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# Monitoring adult populations of *Ceratitis capitata* (Wied.), *Rhagoletis cerasi* (L.) (Diptera: Tephritidae), *Drosophila suzukii* (Matsumura), and *Zaprionus Indians* Gupta (Diptera: Drosophilidae) at different altitudes in fruit orchards of Adana Province in Türkiye

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## ABSTRACT

In recent years, fruit flies (Diptera: Drosophilidae and Tephritidae) have become an increasingly severe problem in fruit production in Turkey. *Ceratitis capitata* (Wied.), *Rhagoletis cerasi* (L.) (Diptera: Tephritidae), *Drosophila suzukii* (Matsumura), and *Zaprionus indianus* Gupta (Diptera: Drosophilidae) are the leading pests that cause worms in fruits. Using adult trapping, the population dynamics of these four pests were investigated in the orchards of Adana at different altitudes in 2019 and 2020. *Rhagoletis cerasi* adults emerged after the second week of May, and with the end of the harvest, the last adult emergence was seen in the first week of July. Adult population density was found at low levels. *Drosophila suzukii* adults appeared at 113 m (Balcalı) in April, and their emergence times were observed to be a little later as the altitude increased. It was determined that they continued their existence in nature until the end of December. It has the highest populations in late June - mid-July and late October - November. The occurrence of *C. capitata* and *Z. indianus* adults in nature in both years was after cherry fruits were harvested. It has been observed that different orchards appear in direct proportion as the altitude increases (from 113 m to 1510 m), the earliest in a low altitude place and the longer their duration in nature.

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# Türkiye'de Adana İli Meyve Bahçelerinde Farklı Yüksekliklerde *Ceratitis capitata* (Wied.), *Rhagoletis cerasi* (L.) (Diptera: Tephritidae), *Drosophila suzukii* (Matsumura) ve *Zaprionus indianus* Gupta (Diptera: Drosophilidae)'un Ergin Popülasyonlarının Takibi

## ÖZET

Son yıllarda Meyve sinekleri (Diptera: Drosophilidae ve Tephritidae) Türkiye'de meyve üretimini azaltan ciddi bir sorun haline gelmiştir. *Ceratitis capitata* (Wied.), *Rhagoletis cerasi* (L.) (Diptera: Tephritidae), *Drosophila suzukii* (Matsumura) ve *Zaprionus indianus* Gupta (Diptera: Drosophilidae) meyvelerde kurtlanma yapan zararlıların başında gelmektedir. Ergin tuzağı kullanarak, 2019 ve 2020 yıllarında Adana'nın farklı rakımlarındaki meyve bahçelerinde dört türün populasyon dinamikleri incelenmiştir. *Rhagoletis cerasi* erginleri mayısın ikinci haftasından sonra ortaya çıkmış, hasatın tamamlanmasıyla birlikte temmuz ayının ilk haftası son ergin çıkışları görülmüştür. Ergin popülasyon yoğunluğu düşük seviyelerde bulunmuştur. *Drosophila suzukii* erginlerinin 113 m'de (Balcalı) nisan ayında çıkmaya başladığı rakım yükseldikçe ortaya çıkış zamanlarının biraz daha geç olduğu belirlenmiş ve aralık ayının sonuna kadar doğada varlıklarını sürdürdükleri tespit edilmiştir. En yüksek popülasyonlarını haziran sonu- temmuz ayı ortasında ve ekim sonu–kasım ayında yapmıştır. *Ceratitis capitata* ve *Z. indianus* erginlerinin her iki yılda da doğada görülme zamanları kiraz meyveleri hasat edildikten sonra da devam etmiştir. Farklı meyve bahçelerinde, rakım yükseldikçe (113 m'den 1510 m'ye) doğru orantılı

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olarak bu türlerin sırasıyla ortaya çıktıkları, düşük rakımlı yerde en erken çıktığı ve doğada görülme süresinin daha uzun olduğu belirlenmiştir.

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## INTRODUCTION

Fruit flies (Diptera: Drosophilidae and Tephritidae) have become an increasingly severe problem for fruit production. The Eastern Mediterranean Region of Turkey has experienced a surge in cherry and fruit infestations due to pests such as *Ceratitis capitata* Wied., *Rhagoletis cerasi* L. (Diptera: Tephritidae), *Drosophila suzukii* (Matsumura), and *Zaprionus indianus* (Gupta) (Diptera: Drosophilidae). These pests are the root cause of fruit worming. These pests lay their eggs on ripening fruits, causing them to decay and reducing the overall yield.

The Mediterranean Fruit Fly, *C. capitata*, is a significant insect pest that attacks a variety of hosts in subtropical and tropical regions around the globe, making it economically important. It belongs to the family Tephritidae and attacks a variety of hosts in subtropical and tropical regions across the world. This pest, which generally prefers ripe and thin-skinned fruits, causes them to fall because it directly damages the fruit during harvest. Buğday & Keçeci (2020) emphasized that it is crucial to follow the current situation of the pest in the Central Anatolia and Eastern Anatolia regions of our country together with the climatic changes.

*Drosophila suzukii* fruit flies were first recorded on the cherry of Yamanashi, Japan in 1916 (Kanzawa,1939). The spotted wing drosophila (SWD), a member of the Drosophilidae family, is widely known for its destructive nature as it inflicts severe damage on small fruit crops across the world (Walsh et al., 2011; Cini et al., 2012; Santos, 2014; Asplen et al., 2015). This is attributed to its high polyphagia (Dreves et al., 2009), dispersion capacity (Walsh et al., 2011; Cini et al., 2012), and rapid population growth (Tochen et al., 2014). It was first recorded on strawberries in Erzurum, Eastern Turkey in 2014 (Orhan et al., 2016). Later, this problem was felt in Turkey's fruit industry, causing significant economic harm to various types of fruits (Çatal et al., 2018; Ögür et al., 2018; Kasap & Özdamar, 2019; Zengin & Karaca, 2019).

The *R. cerasi*, commonly known as the European cherry fruit fly, is the most important pest of sweet cherries in Europe and causes severe yearly damage. Without the use of insecticide treatment, all fruits can become infested. Cherry growers face a challenge with *R. cerasi* due to the market's low tolerance for damaged fruit (maximum 2% of infested fruits).

*Z. indianus* is a common pest that affects over 80 types of fruit crops, such as figs, apples, and cherries (Yassin & David, 2010). It is known to cause significant harm to various kinds of fruit crops. It can cause severe damage to many fruit crops. Gupta (1970) was the first to collect and describe this species in India. Although initially believed to have originated in tropical Africa (Chassagnard & Kraaijveld, 1996), this fly has now spread to numerous countries worldwide, including old and new world nations (Commar et al., 2012). The species *Z. indianus* is known for being highly successful at colonizing (Chassagnard & Tsacas, 1993). According to Parkash & Yadav (1993), populations of this species have habitat-generalist or general niche-width characteristics, i.e., they utilize diverse food resources and display adaptation to variable climatic conditions. In 2017, *Z. indianus* was first reported on fruits such as fig, Trabzon persimmon, mulberry, blackberry, peach, cherry, and plum in Turkey's Eastern Mediterranean region. (Çatal et al., 2019).

Although the pest species is widespread, there is limited knowledge about population trends at varying altitudes. This research aimed to explore how altitude affects the seasonal flight patterns of *C. capitata*, *D. suzukii*, *R. cerasi*, and *Z. indianus*. Based on changing climate conditions, the study also aimed to distinguish any differences in adult emergence between nearby locations at varying altitudes.

## MATERIAL and METHODS

The study examined natural populations of four fruit fly species, including *C. capitata*, *R. cerasi*, *D. suzukii*, and *Z. indianus*, in orchards where mid-season and late cherry varieties are grown. In addition, population monitoring of *C. capitata*, *D. suzukii,* and *Z. indianus* at different altitudes was carried out.

To capture *R. cerasi*, yellow sticky traps measuring 13.5x22.5 cm with ammonia capsules (Trece-Pherocon® AM No-Bait trap with Dual-Pak™ Supercharger™) were utilized. For *D. suzukii* and *Z. indianus*, traps were baited with 50% apple cider vinegar. Finally, a delta trap (KAPAR®AMS) was

employed for capturing *C. capitata*.

### Selection and Planning of Trial Locations

Research has been conducted on the orchards listed in Table 1. To study the flight dynamics of adult specimens, we utilized traps that are typical of their species. The trial orchards' trees have consistently yielded fruit for at least five years.

Table 1. Geographic locations, orchards, and hosts allocated for monitoring the flight activity of *Ceratitis capitata*, *Rhagoletis cerasi*, *Drosophila suzukii,* and *Zaprionus indianus* adults in different locations Adana between 2019 and 2020.

*Çizelge 1. 2019-2020 yılları arasında Adana'nın farklı lokasyonlarında Ceratitis capitata, Rhagoletis cerasi, Drosophila suzukii ve Zaprionus indianus erginlerinin uçuş aktivitesinin izlendiği coğrafi konumlar, meyve bahçeleri ve konukçuları.*

| Location | Orchards | Altitude | Lat. (North) | Long. (East) | Treatment |
|---|---|---|---|---|---|
| Balcalı | 1 | 113m | 37°01'44" | 35°21'37" | Grapefruit |
| Belemedik | 1 | 700m | 37°20'49" | 34°54'38" | Cherry |
| Alpu | 1 | 1070m | 37°28'34" | 34°54'05" | Cherry |
| Aşçıbekirli | 1 | 1180m | 37°36'56.5" | 34°57'54.4" | Apple |
| Hamidiye | 1 | 1170m | 37°34'01.5" | 34°57'06.5" | Apple |
| | 2 | 1300m | 37°33'25.9" | 34°57'32.0" | Cherry |
| Karakışlakçı | 1 | 1300m | 37°39'03.3" | 34°54'32.9" | Apple |
| | 2 | 1430m | 37°39'50.3" | 34°54'03.7" | Strawberry<br>Apricot |
| | 3 | 1510m | 37°40'00" | 34°53'46" | Cherry |

### Flight Activity

To monitor the flight activity of *C. capitata*, *R. cerasi*, *D. suzukii,* and *Z. indianus* adults, we placed traps at the locations given in Table 1 for the 2019-2020 years. The *Rhagoletis cerasi* population was monitored only in Alpu and Belemedik. Traps were set in February for *D. suzukii* and *Z. indianus* and in April for *C. capitata* and *R. cerasi* before their adult flight started.

Yellow sticky traps with ammonia capsules and delta traps were used to monitor the adult flight dynamics for *R. cerasi* and *C. capitata*. For *D. suzukii* and *Z. Indians*, traps were filled with apple cider vinegar and were placed at a height of approximately 1.5 m on cherry trees. To monitor adult fruit flies, two traps were hung around the orchard and checked on a weekly. The attractant was replaced weekly. The identification of species was realized by the authors.

### Climatic Data

The climatic data, which includes the mean daily temperature and precipitation for the two experimental areas, has been provided by the Turkish State Meteorological Service. Mean daily temperatures and rain for the two areas from February 2019 to December 2020 (Figure 6).

## RESULTS and DISCUSSION

### Flight Activity

Populations of four types of fruit flies were evaluated in two cherry orchards (Alpu and Belemedik) in the Pozantı region (Adana) (Table 2; Figure 1, 2) according to the coexistence period of fruit fly species in nature, taking into account harvest times and general seasonal activity. Also, the performance of fruit flies and vinegar flies at different altitudes is illustrated in Tables 3, and 4 and Figures 3, 4, and 5.

For adults to hatch from pupae of fruit flies overwintering in the soil, the soil temperature must reach to certain level. Because the cherry fly is a heterodynamic insect species, it survives unfavorable climatic conditions in diapause (Kansu, 2000). To awaken from diapause, there must be long daylight hours, warmth, soil wetness (humidity), and matching plant phenology (Boller and Prokopy, 1976; Anonymous, 2011). Multivoltine, tropical species such as the Mediterranean fruit fly are homodynamic species and become active at ambient temperatures above their developmental threshold. As each insect species has a different developmental threshold temperature, developmental thresholds of the other biological periods of each species may also differ. The developmental threshold of the Mediterranean fruit fly is 12.4°C, and it cannot overwinter outside the fruit above 400 m and above 700 m when ambient conditions fall below zero degrees. The fig vinegar fly, *Z. indianus*, native to the tropics, is also a homodynamic species and cannot survive in environments below zero degrees Celsius. Winter forms of the adult cherry vinegar fly, *D. suzukii*, can survive winters as low as -35°C without going into diapause. Poikilothermal insects can become active when the ambient temperature rises above the growth threshold. With this general information in mind, the performance of fruit flies and vinegar flies at different altitudes is illustrated in Tables 3 and 4.

The first emergence of *R. cerasi* as an adult in both years took place in the third week of May in Belemedik (elevation 700 m) and Alpu (elevation 1070 m), with the highest number of adult flies emerging in the first week of June, and the final emergence of adults taking place in late June (Table 2; Figure 1, 2). No adults of *R. cerasi*, the primary pest of cherry, were found in traps after harvest. *Rhagoletis cerasi*, which produces one offspring per year, was found to be compatible with cherry phenology as well as duration of illumination, temperature, and wetness (humidity), beginning to appear when fruit entered the yellow ripening period and going into diapause after the harvest period (Table 2). In addition, adult population densities were low in both years. The cherry fruit fly usually pupates in the soil, occupying the area corresponding to the canopy projection of the cherry tree. Depending on soil moisture and ambient temperature in the spring, adults fly to the nearest tree. Since the adult cherry fruit flies are not very mobile, they usually feed on the nectar-containing substances that form in the fresh shoots of the tree on which the ripening food is growing. After mating, they first lay eggs on the fruit of the tree they are on, and when they are forced to do so, they go to the nearest trees and lay eggs on the fruit there. It has been reported that the movement of the cherry fruit fly over long distances is exceedingly small and that these movements are associated with activities such as oviposition, mating, and feeding (Katsoyannos et al., 1986; Wiesmann, 1933).

Table 2. First, maximum, and last capture, and harvest dates and duration of capture of adults at Pozantı (Alpu and Belemedik) in 2019 and 2020 (RC: *Rhagoletis cerasi*, CC: *Ceratitis capitata*, DS: *Drosophila suzukii* and Zİ: *Zaprionus indianus*).

*Çizelge 2. Pozantı'da (Alpu ve Belemedik) 2019 ve 2020 yıllarında ergin bireylerin ilk, maksimum, son yakalanma ve hasat tarihleri ile doğada görülme süreleri (RC: Rhagoletis cerasi, CC: Ceratitis capitata, DS: Drosophila suzukii ve Zİ: Zaprionus indianus).*

| | Belemedik (703m) | | | | Alpu (1077m) | | | |
|---|---|---|---|---|---|---|---|---|
| **Year/2019** | **RC** | **CC** | **DS** | **Zİ** | **RC** | **CC** | **DS** | **Zİ** |
| First capture | 22 May | 12 June | 22 May | 12 Sept. | 21 May | 5 July | 7 June | 23 Sept. |
| Maximum capture | 22 May<br>05 June | 28 Aug.<br>11 Sept.<br>16 Oct. | 10 July<br>30 Oct.<br>27 Nov. | 23 Oct.<br>13 Nov. | 05 June<br>12 June | 31 July | 10 July<br>06 Nov. | none |
| Last capture | 26 June | 5 Dec. | 25 Dec. | 27 Nov. | 5 July | 16 Nov. | 25 Dec. | 27 Nov. |
| Harvest dates | 17 June-26 June | | | | 10 June-05 July | | | |
| Duration of capture (d) | 37 | 178 | 219 | 78 | 47 | 105 | 203 | 68 |
| **Year/2020** | **RC** | **CC** | **DS** | **Zİ** | **RC** | **CC** | **DS** | **Zİ** |
| First capture | 19 May | 7 July | 7 Apr. | 2 June | 12 May | 14 July | 26 May | 1 Sep. |
| Maximum capture | 9 June | 19 Aug.<br>29 Sep. | 14 July<br>10 Nov. | 06 Oct.<br>17 Nov. | 19 May | 18 Aug.<br>20 Oct. | 30 June | 29 Sep.<br>20 Oct. |
| Last capture | 30 June | 10 Nov. | 22 Dec. | 29 Dec. | 30 June | 27 Oct. | 10 Nov. | 10 Nov. |
| Harvest dates | 16 June - 30 June | | | | 23 June - 30 June | | | |
| Duration of capture (d) | 43 | 127 | 260 | 211 | 50 | 106 | 169 | 71 |

In recent years, the first adults of the Mediterranean fruit fly, a pest of stone and pome fruits, especially cherries, were caught in the cool climate zone in pheromone and pole traps in Belemedik on 12 June 2019, when the cherry harvest began in the region. The pest survived in the wild until the first week of December. In the first year, the density of the adult population of *C. capitata* reached its highest values on 28 Agust, 11 September, and 16 October (Figure 2a). In the second year, the first adults were trapped three weeks after the cherry harvest, and the pest remained in the wild between the first week of July and the first week of November. The highest number of adults between these dates was observed on 19 Agust and 29 September (Figure 2b). In Alpu, the pest was trapped the first year after the cherry harvest in the first week of July, reaching its highest adult population on 31 July, and not trapped after 16 October (Figure 1a). The pest was trapped during the second week of July in the second year and was present in the wild until late October. The adult population of *C. capitata* reached high levels twice, on 18 Agust and 20 September 2020 (Figure 1b). In the other altitudinal regions where the experiment was conducted, *C. capitata* was detected on 15 May and 2 June in Sarıçam-Balcalı (altitude 113 m), 10 July and 28 July in Pozantı-Hamidiye (1170 m), on 7 and 4 August in Pozantı-Aşçıbekirli (1180 m), on 4 and 22 September in Pozantı-Karakışlakçı (1300 m), caught in traps in 2019 and 2020, respectively. On the other hand, the pest did not get caught in the traps in Pozantı-Hamidiye (1300 m), Pozantı-Karakışlakçı (1430 m), and Pozantı-Karakışlakçı (1510 m) (Table 3,

Table 3. First, maximum, and last capture dates and duration of capture of adults at different altitudes in Adana in 2019 (RC: *Rhagoletis cerasi*, CC: *Ceratitis capitata*, DS: *Drosophila suzukii* and Zİ: *Zaprionus indianus*).

*Çizelge 3. 2019 yılında Adana'da farklı yüksekliklerde erginlerin ilk, maksimum, son yakalanma tarihleri ve doğada görülme süreleri (RC: Rhagoletis cerasi, CC: Ceratitis capitata, DS: Drosophila suzukii ve Zİ: Zaprionus indianus).*

| Karakışlakçı (1510m) | Karakışlakçı (1430m) | Karakışlakçı (1300m) | Hamidiye (1300m) | Hamidiye (1170m) | Aşçıbekirli (1180m) | Alpu (1070m) | Belemedik (700m) | Balcalı (113m) | **Location** | **2019** |
|---|---|---|---|---|---|---|---|---|---|---|
| * | * | * | * | * | * | 21 May | 22 May | * | First capture | **RC** |
| * | * | * | * | * | * | 05 Jun<br>12 Jun | 22 May<br>05 Jun | * | Maximum capture | |
| * | * | * | * | * | * | 5 Jul | 26 Jun | * | Last capture | |
| * | * | * | * | * | * | 47 | 37 | * | Duration of capture (d) | |
| 4 Sept | * | 4 Sept | * | 10 Jul | 7 Aug | 5 Jul | 12 Jun | 15 May | First capture | **CC** |
| 4 Sept | * | 25 Sept<br>23 Oct | * | 31 Jul<br>23 Oct | 9 Oct | 31 Jul | 28 Aug<br>11 Sept<br>16 Oct | 17 Jul<br>23 Oct<br>27 Nov | Maximum capture | |
| 4 Sept | * | 13 Nov | * | 13 Nov | 13 Nov | 16 Nov | 5 Dec | 15 Dec | Last capture | |
| 1 | * | 71 | * | 127 | 99 | 105 | 178 | 215 | Duration of capture (d) | |
| 17 Jul | 17 Jul | 17 Jul | 17 Jul | 17 Jul | 17 Jul | 7 Jun | 22 May | 3 Apr | First capture | **DS** |
| 13 Nov | 17 Jul<br>13 Nov | 13 Nov | 17 Jul<br>13 Nov | 30 Oct<br>13 Nov | 30 Oct | 10 Jul<br>06 Nov | 10 Jul<br>30 Oct<br>27 Nov | 17 Apr<br>15 May<br>10 Jul | Maximum capture | |
| 27 Nov | 13 Nov | 20 Nov | 13 Nov | 25 Dec | 27 Nov | 25 Dec | 25 Dec | 30 Oct | Last capture | |
| 134 | 120 | 127 | 120 | 162 | 134 | 203 | 219 | 211 | Duration of capture (d) | |
| None | 6 Nov | 23 Oct | 6 Nov | 4 Sept | 23 Oct | 23 Sept | 12 Sept | 28 Aug | First capture | **Zİ** |
| None | None | 13 Nov | None | 13 Nov | None | None | 23 Oct<br>13 Nov | 20 Nov | Maximum capture | |
| None | 13 Nov | 13 Nov | 13 Nov | 13 Nov | 13 Nov | 27 Nov | 27 Nov | 11 Dec | Last capture | |
| None | 8 | 22 | 8 | 71 | 22 | 68 | 78 | 106 | Duration of capture (d) | |

Table 4. First, maximum, and last capture dates and duration of capture of adults at different altitudes in Adana in 2020 (RC: *Rhagoletis cerasi*, CC: *Ceratitis capitata*, DS: *Drosophila suzukii* and Zİ: *Zaprionus indianus*).
*Çizelge 4. 2020 yılında Adana'da farklı yüksekliklerde erginlerin ilk, maksimum, son yakalanma tarihleri ve doğada görülme süreleri* (RC: *Rhagoletis cerasi*, CC: *Ceratitis capitata*, DS: *Drosophila suzukii ve* Zİ: *Zaprionus indianus*).

| Karakışlakçı (1510m) | Karakışlakçı (1430m) | Karakışlakçı (1300m) | Hamidiye (1300m) | Hamidiye (1170m) | Aşçıbekirli (1180m) | Alpu (1070m) | Belemedik (700m) | Balcalı (113m) | **Location** | **2020** |
|---|---|---|---|---|---|---|---|---|---|---|
| * | * | * | * | * | * | 12 May | 19 May | * | First capture | **RC** |
| * | * | * | * | * | * | 19 May | 9 Jun | * | Maximum capture | |
| * | * | * | * | * | * | 30 Jun | 30 Jun | * | Last capture | |
| * | * | * | * | * | * | 50 | 43 | * | Duration of capture (d) | |
| None | * | 22 Sep | * | 28 Jul | 4 Aug | 14 Jul | 7 Jul | 2 Jun | First capture | **CC** |
| None | * | 27 Oct | * | 11 Aug<br>27 Oct | 29 Sep | 18 Aug<br>20 Oct | 19 Aug<br>29 Sep | 30 Jun<br>18 Aug<br>17 Nov | Maximum capture | |
| None | * | 27 Oct | * | 27 Oct | 27 Oct | 27 Oct | 10 Nov | 15 Dec | Last capture | |
| None | * | 36 | * | 92 | 85 | 106 | 127 | 197 | Duration of capture (d) | |
| 8 Sep | 28 Jul | 8 Sep | 23 Jun | 23 Jun | 21 Apr | 26 May | 7 Apr | 7 Apr | First capture | **DS** |
| none | 13 Oct | 8 Sep<br>20 Oct | 7 Jul<br>27 Oct | 8 Sep<br>20 Oct | 3 Nov | 30 Jun | 14 Jul<br>10 Nov | 26 May<br>30 Jun | Maximum capture | |
| 27 Oct | 27 Oct | 3 Nov | 27 Oct | 27 Oct | 3 Nov | 10 Nov | 22 Dec | 10 Nov | Last capture | |
| 50 | 92 | 57 | 127 | 127 | 197 | 169 | 260 | 218 | Duration of capture (d) | |
| 8 Sep | 25 Aug | 8 Sep | None | 8 Sep | 22 Sep | 1 Sep | 2 Jun | 29 Sep | First capture | **Zİ** |
| 8 Sep<br>29 Sep | 8 Sep<br>27 Oct | 8 Sep<br>20 Oct | None | 8 Sep<br>20 Oct | 29 Sep<br>27 Oct | 29 Sep<br>20 Oct | 06 Oct<br>17 Nov | 17 Nov | Maximum capture | |
| 29 Sep | 10 Nov | 27 Oct | None | 10 Nov | 10 Nov | 10 Nov | 29 Dec | 1 Dec | Last capture | |
| 22 | 78 | 50 | None | 64 | 50 | 71 | 211 | 64 | Duration of capture (d) | |

4; Figure 3). During this study, the duration of the appearance of adults in traps was recorded as 178 and 127 days in Belemedik, and 105 and 106 days in Alpu in the first and second years, respectively. Regarding the other altitudinal regions, the pest lasted 215-197 days in Balcalı, 99-85 days in Aşçıbekirli, 127-92 days in Hamidiye (1170 m), and 71-36 days in Karakışlakıçı (1300 m) (Tables 3 and 4).

Many studies show that *C. capitata*, whose distribution and abundance in temperate regions are determined by the lowest winter and highest summer temperatures, exhibits seasonal variations in different parts of the world (Escudero-Colomar et al., 2008). Accordingly, *C. capitata*, abundant in spring and summer, may not be detected in winter (Mansour & Mohamad, 2016). Also, it was reported that with increasing elevation, both the duration of appearance of *C. capitata* adults in the wild shortened and the number of adults was lower than at sites with lower elevation. This is thought to be related to the optimal temperature required for the species to develop. Although the optimal temperature for its development is 26°C, survival is high between 15 and 30°C. Duyck & Quilici (2002) reported that the development of the Mediterranean fruit fly showed a linear relationship with temperature, while Escudero-Colomar et al., (2008) said that the lowest temperature threshold required for its development varied according to developmental stages and that these thresholds were generally between 9 and 11 °C. *Ceratitis capitata* cannot continue its development at temperatures below 5 °C, and absolute death occurs at temperatures below zero (Ulusoy et al., 2022).

Adult specimens of the cherry vinegar fly *D. suzukii*, which has invaded our country recently, were detected in traps in Belemedik in the third week of May in the first year and in the first week of April in the second year. The pest could be trapped in both years until the last week of December. The highest population density of the pest in the cherry orchard was observed three times in the first week of July and the last week of October and November in the first year, and similarly in early July and late November in the second year (Table 2; Figure 2). In the Alpu cherry orchard, the *D. suzukii* was detected in the traps during the first week of June, when the fruit was ripe and about to be harvested. In contrast, in the second year, it was detected during the last week of June, towards the end of the fruit harvest. The pest remained in the wild from the first detection date until the last week of December. The highest adult population was detected in July and early November in the first year and not until late June in the second year (Table 2; Figure 1). In other altitudinal regions, the first capture of the pest in traps occurred on 03 and 07 April in Balcalı in 2019 and 2020, respectively, and the duration of appearance in the wild was determined to be 211 and 218 days (Table 3 and 4). It was detected in Aşçıbekirli on 21 June 2020, and in general, the first captures in traps were in July, and the last in September and October (Table 3 and 4; Figure 4). In studies monitoring the population movements of *D. suzukii*, researchers reported that after capturing a few specimens in early spring, no adults were found until June, and the population increased in late summer. They reported that their population reached higher peaks in October and November, while their numbers declined dramatically in winter, though a few adults were still captured (Mazzetto et al., 2015). According to Briem et al. (2018), the number of adult *D. suzukii* in the summer decreased because temperatures rose above 30°C. They found that the density of flies in the traps increased in September when the temperature started to drop.

Another vinegar fly, *Z. indianus*, was detected in Belemedik during the second week of September in the first year, and adults were caught in traps until late November. In the second year, adults were detected in traps in early June, and the pest was active in the wild until the last weeks of December. The highest adult population was observed in the third week of October and the second week of November in the first year, and in the first week of October and the third week of November in the second year (Figure 2). In the Alpu cherry orchard, the pest was detected in the last week of September in the first year, and in the first week of September in the second year. In both years, the pest was caught in traps from its first emergence until mid-November. The highest populations of adults were observed in the second week of October and November in the first year, the last week of September, in the third week of October in the second year (Table 2; Figure 1). In respect of other regions, the pest first appeared in September and later, as was the case in Belemedik and Alpu, with the last capture of adults seen in the traps in October and November, and the shortest adult time in nature was 8 days in 2019 and the longest was 106 days in Balcalı (Table 3 and 4; Figure 5). In contrast to other species, *Z. indianus* was observed to remain for shorter periods in the wild. Araripe et al., (2004) reported that *Z. indianus* is a tropical species and is not likely to colonize in cold temperate areas due to its low cold tolerance, just like other species.

## CONCLUSION

The results of this study show that *R. cerasi* adults appear after the second week of May when fruits start to ripen and that the last adults emerge after the harvest is complete. In both years, adults were caught in the traps, consistent with cherry phenology, and adult population densities were low.

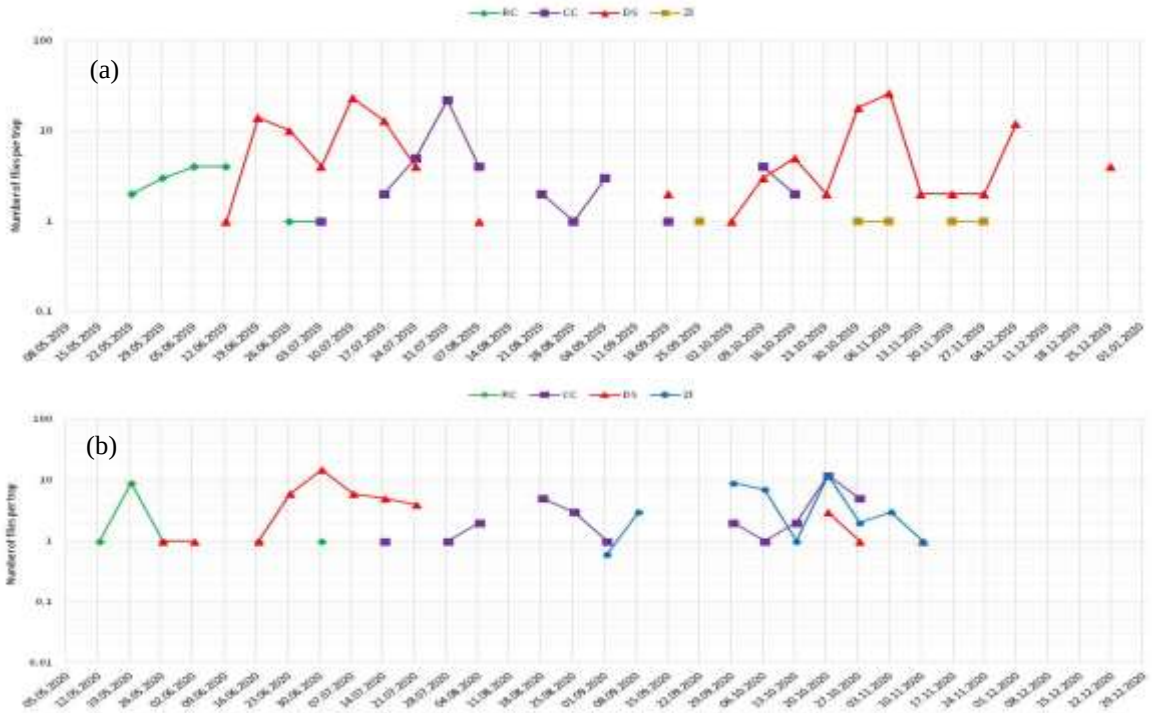


Figure1. Flight activity of *Rhagoletis cerasi* (RC), *Ceratitis capitata* (CC), *Drosophila suzukii* (DS), and, *Zaprionus indianus* (Zİ) in Alpu in 2019 (a) and 2020 (b).

*Şekil 1. Rhagoletis cerasi (RC), Ceratitis capitata (CC), Drosophila suzukii (DS) ve Zaprionus indianus' un (Zİ) 2019 (a) ve 2020 (b) yıllarında Alpu'daki uçuş aktivitesi.*

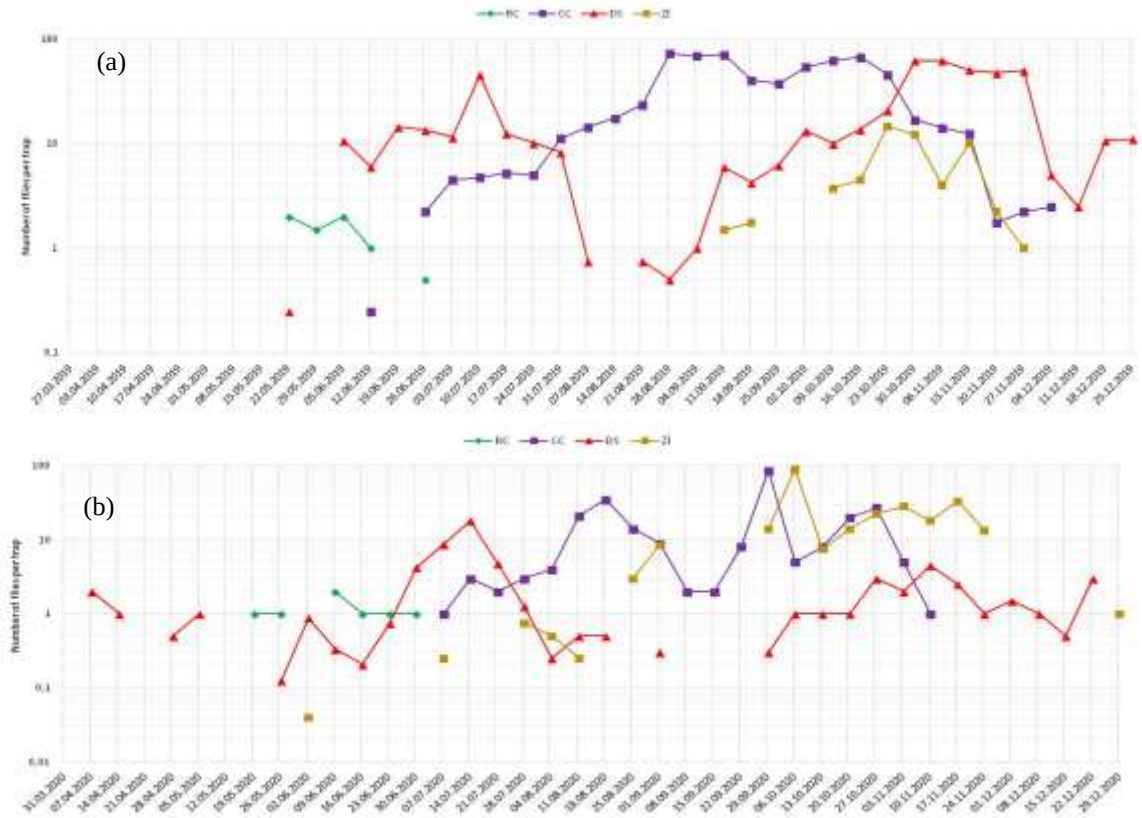


Figure 2. Flight activity of *Rhagoletis cerasi* (RC), *Ceratitis capitata* (CC), *Drosophila suzukii* (DS) and *Zaprionus indianus* (Zİ) in Belemedik in 2019 (a) and 2020 (b).

*Şekil 2. Rhagoletis cerasi (RC), Ceratitis capitata (CC), Drosophila suzukii (DS) ve Zaprionus indianus' un (Zİ) 2019 (a) ve 2020 (b) yıllarında Belemedik'deki uçuş aktivitesi.*

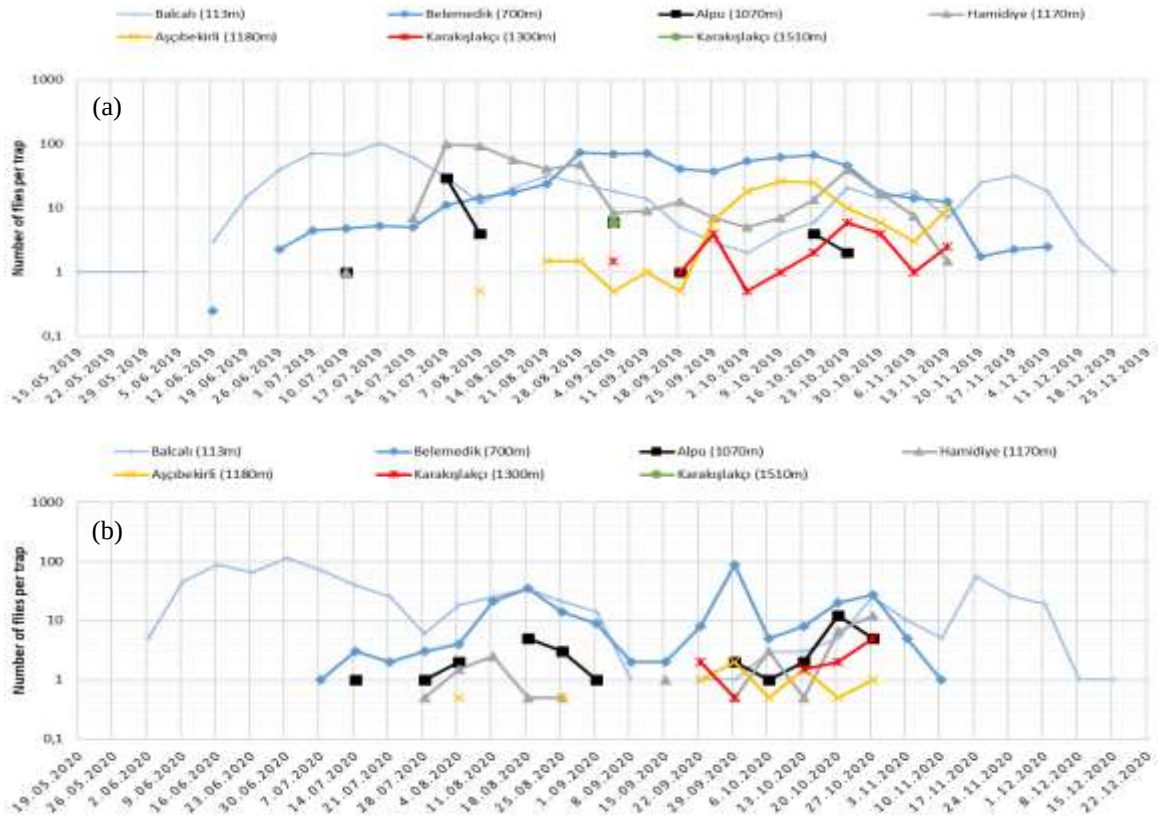


Figure 3. Flight activity of *Ceratitis capitata* in 2019 (a) and 2020 (b) at different altitudes.
*Şekil 3. Ceratitis capitata 'nın 2019 (a) ve 2020 (b) yıllarında farklı yüksekliklerdeki uçuş aktivitesi.*

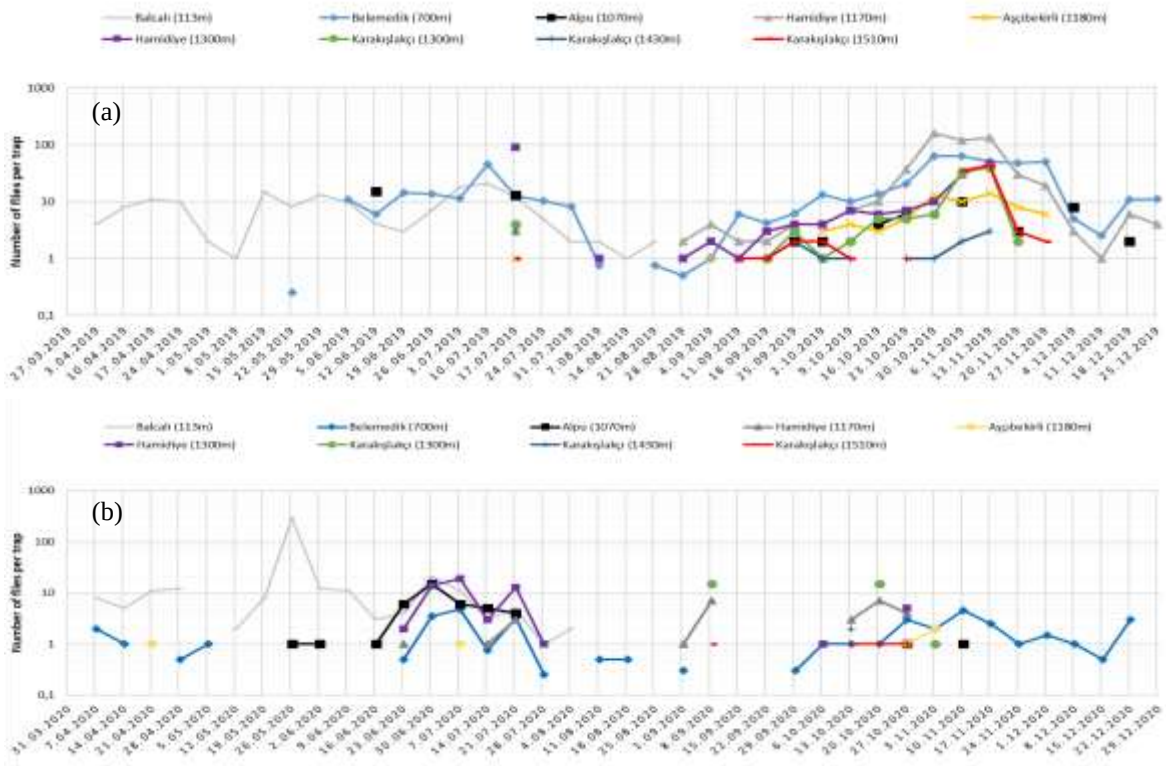


Figure 4. Flight activity of *Drosophila suzukii* in 2019 (a) and 2020 (b) at different altitudes.
*Şekil 4. Drosophila suzukii 'nin 2019 (a) ve 2020 (b) yıllarında farklı yüksekliklerdeki uçuş aktivitesi.*

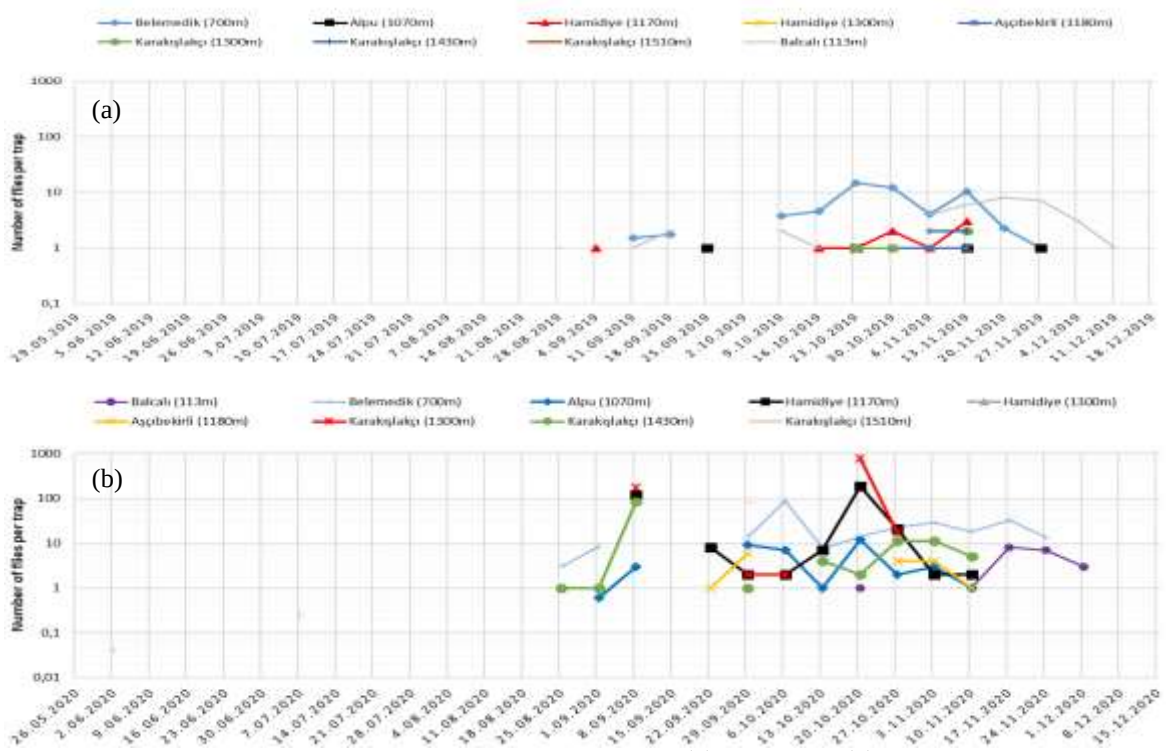


Figure 5. Flight activity of *Zaprionus indianus* in 2019 (a) and 2020 (b) at different altitudes.
*Şekil 5. Zaprionus indianus ' un 2019 (a) ve 2020 (b) yıllarında farklı yüksekliklerdeki uçuş aktivitesi.*

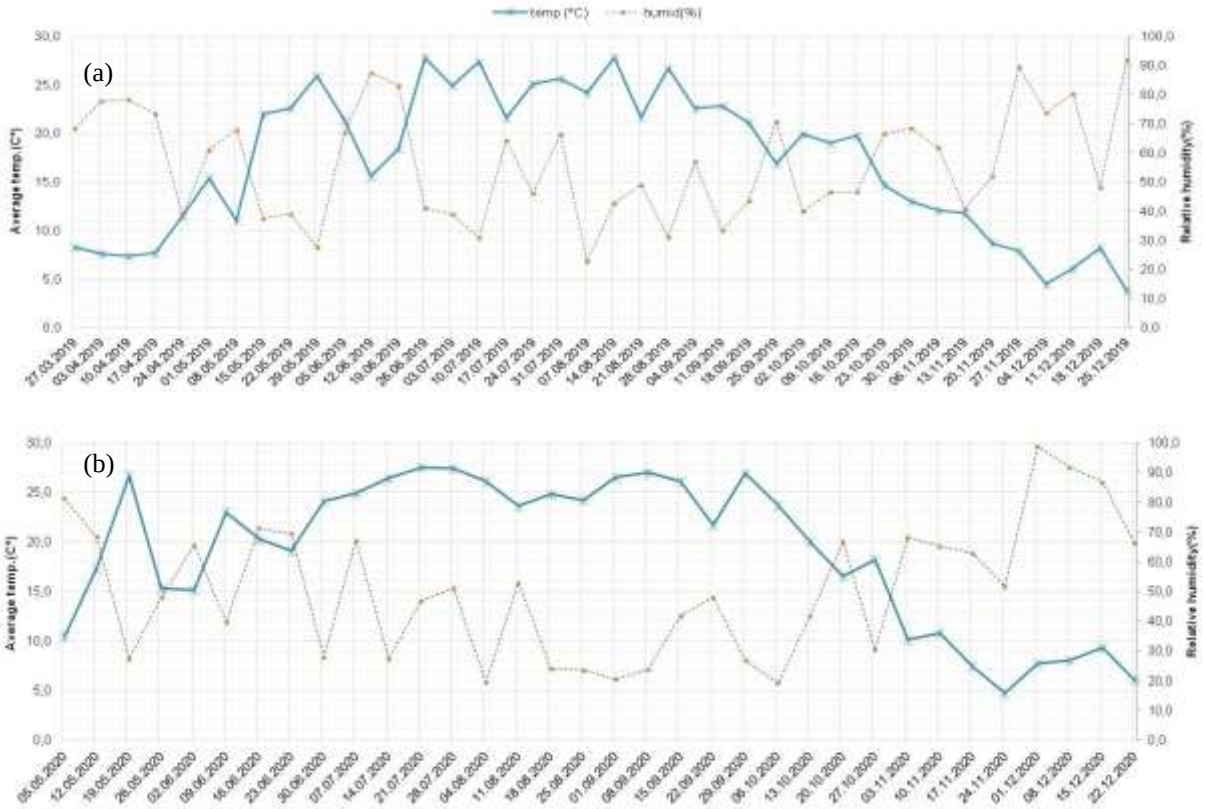


Figure 6. Adana-Pozantı district average temperature (°C) and relative humidity (%) values for March - December 2019 (a) – 2020 (b).
*Şekil 6. 2019 (a) – 2020 (b) yıllarında Adana-Pozantı ilçesi Mart – Aralık ayları ortalama sıcaklık (°C) ve bağıl nem (%) değerleri.*

Although there was an elevation difference of 300 m between the two regions, there was no difference in the first emergence of adults and the duration of their appearance in nature. The reason for this was the topographic structure of the region. Namely, Belemedik is located in a valley between two mountains overshadowed by the mountains, while Alpu, although it is higher, is open on all sides and has more than 12 hours of sunshine in the summer months. We believe that these topographical features directly impact the time of emergence of the cherry fruit fly from its wintering grounds, the flight, and the duration of its stay in the wild, in light of similar results obtained despite the difference in altitude of 300 m.

*Drosophila suzukii* flies began hatching in April at 703 m elevation (Belemedik); at 1077 m elevation (Alpu), the timing of hatching was slightly later due to increasing height, and they were found to survive in the wild until late December. The highest population concentrations were observed in late June to mid-July and late October to November.

*Zaprionus indianus* appeared in late August and early September, was observed in the wild until late November, and was detected once in traps in late December. The highest population was observed in mid-October. Only in Belemedik were adults seen once in June in the second year, detected again a month later, and appearances lasted until December. *Zaprionus indianus* adults were observed in nature following cherry fruit harvest in both years.

Vinegar flies feed mainly on spilled, damaged, decaying fruits and vegetables (Kaneshiro, 2006; O'Grady, 2009). They also survive on other thin-skinned fruits (plums, apples, pears) and fruit-bearing plants such as hawthorn, blackthorn, rose, nightshade, etc., in and around gardens. In gardens with all types of fruits, it is possible to come across adults all year round if climatic conditions allow. Of these species, *D. suzukii* also damages ripening, intact fruit using its sawtooth-like ovipositor. *Zaprionus indianus*, on the other hand, is known as a fig pest and lays its eggs in figs primarily in natural openings where the blowfly makes an entrance and on the ruptured fruit skin of fully ripe figs. These pests are spotted in gardens during harvest time of ripening fruit. Aromatic odors emanating from fruits attract these pests. While there is more damage in orchards having a delayed harvest, their population decreases significantly in gardens harvested on time. For this reason, they are known as sap-sucking insects feeding on fruit that falls to the ground or is left on the tree. We concluded that the irregularity of the populations of both pests was because the orchards were mixed and the harvesting seasons were different. The abiotic factors affecting this situation include the daily variations in daytime and nighttime temperatures between April and June and between September and December, sudden rainfall, and the rapidly decreasing ambient temperature.

*Ceratitis capitata* adults were observed in nature following cherry fruit harvest in both years. The adults of this species were observed in Alpu and Belemedik from July to December. There was also an increase in their population between the end of July and October. In both years, they were observed to appear in direct proportion to increasing altitude (from 703 m to 1077 m), appeared earliest at lower altitudes, and the duration of sightings in the wild was longer. Most adult *C. capitata* were found in July-August and October-November.

The adults of the Mediterranean fruit fly are brought to the cool climate regions by the commercial transport of fruits such as oranges, tangerines, peaches, nectarines, and apricots grown in the subtropical region. Study region, the pest emerged after the cherry harvest, causing no damage to cherries. However, in the first week of July, the pest was detected in fruits such as sour cherry, apple, pear, and quince grown in cool climate regions. It is assumed that the ambient temperature between May and November is suitable for the larvae of the Mediterranean fruit fly transported to the area with contaminated fruit to enter the pupal stage and for the adults hatching from the pupae to perform their biological activities. That altitude does not play an important role. Kansu, (2000) indicated in one of the sketches for the Mediterranean fruit fly that it could theoretically produce three offspring in Ankara during the summer months.

In conclusion, the results of this present study, intended to monitor the population of *R. cerasi*, *C. capitata*, *D. suzukii* and *Z. indianus* in different orchards at different altitudes, will serve as primary data for future studies and researchers and help with pest management in cherry-cultivation areas.

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### Author's Contributions

Each author's contribution is equal.

### Statement of Conflict of Interest

The authors have stated that there is no conflict of interest.

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