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Original article (Orijinal araştırma)

Life table parameters and susceptibility levels of *Hercinothrips femoralis* (Reuter, 1891) (Thysanoptera: Thripidae) to spinosad and abamectin

Hercinothrips femoralis (Reuter, 1891) (Thysanoptera: Thripidae)'in yaşam tablosu parametreleri ile spinosad ve abamectine duyarlılık düzeyleri

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Abstract

The banded greenhouse thrips, *Hercinothrips femoralis* (Reuter, 1891) (Thysanoptera: Thripidae), is a tropical-origin species that has been identified on fruits, vegetables, ornamental and industrial crops in certain regions, such as Africa, the Americas, Europe, Oceania, and Asia. This study aimed to provide essential data on the biology and management of *H. femoralis*. The research was conducted in 2024 at Plant Protection Department Laboratory of Akdeniz University. The *H. femoralis* population was maintained as a stock culture on green bean pods. Experiments were conducted at 25±1ºC, with 65±10% relative humidity and a 16:8 h photoperiod. Results indicated a total development time from egg to adult was 20.82 days. Development time of the egg, first instar, second instar, prepupa, and pupa stages were 9.0, 2.85, 4.0, 1.41, and 3.56 days, respectively. The total adult longevity was 74.88 days, and the mean fecundity was 132.62 offspring per female. In feeding tests, adults caused characteristic damage on bean, pepper, cucumber, and banana fruits. respectively. Life table parameters indicated that *H. femoralis* can reproduce easily under suitable climates and hosts, causing significant economic losses. In laboratory bioassay the recommended doses of spinosad and abamectin caused 100% and 94% mortality in *H. femoralis*, respectively. The high efficacy of spinosad and abamectin against *H. femoralis* demonstrated in this study could be considered in the development of chemical control strategies.

Keywords: Banded greenhouse thrips, *Hercinothrips femoralis,* insecticide efficacy, life table

Öz

Bantlı sera tripsi, *Hercinothrips femoralis* (Reuter, 1891) (Thysanoptera: Thripidae), Afrika, Amerika, Avrupa, Okyanusya ve Asya gibi belirli bölgelerde meyve, sebze, süs ve endüstri bitkilerinde tespit edilmiş tropikal kökenli bir türdür. Bu çalışmada, *H. femoralis*'in biyolojisi ve mücadelesine ilişkin temel verilerin elde edilmesi amaçlanmıştır. Araştırma, 2024 yılında Akdeniz Üniversitesi Bitki Koruma Bölümü Laboratuvarı'nda gerçekleştirilmiştir. *Hercinothrips femoralis* popülasyonu stok kültür olarak yeşil fasulye meyveleri üzerinde yetiştirilmiştir. Deneyler, sıcaklığın 25±1ºC, bağıl nemin %65±10 ve fotoperiyotun 16:8 saat olduğu koşullarda gerçekleştirilmiştir. Sonuçlara göre yumurtadan ergine toplam gelişme süresi 20,82 gün, yumurta, birinci larva evresi, ikinci larva evresi, prepupa ve pupa evrelerinin gelişim süreleri sırasıyla 9.0, 2.85, 4.0, 1.41 ve 3.56 gündür. Toplam ergin ömrü 74,88 gün ve yumurta verimi dişi başına ortalama 132,62 adet olarak bulunmuştur. Beslenme denemelerinde ergin bireylerin fasulye, biber, salatalık ve muz meyvelerinde karakteristik zarar oluşturduğu gözlenmiştir. Yaşam tablosu parametreleri, *H. femoralis*'in uygun iklim koşullarında ve uygun konukçularda kolaylıkla üreyebildiğini ve önemli ekonomik kayıplara yol açabileceğini ortaya koymuştur. Laboratuvar testlerinde spinosad ve abamectin'in tavsiye dozlarının, *H. femoralis*'te sırasıyla %100 ve %94 oranında ölüme neden olduğu tespit edilmiştir. Bu çalışmada tespit edilen spinosad ve abamectin'in *H. femoralis*'e karşı gösterdiği yüksek etkinlik, kimyasal mücadele stratejilerinin geliştirilmesinde dikkate alınabilir.

Anahtar sözcükler: Bantlı sera tripsi, *Hercinothrips femoralis,* insektisit etkinliği, yaşam çizelgesi

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Introduction

Thrips (Thysanoptera) are polyphagous pests that infest a wide range of host plants globally (Mound et al., 2022). To date, approximately 6300 thrips species have been recognized (Thripswiki, 2026), and they are considered members of the Thysanoptera suborders Terebrantia and Tubulifera (Mound et al., 2022). The major pest species belong to the family Thripidae (Mound et al., 2022). The genus *Hercinothrips,* belonging to the Thripidae family, contains 11 species (Goldaracena & Vierbergen, 2022).

The banded greenhouse thrips, *Hercinothrips femoralis* (Reuter, 1891) (Thysanoptera: Thripidae), which originated from the African continent or the tropics, has been reported to have become a pantropic cosmopolitan species and a resident greenhouse pest in temperate regions (Mound et al., 1976; Varga, 2008). This pest thrips, which was first recorded in Europe, was found in Hungary after the first half of the 20th century (Jenser, 1979; Jenser & Czencz, 1988; Varga, 2008). This species is widespread in Australia, Africa, North and Central America, and Europe as well as in Japan, New Zealand, South Korea (Houston et al., 1991, Lee & Lee, 2016), China (Wang et al., 2022), and Canada (Jandricic et al., 2024). A polyphagous pest *H. femoralis* hosts include fruits such as fig, banana, and pineapple, industrial plants, vegetables such as sugar beet, peanut, cotton, corn, sugarcane, sweet potato, beans, and cabbage, and various ornamental plants (Houston et al., 1991; Trdan, 2002; Roditakis et al., 2006; Šimala & Masten Milek, 2008; Varga, 2008; Lee & Lee, 2016; Wang et al., 2022).

Although the first record of *H. femoralis* in Türkiye was made by Alkan (1962) in 1962, there is no detailed additional information regarding the first record of the species or its status since the first record (Tunç & Hastenpflug-Vesmanis, 2016). However, it was reported that this species was encountered in banana fruits in survey studies conducted within the scope of a project in greenhouse fruit areas in Antalya (Türkiye) Province in 2023 (Topakcı, 2023). The literature indicates that this thrips has become a polyphagous greenhouse pest in transition zones worldwide in recent years and can sometimes cause significant economic losses (Roditakis et al., 2006; Varga, 2008). The widespread cultivation of vegetables, ornamental plants, bananas, and some tropical products in greenhouses in Antalya Province and nearby locations on the Mediterranean coast of Türkiye may provide a suitable environment for *H. femoralis* because of the climate and host range. Therefore, the species is likely to spread to more expansive areas and occasionally increase in population density. At this point, it is necessary to raise awareness about *H. femoralis* and collect some basic data about this species when it is encountered in new studies. A few studies in the literature present only some biological data on the immature stages of the species (Laughlin, 1971; Koch, 1981). However, no studies have investigated the adult lifespan and fecundity. In this study, we attempted to understand the extent to which the species could reproduce at 25ºC. In addition, we anticipated that in the future, situations requiring urgent prevention measures against this pest might be encountered. Consequently, we sought to understand the extent to which the active substances spinosad and abamectin, which are considered well known and continue to be used against many pests, would be effective against this species.

Within the scope of the study, the life table parameters of *H. femoralis* were determined. In addition, the susceptibility of *H. femoralis* to spinosad and abamectin was analysed.

Materials and Methods

Materials

Thrips populations

The *H. femoralis* population used in the study was obtained from thrips collected from banana fruits in a project conducted by Topakcı (2023) in greenhouse fruit plantations in Aksu district of Antalya Province, Türkiye, and identified by the third author. This population was maintained on green bean pods without pesticide application in a climate chamber set at 25±1ºC, with a photoperiod of 16:8 hours (light: dark) and a relative humidity (RH) of 65±10%, at the Plant Protection Department, Akdeniz University Faculty of Agriculture, Türkiye, after being obtained from the banana greenhouse.

Insecticides

In this study, insecticides containing the active ingredients spinosad and abamectin were tested. Detailed information related to spinosad and abamectin is provided in Table 1.

Table 1. Detailed information on spinosad and abamectin

Active substance	Commercial-name formulation	Mode of action[a]
Spinosad	Laser, SC 480, Corteva agriscience	Nervous system: Nicotinic acetylcholine receptor allosteric modulators (IRAC Group 5)
Abamectin	Agrimec, EC, Syngenta	Nervous and muscle system: Glutamate-gated chloride channel allosteric modulators (IRAC Group 6)

[a](IRAC 2025).

Methods

Identification of *Hercinothrips femoralis*

Microscopic slides for the collected samples were prepared and identified (Mound & Kibby, 1998). For this purpose, the samples were placed in AGA medium, containing 9 units of (60%) ethyl alcohol, 1 unit glacial acetic acid, and 1 unit glycerine, to partially soften and clean the body. The specimens were left in a dark environment at 25±1ºC under 60±5% humidity for 2 days. They were then placed in glass cells containing 5% NaOH and hold a hot plate at 45ºC for about half an hour. The body contents were drained by inserting a very fine needle through the base of the third pair of legs in a glass Petri dish containing 96% ethyl alcohol. This process was repeated in a medium containing 70% ethyl alcohol. In both medium, the bodies of the sample individuals were gently pressed from the ventral and dorsal sides to expel the body contents. The samples were mounted in Hoyer's medium. The slide-mounted specimens were left in an oven at 45ºC for 7 days to dry. Photographs of the specimens were acquired with a Leica DM300 (Leica Microsystems Germany) light microscope at 10X magnification.

Thrips rearing

The rearing of *H. femoralis* was conducted according to the same methods used for *F. occidentalis* in previous investigations (Steiner & Goodwin, 1998; Murai & Loomans, 2001; Espinosa et al., 2002; Kamış & Dağlı, 2022). The populations were maintained in a climate chamber at 25±1ºC with a 16:8 h light:dark photoperiod and 65±10 RH. Green bean pods purchased from markets were washed thoroughly with tap water and dried for approximately 1 hour. The beans were placed in 2 L plastic containers with two to three sheets of paper towels on the bottom, and the lids were covered with filter paper for ventilation. Adult thrips were collected using a simple mouth aspirator and immobilized with carbon dioxide for a brief period. They were then immediately poured into boxes containing bean pods, and the lids were closed. To obtain adults of the same age, the adults were allowed to oviposit on the bean pods for approximately 1 day. The bean pods, with the eggs taken from the box, were then placed in an empty plastic box. In the rearing of *H. femoralis*, the first-stage larvae hatched from the bean pods, in which eggs were laid after 9-10 days. Notably, bean pods with eggs were not thrown away even if they lost their freshness until the first larvae hatched; they were stored until the larvae hatched and moved to the new bean pods placed next to the existing bean fruit. After the larvae hatched, new bean pods were added to the old pods every 4-5 days. Thrips individuals completed their pupa stage in the paper towel layers at the bottom of the same box and became adults approximately 10 days later. Using this rearing method, the total time from egg to adult emergence for *H. femoralis* was approximately 20 days or more. *Hercinothrips femoralis* could be reared easily in high numbers with bean pods.

Observation of the feeding activities of *Hercinothrips femoralis* adults on certain crops

The potential of *H. femoralis* adults to feed and lay eggs on beans, peppers, cucumbers, and bananas was monitored under laboratory conditions. For this purpose, the products in question were purchased from the market and examined in the laboratory to check that they were not contaminated with any pests. Each product was placed in a separate plastic container, and at least 100 *H. femoralis* adults were left in each box. The fruits were kept until new generation larvae emerged (approximately 10-12 days), and more than 50 larvae were observed in each fruit. At the end of this experiment, images of characteristic feeding symptoms were saved for each crop.

Determination of life table parameters

Immature stage

To determine the development times of the egg, larva, and pupa stages of *H. femoralis*, 3-cm-diameter bean leaf discs placed in Petri dishes containing agar were used. Approximately 30 females were left on the leaf disc and allowed to lay eggs for 24 hours. The discs were covered with stretch film, which was perforated with an insect pin to allow airflow. After 24 hours, the adults were removed from the disks, and egg hatching was recorded daily. Egg duration was determined by monitoring the hatching of 200 eggs. Since the eggs were laid in the plant tissue, the viability of the eggs was ignored. The duration of the egg stage was accounted for as the time from when the adults laid eggs until the first larvae emerged (Atakan & Özgür, 2000). After the eggs had hatched, each newly hatched larva was transferred individually into a separate leaf disc using a fine hair brush, and each leaf disc was considered one replicate. A total of 21 replicates were used in this experiment. The discs were covered with stretch film, the film was perforated, and daily monitoring was performed until the adult stage was reached. The development times of the larva, prepupal, and pupal stages were determined. The life table study was carried out in a growth chamber at 25±1ºC with a 16:8 h light:dark photoperiod and 65±10% RH.

Adult longevity and fecundity

The adults that emerged were removed and then placed on separate leaf discs as described above. Each female was transferred to a new fresh leaf disc daily and monitored until death. The day of death was not included in the lifespan. During the transfer of adult individuals to the new disk, no brush was used to prevent any risk of escape or crushing. Instead, the Petri dish containing the female individual was turned upside down onto the Petri dish to be transferred and closed without leaving any openings. By gently tapping the upper Petri dish, each individual was transferred to the new disc, and quickly stretched. After 24 h, the female was taken from the leaf disc with a mouth aspirator; these were maintained in the climate chamber and monitored until egg hatching. Thus, the life cycle of each female, the number of eggs laid daily, and the total eggs laid were determined. All experiments were conducted in 2024 at Plant Protection Department Laboratory of Akdeniz University.

Insecticide test method (Bioassay)

The effect of serial doses of spinosad and abamectin in population of *H. femoralis* in laboratory bioassays**.** For this purpose, we used a leaf dipping bioassay, which has been routinely applied in previous resistance screenings (Zhang et al., 2008; Dağlı, 2018; Kamış & Dağlı, 2022). The dose series used to obtain a proportional mortality distribution in the populations and create the dose-response dataset ranged from 0.0096 to 96 mg ai/L for spinosad. For abamectin, the range was 0.0045 to 45 mg ai/L. Controls were treated with distilled water only. Discs (3 cm in diameter) were obtained from the leaves of bean plants grown from seeds without pesticides and kept on a moist paper towel. The discs were immersed in the control and dose series for 5 s, after which they were allowed to stand for 1 h to allow the moisture on their surface to dry. The leaf discs with the abaxial side up were placed in Petri dishes with agar at the bottom to preserve their freshness. Female insects obtained from the thrips culture box with an aspirator were

anaesthetized with carbon dioxide for approximately 20 seconds, and these thrips were then placed on leaf discs in Petri dishes These test cells were sealed with stretch film, and 20-30 holes were created using a fine-tipped needle to allow air in. In these bioassays, 3-4 replications were used for each dose, with as many thrips adults as possible (n=17-99 adult females of mixed ages) in each replication. All tested thrips were maintained under the same conditions described above. After two days, thrips survival was checked under a microscope. Thrips that did not move when touched with a brush were considered dead.

Statistical analysis

The life table parameters of *H. femoralis* were analysed using the computer program TWOSEX-MS Chart (Chi & Liu, 1985; Chi, 1988, 2025; Chi et al., 2020). The age-stage-specific fecundity (f_{xj}), age-stage-specific survival rate (S_{xj}), age-specific fecundity (m_x), and age-specific survival rate (l_x) were calculated on the basis of daily survival data. The net reproduction rate (R_0), finite rate of increase (λ), intrinsic rate of increase (r), mean generation time (T), and gross reproductive rate (GRR) were also calculated. The standard errors of the population parameters were calculated using a 100,000-fold replicated sample with the bootstrap technique in the TWOSEX-MS Chart program (Efron & Tibshirani, 1993; Huang & Chi, 2013). The following equations and parameters were used for the life table analysis (Wei et al., 2020; Chi et al., 2022).

$$l_x = \sum_{j=1}^{\beta} S_{xj} \qquad R_0 = \sum_{x=0}^{\infty} l_x m_x$$

$$m_x = \left. \sum_{j=1}^{\beta} S_{xj} f_{xj} \right/ \sum_{j=1}^{\beta} S_{xj} \qquad \sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

$$\lambda = e^r$$

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{\beta} s'_{iy} \qquad T = (lnR_0) / r$$

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{\beta} s'_{iy} f_{iy}$$

$$S_{xj} = \frac{n_{xj}}{n_{0,1}} \qquad f_{xj} = \frac{f_{x,total}}{n_{xj}}$$

In insecticide bioassays, mortality rates obtained for each dose were corrected according to Abbott formula (Abbott, 1925) and then corrected mortality rate averages were determined.

Results

Description of *Hercinothrips femoralis*

Adult females of this species are approximately 1 mm in size. The body is brown, with a pair of longitudinal yellowish areas on the head (Figure 1a). The head, pronotum, and bases of the forelegs have dense polygonal transverse striations on their surfaces. The surfaces of the forewings and hindwings are densely covered with microtrichia. The 3rd and 4th antennal segments are yellowish. The forewings are banded. The forewings are pale at the apex, yellowish at the sub-basal and base parts, and pale in other parts. There are no long setae at the corners of the pronotum. The tarsi are 2-segmented, with the fore tarsi appearing pale or yellowish and sometimes brownish at the apex. *Hercinothrips femoralis* is easily differentiated from the Panchaeothripinae species on the basis of its 2-segmented tarsi and complete longitudinal row of setae on the forewings. Males are rarely observed. The first-stage larvae that hatched from the eggs are transparent (Figure 1b), later turning yellow. The second-stage larvae are also yellowish and have 7-segmented antennae (Figure 1c). The major setae on their bodies are short and pointed. The pupa is yellowish (Figure 1d). During the pupal stage, wing buds are formed, and the antennae are positioned backwards (Figure 1d).

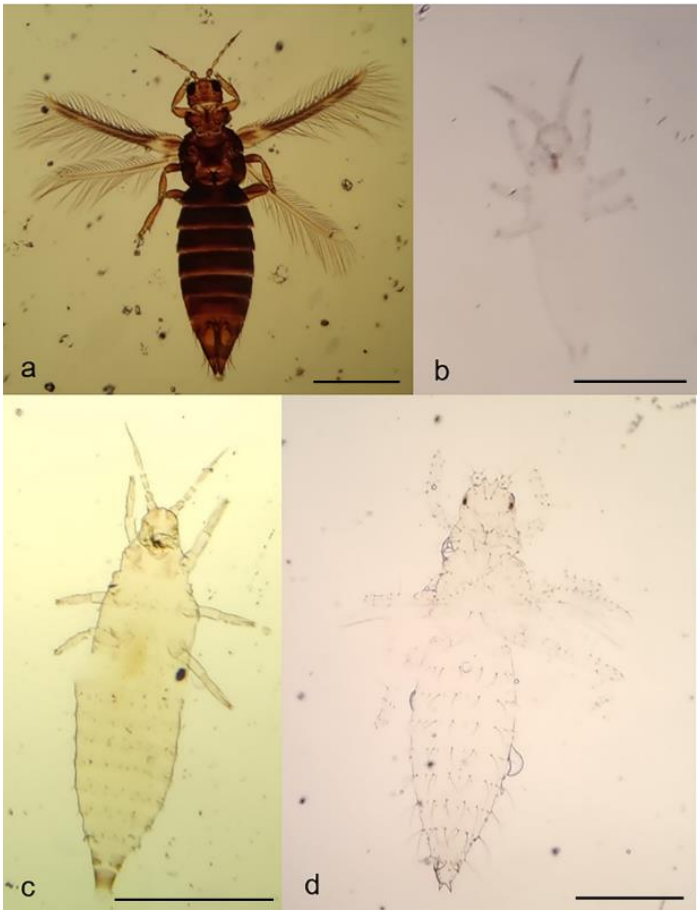

Figure 1. Views of slide-mounted *Hercinothrips femoralis*: a) female, b) first-instar larvae, c) second-instar larvae and d) pupae. Scale bars show 0.3 mm.

Descriptive photographs of the egg, larva, pupa, and adult stages of *H. femoralis* are also shown (Figure 2a-f). Since the eggs are located inside the tissue, they are not visible from the outside. However, the presence of eggs in the tissue can be determined based on the swelling of the tissues containing the eggs two or three days before hatching. The eggs are kidney shaped, and the red eye becomes apparent in the embryo close to hatching (Figure 2a, ~0.5 mm in size). The larva that hatches from the egg is initially opaque and white (Figure 2b, ~0.65 mm in size) and then turns yellow. The first-stage larva reaches the second stage after exuviation. In the second stage, the larva swells and becomes dark brown as it feeds (Figure 2c, ~0.75 mm in size). It is typical for droplets to appear at the end of the abdomen during this stage When the droplet is left on the leaf, it creates dark dots. When the larva is touched with a thin brush under a microscope, the droplets move away from the body and spread to the leaf. As the larvae prepare to become prepupae, they tend to seek out hidden places and are quite active. The second-instar larva develop after exuviation and enter the prepupal period. During this period, the wing buds of the individual begin to appear, and the antennae are directed forward and shortened. The prepupal stage is followed by the pupal stage after one more exuviation. The exuviums of the 2nd larva and prepupa can be seen where the pupa was hidden. The prepupal and pupal periods are generally periods of inactivity. During the pupal period, the antennae are directed backwards (Figure 2d, ~1.1 mm in size). The adult stage is initially light brown, and the antennae return to their original form and are directed forward (Figure 2e). After one day, the colouration is complete, and the colour becomes darker (Figure 2f, ~1.1 mm in size).

Figure 2. Natural views of *Hercinothrips femoralis*: a) egg, b) first-instar larva, c) second-instar larva, d) pupa and e, f) adult female. Scale bars show 0.3 mm.

Feeding activities of *Hercinothrips femoralis* adults on certain crops

Since the *H. femoralis* culture used during the study was continued with bean fruits, it was expected that this species could feed on bean fruits. It was observed that this population, which continued to produce beans, could readily and voraciously feed on peppers, cucumbers, and bananas, cause damage, lay eggs, and these eggs then hatched. On these host plants, thrips are able to successfully reproduce (reproductive hosts). The characteristic symptoms resulting from the feeding are shown in Figure 3a-d. Notably, the observed populations consisted exclusively of females, with no male individuals detected.

Figure 3. *Hercinothrips femoralis* damage on a) bean, b) bell pepper, c) cucumber and d) banana fruits.

Life table studies on *Hercinothrips femoralis*

In this study, the life table parameters of *H. femoralis* were determined on bean leaf discs at 25ºC. The egg, first larval, second larval, prepupal, and pupal stages were 9.0, 2.85, 4.00, 1.41, and 3.56 days, respectively. The longevity of development from egg stage to adult stage was 20.82 days (Table 2).

Table 2. Development time of the preadult stages of *Hercinothrips femoralis* on bean leaf discs at 25ºC (days; mean ±SEM)

Egg	1st instar larvae	2nd instar larvae	Prepupa	Pupa	Total
9.00±0.0 (21)*	2.85±0.13 (20)*	4.00±0.14 (18)*	1.41±0.12 (17)*	3.56±0.13 (16)*	20.82±0.14

*Number of thrips

The adult pre-ovipositional period (APOP) and the total pre-ovipositional period (TPOP) adult longevity and total fecundity of *H. femoralis* are shown in Table 3. While the total preoviposition period was 20 days, the adult preoviposition period was 0 days, and all individuals that reached the adult stage laid eggs on the first day of their life. The total adult longevity of *H. femoralis* was 74.88 days, while the total fecundity was 132.62 offspring.

Table 3. Total preoviposition period, (adult preoviposition period) oviposition, postoviposition period (mean with SEM (±), and total fecundity of female *Hercinothrips femoralis* on the leaf discs of beans at 25ºC

n*	TPOP	APOP	Oviposition days	Adult longevity	Total fecundity
16	20.81±0.14	0.00±0.00	38.94±3.90	74.88±4.15	132.62±13.02

*Number of adult thrips

The age-stage specific survival rate (S_{xj}) of *H. femoralis* on bean leaf discs indicates the probability that a newly hatched larva will remain alive to age x and develop to stage j. The graph also shows the occurrence of death in the preadult period. The first adult (female) was observed on day 22. Adult female deaths started on day 51 (Figure 4a).

Age-specific survival rate (l_x), age-specific fecundity (m_x), and age-specific maternity ($l_x m_x$) curves of *H. femoralis*, which were fed bean leaf discs, are shown in Figure 4b. When the reproductive curves of *H. femoralis* were examined, the first reproduction event occurred on day 20. The age-specific fecundity (m_x) peaked on day 35 (4.625 eggs/female). Age-specific maternity generally exhibited a similar curve as that of age-specific fecundity and decreased with age.

The mean value of the net reproductive rate of *H. femoralis* on bean leaf discs was 101.05 (offspring/individual). The generation time was 35.40 days. The mean intrinsic rate of increase was 0.13, whereas the finite rate of increase was 1.139, on the bean leaf discs at 25ºC (Table 4).

Table 4. Population parameters of *Hercinothrips femoralis* on bean leaf discs at 25ºC

The intrinsic rate of increase, r	Finite rate of increase (λ)	Net reproductive rate, R_0 (offspring/individual)	Generation time (T)
0.130±0.005	1.139±0.005	101.048±15.625	35.401±0.623

The age-stage life expectancy (*exj*) is used to estimate the time an individual of age *x* and stage *j* is expected to live. The life expectancy of *H. femoralis* at age zero (*e01*) was 61.05 d on bean leaf discs. On the basis of the deaths observed during the larval period, the expected lifespan of the adult female was calculated as 54.88 days (Figure 4c).

The age-stage reproductive value (v_{xj}) represents the contribution of an individual from age *x* to stage *j* of *H. femoralis* to the future population. The reproductive value starts at 1.139 (v01), which corresponds exactly to the finite rate of increase. As shown in Figure 4d, the reproductive value increased significantly when reproduction began. This value increased rapidly, reaching 22.65 per day when the females were first observed (Figure 4d).

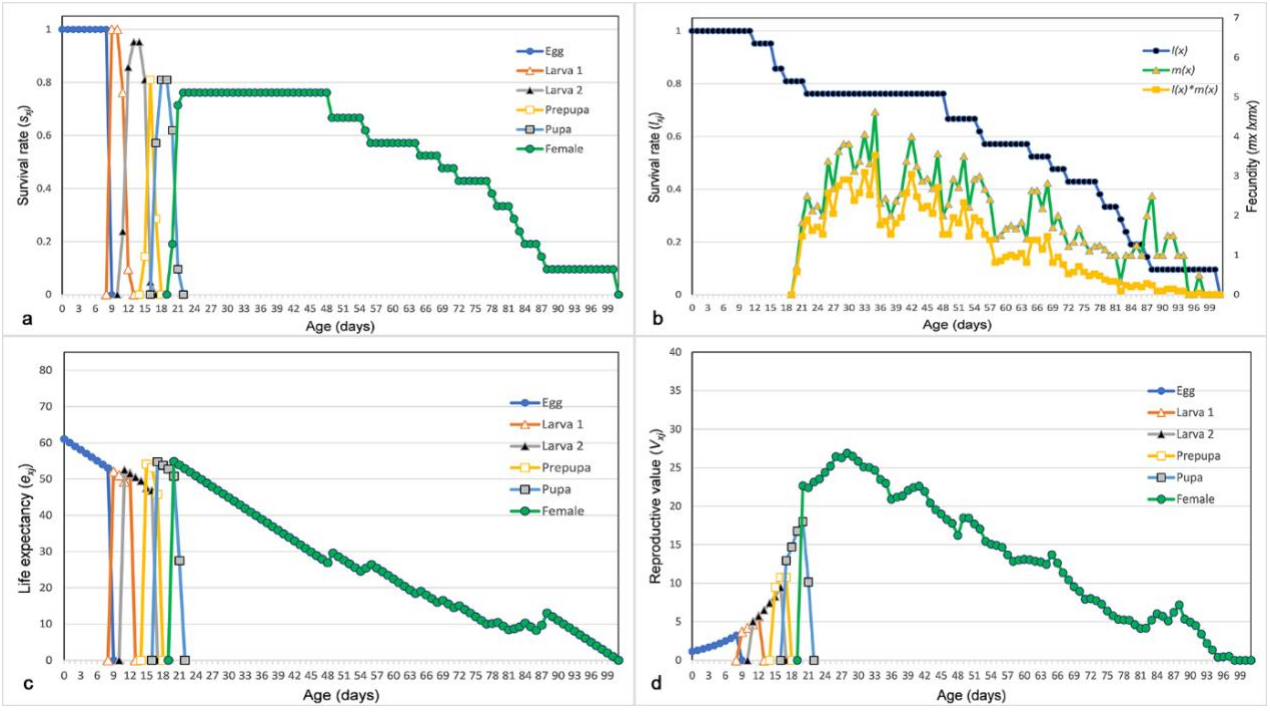

Figure 4. a) Age-stage specific survival rate of *Hercinothrips femoralis* on bean leaf discs at 25ºC, b) Age-specific survival rate (*lx*), age-specific fecundity (m_x), and age-specific maternity (l_xm_x) of *Hercinothrips femoralis*, c) The age-stage life expectancy of *Hercinothrips femoralis*, d) Age-stage specific reproductive value (v_{xj}) of *Hercinothrips femoralis*.

Susceptibility of *Hercinothrips femoralis* to spinosad and abamectin

Table 5 show the mortality rates at in different dose series obtained in tests performed to reveal the effects of the active ingredients spinosad and abamectin on *H. femoralis*. Spinosad, at the commonly used recommended dose against major greenhouse pests (96 mg-ai/L), caused 100% in the *H. femoralis* adults. The findings revealed that the tested population of *H. femoralis* was highy susceptible to spinosad. Abamectin has been widely used for many years to control spider mites. The label dose for spider mites, 4.5 mg-ai/L killed 94% of the *H. femoralis* population (Table 5). Considering the relatively long lifespan of adults, it was thought that *H. femoralis* has the biological potential to produce overlapping generations in greenhouses with a Mediterranean climate. Therefore, in insecticide bioassays, a high number of adult female thrips of mixed ages were used in replicates to more reliably reflect the effectiveness of the tested insecticides. It should be noted that the efficacy of spinosad and abamectin under these conditions may differ among adult age groups.

Table 5. The effect of serial doses of spinosad and abamectin in population of *H. femoralis* in laboratory bioassays

Spinosad bioassay						
Spinosad doses (mg a.i./L)	0.0096 (214)**	0.096 (219)**	0.96 (205)**	9.6 (108)**	96* (141)**	Control (424)**
Mortality (%)	15.2	80.7	98.5	100.0	100.0	6.7
Abamectin bioassay						
Abamectin doses (mg a.i./L)	0.0045 (121)**	0.045 (127)**	0.45 (106)**	4.5* (138)**	45 (122)**	Control (244)**
Mortality (%)	3.9	42.1	86.0	93.7	100.0	2.6

* Recommended label doses against common greenhouse pests in Türkiye (Department of Plant Protection Products 2025).
** Number of tested adult female thrips.

Discussion

Hercinothrips femoralis is very similar to *Hercinothrips bicinctus* (Bagnall, 1919) but it is distinguished from the other species by the darker middle part of its forewings. Laughlin (1971) noted that *H. femoralis* has two larval stages that are difficult to distinguish, with minimal differences in antennae. However, he noted that exuviation is a sign of the first larval stage but also stated that the exuvium was often hidden in the excrement end of the abdomen or left on the leaf surface. In the present study, all the exuvium, which was evidence of the completion of the larval stages, was visible on all the leaf discs. Unlike in Laughlin's observation, the exuviae were not hidden in excrement but were found close to the larvae on the leaf surface.

Hercinothrips femoralis is a highly polyphagous species in greenhouses (Mound et al., 1976). Figs, sugar beets, groundnuts, bananas, cotton, pineapple, sugarcane, and ornamentals have been reported as hosts for this species (Houston et al., 1991). It has been reported that this species damages many ornamental plants, including *Philodendron selloum* Koch (Arales: Araceae)*, Brassaia [Schefflera] actinophylla* Endl. (Araliales: Araliaceae)*,* and *Peperomia* spp. (Piperales: Piperaceae), making them unsellable (Denmark, 1976). The species infests some ornamental plants, such as *Aspidistra elatior* Blume (Asparagales: Asparagaceae) and *Arum italicum* Miller (Arales: Araceae) (Lacasa & Martinez, 1988), as well as other species from various genus, including *Passiflora* sp. (Malpighiales: Passifloraceae), *Chorisia* sp. (Malvales: Bombacaceae), *Phaseolus vulgaris* L. (Fabales: Fabaceae), and *Washingtonia* sp. (Arecales: Araceae) (Varga, 2008). It has been recorded as being severely damaging to *Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht & J Pres (Solanales: Solanaceae) and *Hedera helix* L. (Apiales: Araliaceae) (Lee & Lee, 2016) among indoor ornamental plants, as well as *Monstera deliciosa* Liebm. (Alismatales: Araceae), *Freesia* spp. Eckl. ex Klatt (Asparagales: Iridaceae), *Iresine herbstii* Hook. ex Lindl. (Caryophyllales: Amaranthaceae), *Podophyllum* spp. L. (Ranunculales: Berberidaceae), *Impatiens walleriana* (Hook.) (Ericales: Balsaminaceae), *Alocasia* sp. (Schott) G.Don (Alismatales: Araceae) and *Orchis* spp. Tourn. ex L. (Asparagales: Orchidaceae) (Orosz et al., 2017). Although this species has been recorded in greenhouses in Europe, its hosts *Origanum majorana* L. (Lamiales: Lamiaceae), *Hippeastrum* sp. Herb. (Asparagales: Amaryllidaceae), *Ocimum basilicum* L. (Lamiales: Lamiaceae), and *Calendula officinalis* L. (Asterales: Asteraceae) have also been reported to grow outdoors in warmer climates. *Hercinothrips femoralis* has been recorded on maize (Trdan, 2002), and a large population was found in the greenhouse, damaging cabbage leaves and sweet potatoes (Wang et al., 2022) among plants growing outside (Degabriele et al., 2023). Recently, it has been identified as a thrips species that causes unusual damage in greenhouse ornamentals (Jandricic et al., 2024).

Hercinothrips femoralis has been found almost everywhere where bananas are cultivated (Trdan et al., 2007). It was collected from *Musa* sp. L. (Zingiberales: Musaceae) grown with *Capsicum annuum* L. (Solanales: Solanaceae) in France (Etienne et al., 2015) and recorded on bananas in Australia and Greece (Houston et al. 1991; Roditakis et al., 2006). This species is known to cause significant damage in conventional banana plantations, resulting in a typical smoky, dark red colour change in infested fruits (Roditakis et al., 2006).

Considering the relevant literature data, it is understood that *H. femoralis* has remarkable host diversity. In our study, we demonstrated that this thrips species could readily feed directly on beans, peppers, cucumbers, and bananas and lay eggs, from which larva emerged. In light of these findings, it is essential to consider the potential of this species to spread to different regions through contaminated fruit or plant materials.

Laughlin (1971) reported that the eggs, first-instar larvae, second-instar larvae, prepupae, and pupae of *H. femoralis* require 7.5, 3.0, 3.5, 2.1, and 2.7 days for development, respectively, at 27ºC. In the same study, the total developmental period from egg to adult was 18.1 to 19.8 days. In another study, the developmental times of the eggs, first-instar larvae, second-instar larvae, prepupae, and pupae of *H. femoralis* at 24ºC under approximately 100% RH and with LD 12:12 h were 9.5, 3.9, 4.8, 2.3, and 4.2 days,

respectively. The total developmental period was approximately 24.4 days (Koch, 1981). On the basis of these two studies, the preadult development time is, on average, 18 and 25 days at 27 and 24ºC, respectively. The development time of 20.82 days at 25ºC determined in our study was quite similar to those reported in the literature.

No biological data were found for the adult stages of *H. femoralis.* Another important thysanopteran pest, *F. occidentalis*, has a female longevity of approximately 25 days and fecundity of 80 eggs on beans at 25±1ºC with a 14:10 h light-dark photoperiod and 70% RH (Zeng et al., 2021). The adult longevity of female *F. occidentalis* on cucumber and tomato leaves at 27ºC ±1 was determined to be approximately 14 and 11 days, respectively, and the fecundity was 27 and 15 eggs, respectively. Under the same conditions, the adult longevity of *Frankliniella intonsa* (Trybom, 1895) (Thysanoptera: Thripidae) was 17 and 9 days and the fecundity was 35 and 2 eggs on cucumber and tomato leaves, respectively (Li et al., 2015). Moraiet et al. (2017) reported that the longest adult longevity of *Thrips tabaci* (Lindeman 1889) (Thysanoptera: Thripidae) was 22 days, and the fecundity was 83 eggs on different onion cultivars at 25±1ºC under 65±5% RH. The adult longevity and fecundity found in this study (nearly 74.88 days and 132.62 eggs) at 25ºC ±1 are higher than those reported in the aforementioned studies. Temperature and host plant may influence these differences. However, the longevity of *H. femoralis* adults appears to be greater than that of *F. occidentalis* adults under similar temperature conditions and on the same host.

No study has determined the population parameters of *H. femoralis*. The *r* value of *H. femoralis* (0.130) on bean leaves was slightly lower for *F. occidentalis* (0.19), and the λ value was also lower than the value of 1.21 reported by Zeng et al. (2021). In another study, the *r* and λ values were found to be 0.18 and 1.19, respectively, for *F. intonsa* on bean pods (Li et al., 2024). The values determined in the present study show the potential to increase the population of *H. femoralis* compared with that of *Frankliniella* species.

Frankliniella occidentalis is widespread worldwide, and numerous resistance screenings conducted with populations in different countries have demonstrated its high levels of resistance to organophosphorus, carbamate, and pyrethroid class active substances, as well as to the commonly used and still widely used avermectin and spinosyn class active substances (Immaraju et al., 1992; Brodsgaard, 1994; Jensen, 1998, 2000; Kontsedalov et al., 1998; Espinosa et al., 2002; Herron & James, 2005; Bielza et al., 2007; Thalavaisundaram et al., 2008; Zhang et al., 2008; Gao et al., 2012; Sparks et al., 2012; Li et al., 2016; Dağlı, 2018; Cubillos-Salamanca et al., 2019; APRD, 2022). In a recent study, Antalya populations of the species were also found to be significantly resistant to spinosad (Dağlı, 2018; Kamış & Dağlı, 2022). Present study bioassay finding indicated that *H. femoralis* might be naturally (species-specific) susceptible to spinosad. Because *H. femoralis* population was ultimately killed even at 1/10 the recommended dose of spinosad. Data for a population from only one location might not be sufficient to generalize the insecticide susceptibility status of *H. femoralis*; insecticide susceptibility levels of populations from other locations or countries should also be considered. No prior studies have reported on the resistance of this species to the active substances spinosad and abamectin. However, some previous studies have described a low insecticide resistance in this species and the opportunity for effective chemical control (Scarpelli & Bosio, 1999; Varga, 2008). Two studies were conducted to investigate the effects of certain biopesticide preparations on *H. femoralis* species (Trdan et al., 2007; Zvaríková et al., 2023). First, the effectiveness of the entomopathogenic nematode species *Steinernema feltiae* (Filipjev, 1934) Wouts, Mráček, Gerdin & Bedding, 1982 (Rhabditida: Rhabditida) and *Heterorhabditis* spp. Poinar, 1975 (Rhabditida: Heterorhabditidae) were investigated through foliar application, and the highest mortality rates were found in larvae, with values of 23% and 50%, respectively (Trdan et al., 2007). The potential effects of five different essential oils against *H. femoralis* were investigated under laboratory conditions (Zvaríková et al., 2023). Cinnamon oil, which was found to be the most effective essential oil, caused 42% mortality.

Related knowledge on the distribution of *H. femoralis* in Europe indicate that the species reached economically damaging population levels on bananas in Greece in 2005 (Roditakis et al., 2006) and was later detected in Slovakia in 2007 (Varga, 2008). However, there is no evidence suggesting a consistent or rapid spread of the species across the continent. In contrast, *F. occidentalis* began spreading from its native range in North America during the 1970s, reached Europe in 1983, and became widespread globally within 10-15 years (Kirk & Terry, 2003). Considering the distribution status of these two thrips species, it is highly probable that their biological characteristics, potential to acquire resistance to insecticides, and ability to survive in different climatic conditions are effective. Insecticide testing revealed that *H. femoralis* populations are highly susceptible to spinosad and abamectin, probably because they are not yet economically important with regard to crop plants. These two well known active substances have been widely used worldwide for over 20 years against several important pests including *F. occidentalis*. Considering this information, it is highly probable that controlling pest species with spinosad and abamectin also eliminated or significantly suppressed *H. femoralis* populations. This phenomenon may be one of the reasons why *H. femoralis* species have a limited ability to spread to more expansive geographical areas compared with insecticide-resistant species (or those with a high potential to acquire resistance), such as *F. occidentalis* species.

The typical feeding behaviour of a species may also be a key factor limiting its rapid and stable spread from its current locations to nearby or distant areas. Previous studies and observations have reported that *H. femoralis* remains mostly slow-moving as long as the host plant provides sufficient resources for feeding and oviposition. When the host becomes unsuitable, however, individuals begin to move in search of new plant material (Laughlin, 1971; Štefánik et al., 2019). A study on this subject has also shown that passive transport by humans plays a significant role in the spread of *H. femoralis* (Štefánik et al., 2019). The finding that the species is generally much less mobile as long as there is a suitable plant for feeding and laying eggs is consistent with our observations during the rearing of *H. femoralis* in the present study. *Hercinothrips femoralis* was reared on bean fruits in rearing containers. Both adults and larvae remained almost stationary on the bean fruits and fed on them unless they were fresh and the population density was very high. When the bean fruits lost freshness and the population density increased, adults and larvae were observed leaving the fruits and actively moving across the inner surfaces of the containers and lids, likely in search of a new host.

In conclusion, the life table parameters obtained in this study demonstrated that *H. femoralis* can easily reproduce under suitable climates and host plants, leading to significant economic losses. It should be considered that control measures may be necessary in locations where this species is found. In cases where chemical control is required, the finding from this study that spinosad and abamectin have a high efficacy against *H. femoralis* can be taken into account. No comprehensive research has been conducted to examine how *H. femoralis*, which originates from the tropics, is affected by low winter temperatures, high summer temperatures, and variable humidity levels in subtropical and temperate regions such as Antalya (Türkiye). There are very large differences in the temperature and humidity ranges between tropical and subtropical/temperate regions. Therefore, to obtain accurate estimates of the future distribution potential of *H. femoralis*, it is necessary to determine the extent to which climatic factors affect the population of this species, considering the low winter temperatures and high summer temperatures in subtropical and temperate regions.

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