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Evaluations on Bioecology of *Contarinia pruniflorum* Coutin & Rambier, 1955 (Diptera: Cecidomyiidae)

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ABSTRACT
Apricot flower midge (*Contarinia pruniflorum* Coutin & Rambier Diptera: Cecidomyiidae) was first detected in *Prunus* species in the 1950s and did not become a significant pest for a long time. However, towards the 2000s, the pest caused damage to apricot and plum especially in Mediterranean countries and its distribution continued to increase. The population density of the pest is closely related to the climate of the agricultural area. In recent years, the fluctuation in climatic data causes the population fluctuations. The study was carried out in the Kale and the Yeşilyurt district of Malatya province (Turkey) in 2017-2018. Some biological stages of apricot flower midge were determined in Malatya province and these data were interpreted together with climatic data. It was determined that the pest overwinters as a pupa in the soil. In February, the adult emerges from the pupa with the warming of the air and soil temperatures. It was determined that the adult emerged from the pupa when the soil temperature was 13-14 °C and the air temperature was 7-15 °C. At the beginning of the pink-bud stage of apricot, the pests lay eggs into flower buds. The larval development is approximately 25-28 days. The average number of larvae in the damaged buds was 14, the maximum number of larvae in a bud was 26, and the pest gave an offspring annually and the ratio of male to female was 0.08.

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Contarinia pruniflorum Coutin & Rambier, 1955 (Diptera: Cecidomyiidae)'un Biyoekolojisi Üzerine Değerlendirmeler

ÖZET
Kayısı çiçek tomurcuğu sineği (*Contarinia pruniflorum* Coutin & Rambier Diptera: Cecidomyiidae) 1950 li yıllarda ilk olarak *Prunus* türlerinde tespit edilmiş olup uzun bir süre önemli bir zararlı olmamıştır. 2000'li yıllara doğru özellikle Akdeniz ülkelerinde kayısı ve erikde zarar oluşturmuş ve yayılış alanı artarak devam etmiştir. Zararlının popülasyon yoğunluğu yetiştiricilik yapılan alanın iklimi ile çok yakın ilişki içerisindedir. Son yıllarda iklimsel verilerdeki dalgalanma popülasyon seviyesinde de dalgalanmaya neden olmaktadır. Çalışma, 2017-2018 yıllarında Malatya ili Kale ve Yeşilyurt ilçelerinde yürütülmüştür. Çalışmada Malatya ilinde Kayısı çiçek tomurcuğu sineğinin özellikle mücadeleye esas bazı biyolojik dönemleri belirlenmiş ve bu veriler iklimsel verilerle birlikte yorumlanmıştır. Türün kışı toprakta pupa olarak geçirdiği, şubat ayı içerisinde hava (7-15 °C) ve toprak sıcaklıklarının (13-14 °C) ısınmasıyla birlikte erginin pupadan çıktığı tespit edilmiştir. Kayısının pembe tomurcuk döneminin başlarında çiçek tomurcukları içerisine yumurtasını bıraktığı, zarar görmüş tomurcuktaki ortalama larva sayısının 14 olduğu, bir tomurcukta görülen en fazla larva sayısının ise 26 adet olduğu ve yılda 1 döl verdiği, erkek bireylerinin dişi bireylere oranı ise 0.08 olarak belirlenmiştir.

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INTRODUCTION

Contarinia pruniflorum Coutin & Rambier (Diptera: Cecidomyiidae) (Apricot flower midge) was firstly identified in *Prunus* species and some biological characters were determined (Coitin and Rambier, 1955). It was later seen in cultivated *Prunus* species in Czechoslovakia, Italy, Greece, and Turkey. Some morphological features, biological periods, pest control, and determination of cultivar preferences were carried out by researchers on this pest (Pollini and Bariselli, 1996; Montuschi et al., 2004; Tsagarakis and Mitsopoulus, 2007; Doğanlar et al., 2014; Gagne). , 20014; 2017). It was determined for the first time in Turkey that this pest damages apricots in Malatya (Kale district) and Mersin (Mut district) provinces (Doğanlar et al., 2014). It was firstly identified morphologically by molecular characterization using the COI gene sequence (Kaplan and İnal, 2021). The adults of the pest lay eggs on the flower buds of the tree, the hatched larvae feed on the bud wall, and the flower genitalia. The damaged flower does not turn into fruit.

Apricot is an important source of economic income for Malatya and its districts. Half of the 16 million apricot trees in Turkey are located in Malatya (Anonymous, 2020). This number is increasing every year. Turkey which produces 60% of the world's dried apricot is also the dominant country in apricot export (INC, 2019). Approximately 85% of dried apricot production in Turkey is produced in Malatya (Gündüz et al., 2021). In addition to many pest species threatening this source of income, species such as Apricot flower midge have recently emerged. It is not known whether the pest has been present in these areas before. It is also unknown whether the pest came from other regions to adapt to the ecology of this region or whether this pest is among the species found in the natural fauna of the region. Especially due to climatic reasons, the pest population has increased for a few years and it has caused serious damage, especially in the apricot fields of Malatya province and the necessity of pest control has emerged. The population density of the pest has changed due to the sudden temperature changes occurring in some biological ecological stages of the insect and the irregular climate over the years. The damage is very intense for some years, while some years are rarely seen. The fluctuation in the population worries producers and thus leads to unconscious pest control. Therefore, the study was carried out in order to determine some biological stages that can be the basis for pest control and to help control the pest correctly.

MATERIAL AND METHOD

The studies were carried out in 2017 and 2018 in an orchard with at least 20 Hacıhaliloğlu varieties (without pesticide application) between the ages of 12-15, in Kale district of Malatya, where the insect population is dense. It was carried out in the apricot orchard of the 15-year-old Hacıhaliloğlu variety in the Yeşilyurt Apricot Research Institute Central Campus in Malatya, Turkey, in 2018. In these orchards, a large number of mature larvae collected from the land in 2017 were placed on a certain area (2 m²) and 25x40 cm square prism above ground cages were established and observations and counts were made for a year. The time of adult emergence from the pupa, time to be seen in nature, time of egg-laying, time of larvae to exit from the bud, and the population growth under natural conditions were determined with survey studies, field observations, and taking the pest into culture cages. These studies were carried out under field conditions.

The determined biological stage data were compared with the meteorological data obtained from the climate station of the Meteorology Regional Directorate in Kale district and Yeşilyurt Campus of Apricot Research Institute. The results were analyzed and the relationship between climate data and biological stages was revealed.

Determining some biological terms

- Determination of adult emergence time from pupa; 25x40 cm square prism above-ground cages were placed on the soil surface at the crown level of apricot trees in January. The cages were checked daily in February, the counts were made and notes were taken. Four cages were used in the studies in the Kale district and eight cages were used in the Yeşilyurt district. In addition, soil temperatures (5 cm depth) were measured with Ituin KCB 300 Soil Survey Instrument between 1-2 pm which is the time when the soil temperature during the day may be high. The relationship between soil temperature and emerging time from pupa was revealed.

- Determination of time for the adult to be seen in nature; daily field observations were made and the trees were examined by eye to see when the insect began to appear in nature and how long it lasted in February-March.

- Determination of oviposition time; starting from the time before the insect was seen in nature, 200 apricot

flower buds were taken from the trees daily. The samples were brought to the laboratory and kept in 15x25 cm jars with water until the flowering term. In the laboratory, at room temperature (24 °C), at a relative humidity of 55-60%, the buds have been waited until the flowers were fully opened (10 days), then the flowers that did not bloom were checked and egg-laying dates were determined.

- Determination of the larval output from the apricot flower bud; the study was carried out on 3 apricot trees aged 12-15 years. Four 30x40 cm cylindrical chiffon branch cages were placed in 4 directions of the tree. The cages were checked daily. The larval exit time and duration were determined.

Population growth and number of offspring in natural conditions

Since there is no trap method for pests, mature larvae were collected from the soil in March 2017 in the garden where bioecological studies were carried out in Kale district and in the garden where bioecology studies were carried out in Yeşilyurt district of Malatya province in Turkey. 25x40 cm cages were placed and observed for 1 year. Adult insect emergences were recorded. The relationship between the adult emergence stage and the climate and phenological stages of the plant has been revealed.

RESULTS and DISCUSSION

Bioecology studies

The dates of some biological periods of *C. pruniflorum* are given in Table 1 and the dates of apricot phenology are given in Table 2. The number of adults obtained from cages by comparing pest biological stages with meteorological data is given in Figure 1-2-3.

When examined Table 1 and Table 2, it is seen that when the pest emerges from the pupa in nature, apricot is the beginning of the bud swelling period as a phenological period. It was determined that the time to complete the feeding of the insect and fall into the soil as a mature larva lasted from the middle of flowering (50%) to the end of flowering. The average flowering period of the plant is 11-12 days.

Table 1. Some biological stage and dates of Contarinia pruniflorum
Çizelge 1. *Contarinia pruniflorum*'un bazı biyolojik dönemleri ve tarihleri

Locations Lokasyonlar	Time the adult beetle leaves the pupa Ergin böceğin pupadan çıkış zamanı	Time for adult beetle to be seen in nature Ergin böceğin doğada görülme zamanı	Beginning of oviposition Yumurta bırakma başlangıcı	Larvae exit from the bud Larvanın tomurcuktan çıkışı
Kale (2017)	19.02.2017- 22.02.2017	22.02.2017	24.02.2017	22.03.2017-01.04.2017
Kale (2018)	07.02.2018- 12.02.2018	08.02.2018	09.02.2018	08.03.2018- 19.03.2018
Yeşilyurt (2018)	16.02.2018- 22.02.2018	18.02.2018	19.02.2018	15.03.2018-24.03.2018

Table 2. Some phenological periods and dates of apricot
Çizelge 2. Kayısının bazı fenolojik dönemleri ve tarihleri

Locations Lokasyonlar	Beginning of bud swell period Tomurcuk kabarma zamanı başlangıcı	Beginning of flowering (5-10%) Çiçeklenme başlangıcı(%5-10)	Mid-blooming (50%) Çiçeklenme ortası(%50)	Full blooming (90-100%) Tam çiçeklenme(%90-100)	End of Flowering Çiçeklenme sonu
Kale (2017)	20.02.2017	20.03.2017	22.03.2017	24.03.2017	31.03.2017
Kale (2018)	07.02.2018	05.03.2018	08.03.2018	10.03.2018	17.03.2018
Yeşilyurt(2018)	17.02.2018	12.03.2018	15.03.2018	18.03.2018	23.03.2018

When Table 1 and Figure 1 are examined, the first exit from the pupa started on February 19 when the soil temperature was 13 °C and it continued for 4 days and ended the emergence from the pupa. The highest air temperatures during the emergence period of the adult were 8.5-14.6 °C, average daily temperatures were 1.8-6.5 °C and the lowest daily temperature was -3.2 to 1.1 °C. When figure 1 is examined, it is seen that daily maximum and soil temperatures move in parallel. The adult insects lay eggs on the buds on February 24. On March 22, 26 days after the first egg-laying, the larva left the bud and began to fall into the soil. The fall of the larva into the soil lasted for 10 days until the flower petals were completely shed and ended on April 1st. Daily maximum temperatures were between 10-21.2 °C, average daily temperatures were between 7.4-15.2 °C and the lowest daily temperatures were between 2.3-9.7 °C.

When Table 1 and Figure 2 are examined, it was seen that the first emergence from the pupa started on February 7, when soil temperature was 14 °C and

continued for 6 days. During the adult emergence period, the maximum daily air temperatures were 8.3-15.8 °C, average daily temperatures were 4.8-11.3 °C and the lowest daily temperature was between 2.2 and 7.3 °C. When figure 2 is examined, it is seen that daily maximum and soil temperatures move in parallel. The adult insects lay eggs on the buds on February 8. On March 8, 28 days after the first egg-laying, it was observed that the larvae left the buds and began to fall into the soil. The fall of the larva to

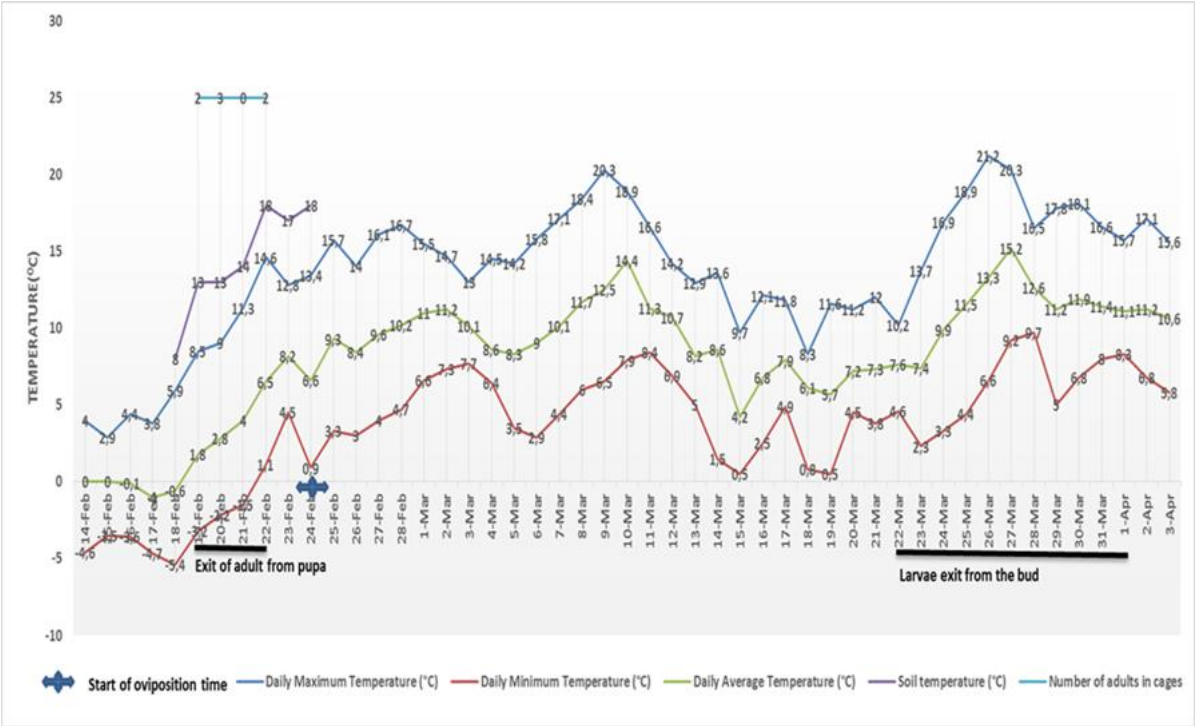

Figure 1. Relationship between some biological periods of Contarinia pruniflorum and climate data (Kale-2017)
Şekil 1. *Contarinia pruniflorum*'un bazı biyolojik dönemleri ve iklim verileri arasındaki ilişki (Kale-2017)

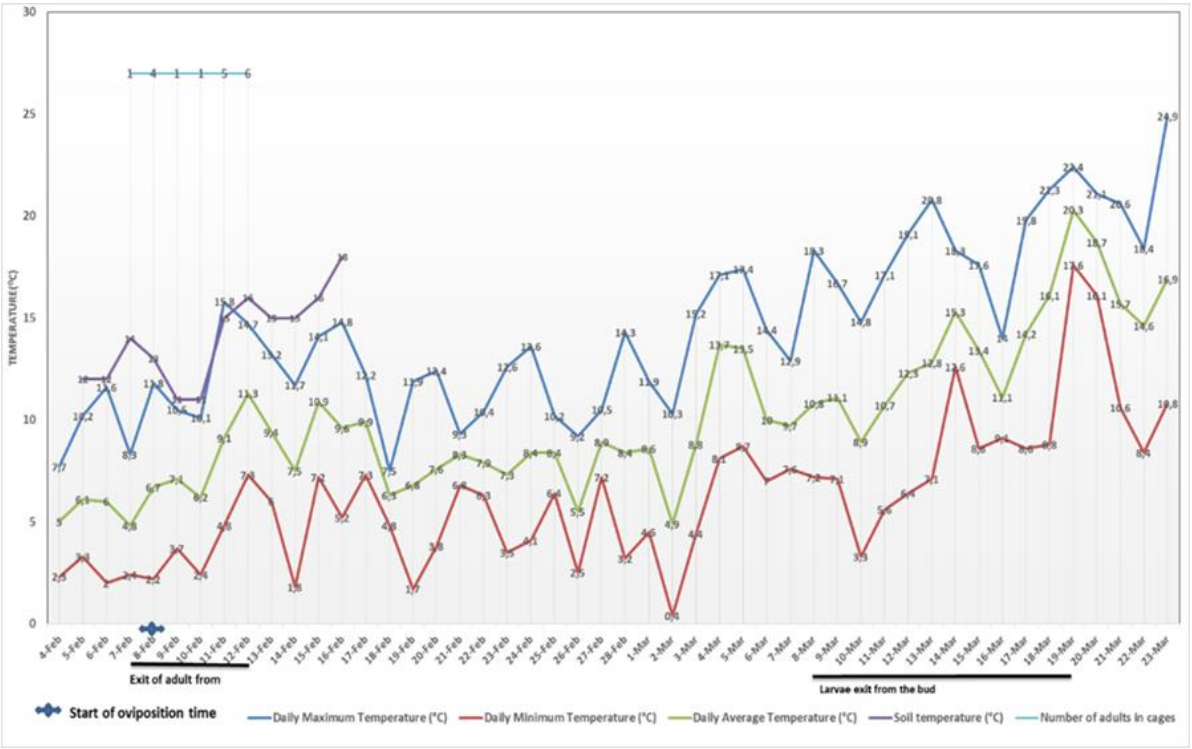

Figure 2. Relationship between some biological periods of Contarinia pruniflorum and climate data (Kale-2018)
Şekil 2. *Contarinia pruniflorum*'un bazı biyolojik dönemleri ve iklim verileri arasındaki ilişki (Kale-2018)

the soil ended on March 19 and continued for 11 days until the flower petals were completely shed. In the larval fall period, the highest daily temperatures were between 14-22.4 °C, the average daily temperatures were between 8.9-20.3 °C and the lowest daily temperatures were between 3.3-17.6 °C.

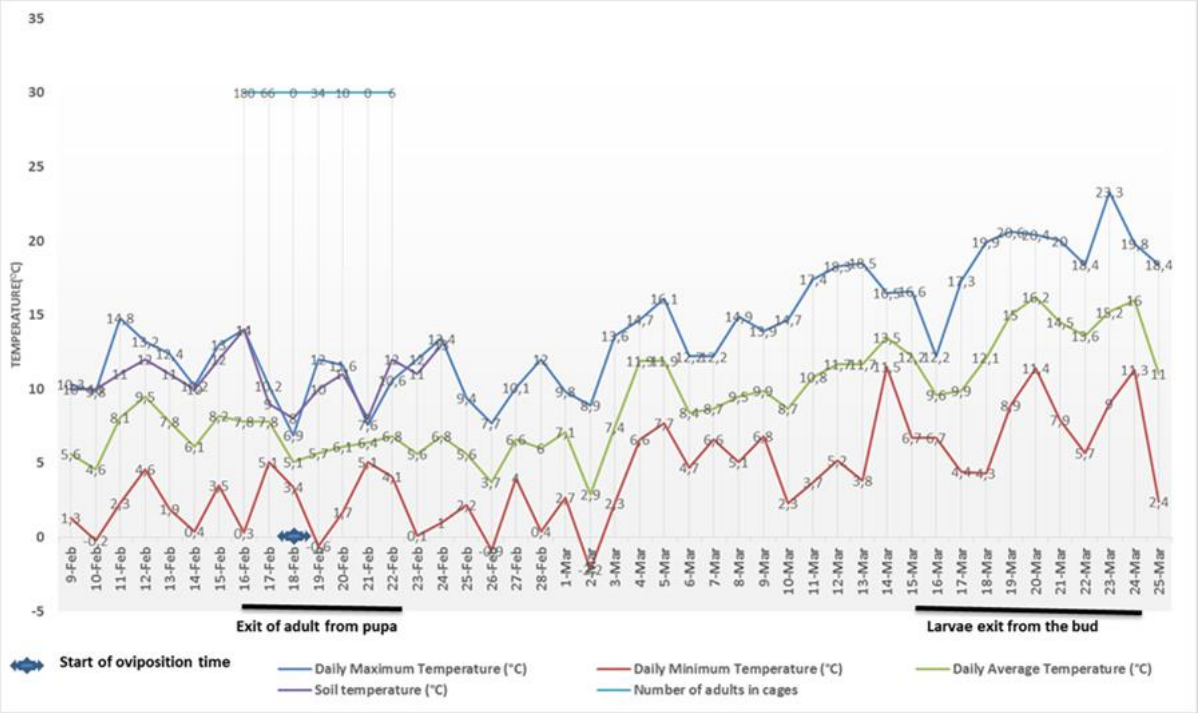

Figure 3. Relationship between some biological periods of Contarinia pruniflorum and climate data (Yeşilyurt-2018)

Şekil 3. *Contarinia pruniflorum*'un bazı biyolojik dönemleri ve iklim verileri arasındaki ilişki (Yeşilyurt-2018)

When Table 1 and Figure 3 are examined, it was seen that the first emergence from the pupa started on February 16, when soil temperature was 14 °C and continued for 7 days. However, on February 18 and February 21, when the soil temperature fell below the norms, no adults were found in the cages. The highest air temperatures during the emergence of the adult period were 6.9-14 °C, average daily temperatures were 5.1-7.8 °C and the lowest daily temperature was between -0.6 and 5.1 °C. When figure 3 is examined, it is seen that daily maximum and soil temperatures move in parallel. The adult insects lay eggs on the buds on February 18. On March 24, 25 days after the first egg-laying, it was seen that the larva left the buds and began to fall into the soil. The fall of the larva to the soil ended on March 24 and continued for 9 days until the flower petals were completely shed. It was seen that the maximum daily temperatures were 12.2-23.3 °C, the average daily temperatures were 9.6-16.2 °C and the lowest daily temperatures were 4.3-11.4 °C.

When the studies of both years are evaluated;

Adult emergence time from pupa and time of egg laying are the stages where the most effective pest control should be done. This period varies depending on the climatic conditions of the region. It was determined that the adult beetle emerged 12 days earlier in 2018 compared to the previous year in the Kale district. This is because the weather conditions in 2018, especially the February temperatures, were more temperate than in 2017. The same situation was observed in the phenology of the plant. The plant entered the early pink-bud stage and entered the early flowering period. When the climate data of both years are analyzed, it is seen that there is a parallel between air and soil temperatures. Soil temperature increases with increasing air temperatures. The most important factor in the emergence of adult insects from the pupa is the increase in soil temperatures. There is a direct correlation between adult emergence from the pupa and soil and air temperatures. The adult emerges from the pupa when the soil temperature is 13-14 °C and the air temperature is 7-15 °C. It is seen that there is no adult emergence on the days when soil temperature falls below 8 °C after the beginning of adult emergence. The time for the adult insect to occur in nature varies depending on the regions, climate, and phenology of the host plant. It occurs in the first week of February in some places, but in the middle of March in other regions. Pierre

and Chauvin-Buthaud (2001) stated that adult activity started in the apricot orchards in Drome on the first days of February. Gomez et al. (2006) reported that the first emergence of the insect was relatively late (around mid-March). Alford (2007) stated that adults were seen in early February or early March.

The adult emergence from the pupa continued for a maximum of 7 days. Even if the weather conditions were appropriate, it was observed that there was no adult emergence after that time. In other words, the period of adult emergence is very limited and the adverse weather conditions that may occur during this period directly affect the insect density. In particular, adverse events such as sudden temperature drops will cause the population to fall.

The pest was seen in nature and had flight within 1-3 days following the first emergence from the pupa. During this time, the insect mates and prepares to egg-laying into the buds.

It has been determined that the pests start to lay eggs 1-2 days after they appear in nature. The oviposition period of the pest is the beginning of the pink bud period of the plant. During this period, the females lay eggs between the sepals of the unopened flower. It was observed that more than one insect lay eggs in one bud. Alford (2007) stated that the adults deposit eggs in the outermost petals of the unopened flower buds and then the eggs were opened after a few days. Kyttariolou and Tsagarakis (2013) stated that adults lay eggs in the sepals of closed flower buds and that hatching larvae damage the flower organs. In addition to the air temperature, rainfall and the severity of the wind also affect egg-laying. Rainy and extremely windy weather reduces egg-laying activity. It was observed that adverse weather conditions during this period caused a decrease in the population. Another factor affecting egg-laying is the phenology of the plant. The oviposition time of the pest and the plant phenology must be in harmony with each other. Low air temperatures at the time of emergence from the pupa cause a decrease in the insect population and consequently a decrease in the number of damaged flowers. In addition, air temperatures above seasonal norms after the insect was seen in nature cause an acceleration in plant phenology. As a result, the harmony between the oviposition time and the phenology is impaired and the egg-laying period is shortened. As the flowering process accelerates, the eggs will die before the hatching or the newly emerged larvae do not cause damage to the bud. In 2018, with the sudden increase in air temperatures in February, the insect population increased and plant phenology accelerated. Therefore, although the insect population is high, it is not reflected in the damage rate of flowers.

It was determined that 25-28 days after the adult beetle was seen in nature, the first larvae completed their larval development and started to fall into the soil as mature larvae. Under laboratory conditions (24 °C and 55-60% relative humidity), the time between adult egg-laying and mature larvae emerging from the bud was determined for 9-10 days. Pierre and Chauvin-Buthaud (2001) reported that larval development lasted about 3 weeks. It is normal for this period to vary for several days depending on the weather temperatures. The larvae completed their development and continued to fall into the soil for 9-11 days. This period, starting from a 50% flowering period of the plant as the phenological period, continued until the period when all the flower petals were shed. After the mature larva falls into the soil, it goes to a suitable depth (2-3 cm). It was observed that it waited there for a while as a mature larva and became a pupa in summer. The insect overwinters as a pupa in the soil. Towards the end of winter, as the weather warmed in February, adults began mating and laying eggs.

Population growth and number of offspring in natural conditions

It was found that the insect gave offspring once a year. Pollini & Bariselli (1996) noted that *C. pruniflorum* gave one offspring in a year and overwintered at the pupa stage in the soil in Bologna Imola, Italy. Alford (2007) stated that the larvae fed in flower buds for about 3 weeks, then the larvae fell into the soil for being pupa. And the pest gives one generation a year, but some adults have emerged after the second winter. Tommasini (2006) stated that the pest was seen in Italy in 1996 in Emilia Romagna during the pink bud period in early March and that females laid their eggs into the flower with their ovipositor. The study showed that the larvae hatched out of the flower after 3 weeks and left themselves in the soil to become a pupa. Pierre and Chauvin-Buthaud (2001) indicated that mature larvae usually leave their hosts at the beginning of flowering and become pupae by burying themselves in the soil at a suitable depth. They also showed that a small percentage would wait until the next winter to become adults. Kyttariolou and Tsagarakis (2013) stated that the pest pupates in the soil and stays there until the next spring and gives offspring once a year when they become adults. In the same study, it was seen that some of the pests completed their life cycle in two years and that this was a biological safety measure for the survival of the species so that a population was transferred to the next year when unfavorable climatic conditions occurred.

In this study, of the 204 adult individuals identified, 188 were female and 16 were male. Based on this data, the ratio of male individuals to female

individuals was 0.0784. 7.84% of the individuals were male and 92.15% were female.

In the examination conducted on 1000 apricot flower buds, the number of buds infected with pests was 97 in 2017 and 42 in 2018. In 2017, the average number of larvae in each bud was 14 while in 2018 it was 13. The average number of larvae in the buds was 14 and the maximum number of larvae in a bud was 26. Kaplan (2014) stated that they leave 20-30 eggs in the flower buds of the pest species.

With this study, some bioecological features of the pest were revealed. It is important to determine the effects of changes in the climate on the insect by doing more studies on the pest.

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Statement of Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Author's Contributions

The contribution of the authors is equal.

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