sour cherry orchards, hedges, and small patches of ruderal vegetation and woodland. The experimental orchard was a completely abandoned area and was left untreated during the experimental period. No specific management practices were applied to the adjacent hedges, ruderal areas, or woodland patches, while the surrounding cherry orchards were managed conventionally, including standard horticultural practices such as pruning and pesticide applications (Fig. 1).

Map visualization

Map visualizations were generated using OpenStreetMap (OSM), a collaborative, openly accessible, and modifiable mapping platform developed as an alternative to official sources (Fig. 1).

Figure 1. Localization of the experimental area.

Trap designs

The experiment originally aimed to monitor *D. suzukii* populations and compare the effectiveness of different lures and trap designs. In the complete experiment, we used commercially available pan traps, modified pan traps, various types of bottle traps with different hole sizes and color patterns, and different lures. We describe in detail only the traps in which specimens of *Z. indianus* were caught, including a modified pan trap (Trap design 1) and four types of bottle traps (Trap designs 2, 3, 4, and 5). The pan trap contained 200 ml apple cider vinegar as an attractant in the collecting plate. All bottle traps were made from a 500 ml mineral water bottle and contained 100 ml apple cider vinegar as an attractant. For more detailed description of the traps see Fig. 2.

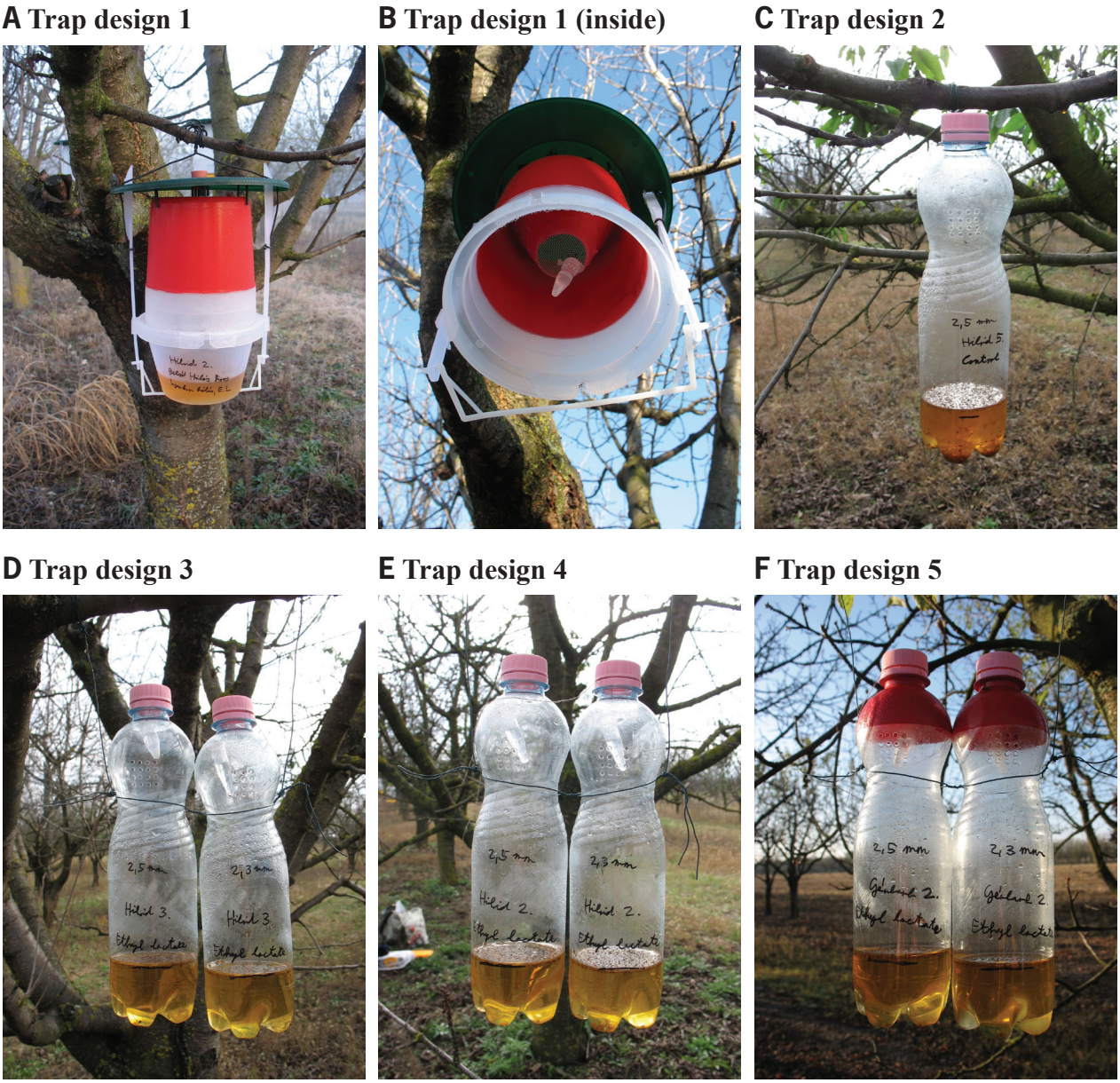

Figure 2. Photos of the various trap designs. **Trap design 1:** modified pan trap from the original, commercially available Csalomon VARL trap in the following ways (1) on the entrance hole, the original net with 3.5 mm mesh size (designated to exclude large-sized insects such as wasps and large flies) was replaced with a finer net of 1.55 mm mesh size (**B**) to further exclude medium-sized, non-target species, (2) the main body of the trap has been coloured to red at the upper two third part, at 35 mm width (**A**) and (3) an attractant dispenser has been included into the trap hanging on a wire consisting of a 1.5 ml Eppendorf tube with 20 holes (1 mm in diameter) in 2 circles on the upper side of the tube and filled with 1 ml ethyl-lactate as an attractant (**A, B**). **Trap design 2:** bottle trap with 16 entrance holes (2.5 mm in diameter, 2.5 mm distance apart from each other) in a square shape at the upper part on 1 side, and the whole body of the trap was left colorless (**C**). **Trap design 3:** similar to Trap design 2, but an attractant dispenser had been included into the trap hanging on a wire filled with 1 ml ethyl-lactate as an attractant. The design of the lure was the same as in the case of Trap design 1 (**D**). **Trap design 4:** similar to Trap design 2, but the entrance holes were 2.3 mm in diameter. An attractant dispenser was also added to the trap filled with 1 ml ethyl-lactate in the same way then in the cases of Trap designs 1 and 3 (**E**). **Trap design 5:** similar to Trap design 4, but the upper part of the trap was coloured to red in 35 mm wide (**F**).

Experimental design and data collection

The study was conducted between 2022 and 2024, covering the entire growing season. At each site, there were three replicates for trap designs 1, 3, 4, and 5, and five replicates for trap design 2. Traps were randomly placed on trees at a height of 1.5 m and emptied weekly. During each sampling, a portion of the vinegar bait was removed and replaced with fresh vinegar, and the ethyl-lactate was refilled to a total volume of 1 ml. Captured insects were filtered from the apple cider vinegar using a plastic tea strainer, stored in 70% ethanol, and

later examined under a stereomicroscope in the laboratory. Specimens of *Z. indianus* were identified following Yassin and David (2010).

Results

The genus *Zaprionus* Coquillett can be identified by its distinctive longitudinal white stripes on the frons and mesonotum (Figs 3A, 4A).

For the proper identification of our collected specimens, we followed the descriptions and keys of van der Linde et al. (2006), van der Linde (2010) and Yassin and David (2010). Van der Linde (2010) identified seven key diagnostic characters, all of which must be present to confidently assign a specimen to *Z. indianus* within the genus *Zaprionus*. These characters are as follows: the basic color of the body of the fly must be uniformly yellowish, including the head, thorax and abdomen as well (Figs 3A, 4A); an even number of black-bordered white stripes across the head and thorax (Figs 3A, 4A); the black margins of the white stripes are of equal width along their entire length and do not widen on the scutellum (Figs 3A, 4A); the scutellum is without a white tip (Figs 3A, 4A); composite spines are present on the forefemur, each with a short secondary branch at its base (Fig. 4C); these spines are not located on tubercles, they emerge directly from the leg (Fig. 4C) and subapical setae on the fourth and fifth tergites grow from brownish-blackish spots (Figs 3A, 4A). The combination of these characters is appropriate to separate *Z. indianus* from all other known species of the genus (van der Linde 2010). Additionally, a detailed morphological analysis of the specimens, using the classification key of Yassin and David (2010), also confirmed that they belong to the same species, *Z. indianus*.

A total of five specimens (one female, four males) of *Z. indianus* were detected in October 2023 (Table 1). The specimens were found in five different samples collected on three different dates and from two different orchards. No specimens were captured in the previous year or in 2024. Identification was based on morphological characteristics as described before. The specimens are stored in the collection of the first author.

Table 1. *Zaprionus indianus* specimens collected in Hungary.

Specimen id	Sex	Collection site	Date	Trap design	Ethyl-lactate
Num. 1	Female	Érd, Elvira-major, Site 1, Rep. 4	13-Oct-2023	Bottle trap, Trap design 5.	Yes
Num. 2	Male	Érd, Elvira-major, Site 2, Rep. 2	25-Oct-2023	Pan trap, Trap design 1.	Yes
Num. 3	Male	Érd, Elvira-major, Site 2, Rep. 2	26-Oct-2023	Bottle trap, Trap design 4.	Yes
Num. 4	Male	Érd, Elvira-major, Site 2, Rep. 3	26-Oct-2023	Bottle trap, Trap design 3.	Yes
Num. 5	Male	Érd, Elvira-major, Site 2, Rep. 5	26-Oct-2023	Bottle trap, Trap design 2.	No

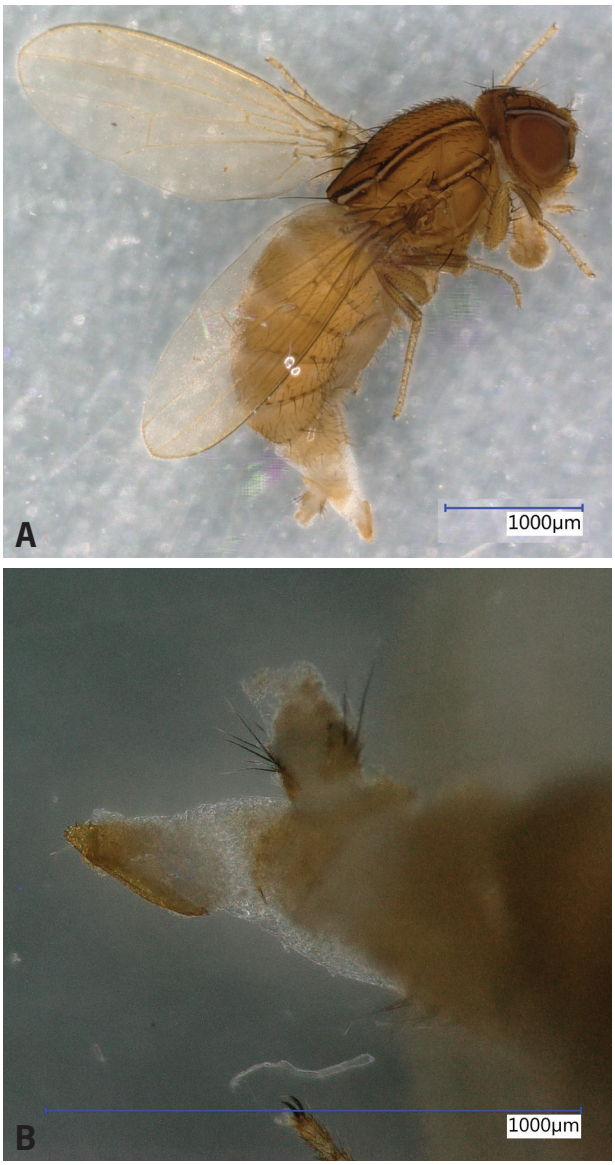

Figure 3. *Zaprionus indianus* female: **A.** Lateral view of a female showing two of the four silvery-white stripes on the thorax, the scutellum without a white tip and the subapical setae oon the fourth and fifth tergites growing from brownish-blackish spots; **B.** Enlarged image of the ovipositor.

Discussion

The collection of multiple *Z. indianus* specimens from different traps and sampling dates suggests the presence of a temporarily existing population at the study site in 2023. The absence of individuals in 2024, despite a relatively mild winter, indicates that the species may be unable to overwinter in Hungary. Comparable seasonal occurrences of *Z. indianus* have been documented in Eastern North America (Rakes et al. 2023).

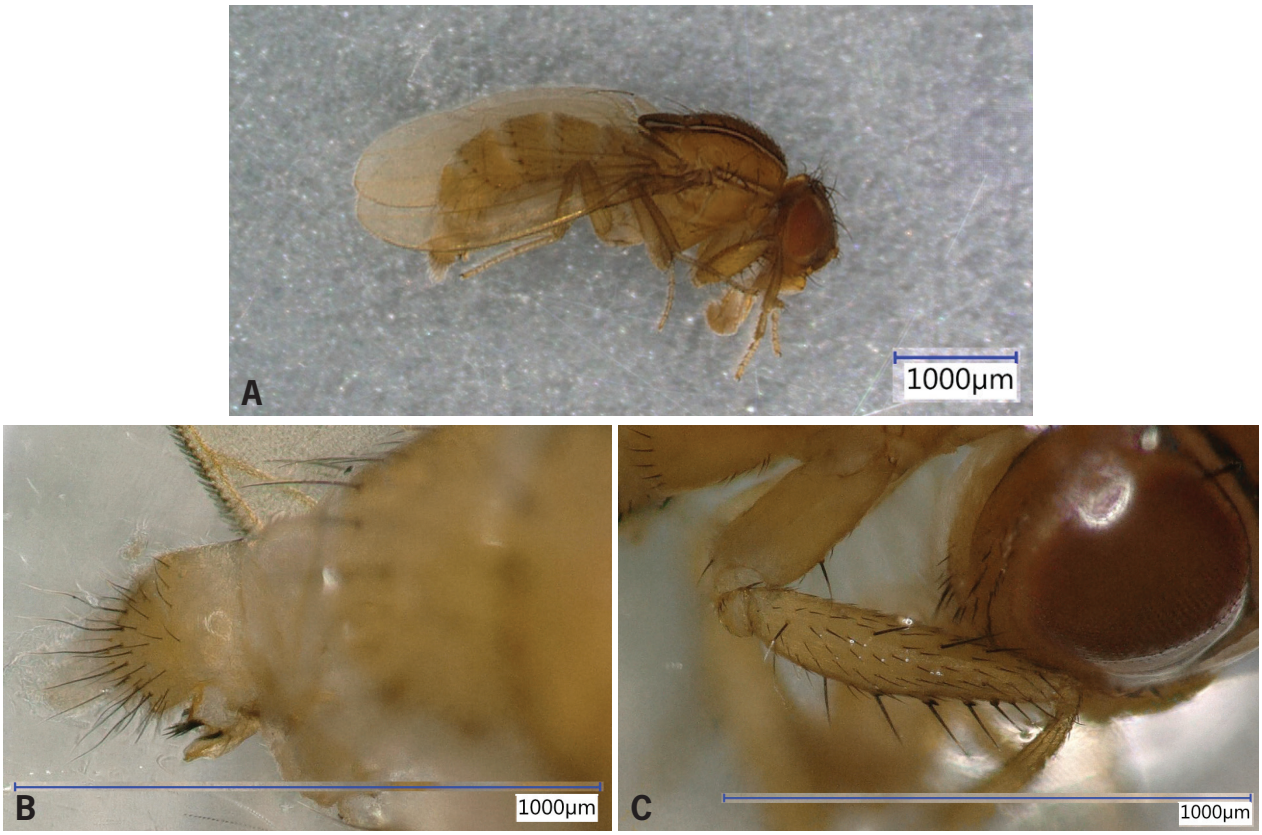

Figure 4. *Zaprionus indianus* male: **A.** Lateral view of a male showing two of the four silvery-white stripes on the thorax, the scutellum without a white tip and the subapical setae on the fourth and fifth tergites growing from brownish-blackish spots; **B.** Enlarged image of the genitalia; **C.** Magnified image of the forefemur showing composite spines, each bearing a short secondary branch at its base and emerging directly from the leg.

In Hungary, a similar phenomenon has been reported for *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae), where transient outbreaks occur as a result of repeated introductions via imported fruits but fail to establish persistent populations in frost-prone regions (Kontschán 2021). The introduction of *Z. indianus* into Hungary is likely associated with fruit transport from warmer regions (Commar et al. 2012). Climate change may facilitate the northward expansion of *Zaprionus* spp., including *Z. indianus* (Da Mata et al. 2010). As being native to tropical regions, *Z. indianus* has limited cold tolerance, though it displays some plasticity in response to cold stress. Amoudi et al. (1993) and Nava et al. (2007) studied the effect of temperature on the development of *Z. indianus* and reported different values for lower developmental thresholds (TT) and thermal constants (K) across life stages. According to Nava et al. (2007), the TT and K values were 9.7°C and 10.5 degree days (DD) for eggs, 9.2°C and 148.6 DD for larvae, and 10.7°C and 66.25 DD for pupae, with an overall developmental threshold (TT) of 7.9°C and a total thermal constant (K) of 262.2 DD for the egg-to-adult cycle. In contrast, Amoudi et al. (1993) found the TT values to be 7.7°C for eggs, 11.7°C for larvae, and 8.0°C for pupae, resulting in a combined threshold of 10.1°C for the full biological cycle. Females can arrest ovarian maturation and retain fertility after recovering from cold exposure, with the critical temperature for ovarian maturation being approximately 13 °C—intermediate between tropical and temperate drosophilid species (Lavagnino et al. 2020). Populations of *Z. indianus* from an invaded South American region (Yuto) show greater cold tolerance and faster recovery from chill coma (20%) compared to those from its native African range (Yokadouma), suggesting potential local adaptation (Lavagnino et al. 2020). Seasonal declines of *Z. indianus* in U.S. populations, with individuals appearing from July and disappearing by December, underscore the species' cold sensitivity, as the northernmost population is recorded in Massachusetts, with no presence in colder regions like Maine (Rakes et al. 2023). Furthermore, the males of *Zaprionus* species, particularly *Z. indianus*, exhibit cold and heat sensitivity, with cold sterility thresholds at approximately 15°C and heat sterility thresholds at 30°C (Araripe et al. 2004). The lower survival threshold is estimated at 9–10°C, with optimal development occurring at 28°C, indicating that while *Z. indianus* may persist in milder temperate zones, harsh winter conditions restrict its establishment (Amoudi et al. 1993; Nava et al. 2007; EFSA Panel on Plant Health et al. 2022).

Overall, while *Z. indianus* exhibits some ability to withstand cold stress and demonstrates different sur-

vival across regions, temperatures below approximately 15°C — the threshold at which male sterility occurs — remain a significant barrier to its permanent establishment in temperate climates. However, the current winter climate in most parts of Europe appears unsuitable for its permanent establishment (EFSA Panel on Plant Health et al. 2022). Long-term monitoring, especially through *D. suzukii* surveys, offers valuable opportunities to track the sporadic introduction of non-native species.

In various European countries such as France, Italy, Malta, Cyprus, and Türkiye, *Zaprionus* spp. has been previously reported (Ebejer 2001; Bächli 2013; Kremmer et al. 2017; Başpınar et al. 2022), with most records concentrated in Mediterranean regions. In contrast, our study provides the first documented instance of *Z. indianus* in Central Europe under continental climate. Further studies should investigate the cold tolerance of *Z. indianus* (Araripe et al. 2004) and its pathways of introduction.

A study proposes that the spread of *Z. indianus* has been promoted by genetic mixing and natural selection. Managing this invasion could focus on limiting future genetic mixing by regulating the movement of individuals within this area rather than between the western and eastern hemispheres (Comeault et al. 2021). Research on Drosophila species indicates that global warming has driven genetic adaptations, including changes in chromosome inversion frequencies, highlighting the potential for widespread species to adapt to climate change (van Heerwaarden and Hoffmann 2007).

Although *Z. indianus* is no longer included in the EPPO alert list, its ability to oviposit in healthy fruits like figs and strawberries, leading to economic losses, combined with its thriving temperature range and the effects of global warming, enables it to complete 12–16 generations per year, increasing its potential for establishment in many EU areas (EFSA Panel on Plant Health et al. 2022). Researchers have highlighted the need for standardized methods to evaluate the ecological and economic impacts of invasive drosophilids like *Zaprionus* spp., ensuring consistent data collection across regions for more reliable assessments and also informed management strategies to mitigate their adverse effects on agriculture and ecosystems (Viana et al. 2024). Therefore, we recommend more extensive monitoring of *Zaprionus* species in Hungary and other Central European countries, with a particular focus on its host plants, such as figs and wild persimmons, to ensure a more accurate assessment of both agronomic risks and ecological impacts.

Author contributions

Csaba Nagy conceived the idea. Csaba Nagy performed the experiment's analysis in the field and laboratory. Emre Şen and Balázs Kiss drafted the article. All authors took part in the writing process of the manuscript.

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Supplementary material 1

Data deposit for *Z. indianus*

Authors: Csaba Nagy, Emre Şen, Balázs Kiss
Data type: csv

Link: https://doi.org/10.3897/bull.insectology.154143.suppl1