INTEGRATED APPROACHES TO SUSTAINABLE AGRICULTURE

OCTOBER 2025

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DOÇ. DR. ALİ MURAT TATAR

SERÜVEN YAYINEVİ

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SERÜVEN YAYINEVİ

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Chapter 1

FEMALE EFFECT IN FARM ANIMALS: INFLUENCE OF FEMALE STIMULATION ON MALE REPRODUCTIVE PHYSIOLOGY AND BEHAVIOUR

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1. INTRODUCTION

Reproduction is the result of endogenous neuroendocrine regulatory mechanisms interacting with external factors. Environmental conditions influence these mechanisms by stimulating or inhibiting physiological processes, most of which are closely related to reproduction. In ruminants, social cues can either stimulate or suppress reproductive activity. Social hierarchy and lactation, for example, are considered inhibitory cues that can affect reproductive behavior (Ungerfeld, 2007).

The effects of social stimuli on reproductive physiology have been widely investigated in rodents and various species of farm animals. In ruminants, several reproductive responses can be induced in females following exposure to male stimuli (Ungerfeld, 2007). Sexually active males that have undergone photoperiodic stimulation can induce luteinizing hormone (LH) secretion and trigger ovulation in seasonally anestrous females. This phenomenon is referred to as the "male effect" (Delgadillo et al., 2022). Indeed, numerous studies have demonstrated that females exposed to male stimuli exhibit heightened endocrine and ovulatory responses (Murtagh et al., 1984; Oldham and Pearce, 1983; Signoret et al., 1982; Chanvallon et al., 2010; Scaramuzzi et al., 2014).

Similarly, heterosexual stimulation is crucial for the sexual and behavioral development of males (Zenchak and Anderson, 1980; Casteilla et al., 1987). In this context, male lambs reared in continuous contact with females develop larger testicular volumes and display more advanced sexual behavior compared to those reared in isolation from females (Illius et al., 1976a; Katz, 2008). Katz et al. (1988) reported that males reared with sexually mature females prior to puberty exhibited a higher mating drive than those reared in male-only groups. Conversely, males raised in isolation from females tend to develop homosexual behaviors and show reduced sexual motivation when reintroduced to females during the breeding season. Therefore, the sex composition of the social environment in which males are raised exerts a profound influence on their adult reproductive behavior (Lacuesta et al., 2018).

Considering the sustainability and profitability of livestock production, photoperiodic treatments and hormonal supplements are commonly used to enhance reproductive performance. However, these approaches directly increase labor and production costs. In contrast, biostimulation methods represent natural and cost-effective alternatives to mitigate the negative environmental effects on male reproductive performance (Rodríguez-De Lara et al., 2010). Studies conducted on cattle (Bailey et al., 2005), pigs (Mader and Price, 1984), and sheep (Rosa et al., 2000; Kheradmand and Babaei, 2006) have demonstrated that female stimulation plays a significant behavioral and physiological role in males.

This review aims to examine the effects of the *female effect* on male reproductive physiology and behavior in farm animals in light of current

literature, while discussing practical limitations and future research needs. Although numerous studies have explored the *male effect*, the physiological implications and management potential of the *female effect* remain insufficiently elucidated. This highlights both a scientific gap requiring further investigation and a practical need for economically viable, natural biostimulation approaches in herd management. Therefore, this review seeks to contribute to a deeper understanding of the *female effect* and to assess its potential applicability in livestock production systems.

2. MALE EFFECT AND FEMALE EFFECT

Small ruminants are seasonally polyestrous species. They enter estrous cycles during the autumn months when day length decreases, ensuring that parturition coincides with spring the period most favorable for offspring survival under environmental conditions. As day length increases, hypothalamic activity is suppressed, and animals enter the anestrous phase.

In females, exposure to a male's presence or the perception of male cues through visual, auditory, or pheromonal signals may not always trigger overt behavioral changes but typically increases alertness, attention, and behavioral signs such as frequent urination (Gelez et al., 2004). However, in the phenomenon known as the "male effect," direct contact or close physical interaction between the sexes stimulates hypothalamic gonadotropin-releasing hormone (GnRH) secretion via the central nervous system. This stimulation induces a rapid surge in luteinizing hormone (LH) concentrations (Oldham et al., 1979; Chanvallon et al., 2010), while follicle-stimulating hormone (FSH) levels increase more gradually. Following the LH surge, follicular development accelerates, leading to ovulation in females that were previously in seasonal anestrus.

This neuroendocrine process is considered a fundamental biostimulation mechanism that reactivates reproductive cycles in seasonally anestrous females (Martin et al., 1980; Poindron et al., 1980). The efficacy of the male effect is influenced by several factors, including the male's age, sexual experience, duration of isolation from females, and seasonal photoperiod (Chanvallon et al., 2010; Delgadillo et al., 2022).

Reproductive behavior in ruminants is affected not only by hormonal regulation but also by early-life social environment and rearing conditions. Rams raised in continuous contact with females prior to puberty exhibit higher libido and superior mating performance in adulthood compared to those reared in complete isolation from females (Katz et al., 1988). Similarly, young males raised in long-term isolation from females require multiple exposures to sexually mature females to reach comparable reproductive performance to males reared in mixed-sex environments (Kridli and Said, 1999). Otherwise, prolonged isolation reduces sexual interest toward females and decreases

mating success (Zenchak and Anderson, 1980). Moreover, extended isolation can increase homosexual behavior tendencies among males, possibly due to social dominance hierarchies and stress-related factors (Ungerfeld et al., 2013). Nevertheless, no significant differences have been reported in sperm viability or sperm concentration between rams reared in isolation and those exposed to female stimuli (Winfield and Makin, 1978).

In the literature, the concept of the "female effect" is not as clearly defined as the male effect. However, existing research indicates that the presence of females stimulates neuroendocrine activity, testosterone secretion, testicular development, spermatogenesis, and sexual motivation in males (Ungerfeld et al., 2013; Lacuesta et al., 2015; Caraty and Fabre-Nys, 2020). Therefore, within the scope of this study, it can be defined as follows:

"The female effect refers to the stimulatory influence of the presence or cues of sexually mature females on the reproductive physiology, hormonal responses, and behavioral performance of males."

Recent studies have demonstrated that exposure to female odors or visual cues elevates GnRH/LH secretion in males, resulting in testosterone surges that positively influence libido, ejaculation latency, and mating frequency (Ungerfeld and Silva, 2022). Thus, the *female effect* should be considered a physiologically significant phenomenon with practical implications for biotechnological and behavioral strategies aimed at enhancing breeding performance in male livestock.

3. EFFECTS OF FEMALE STIMULATION ON MALE ANIMALS

3.1 Effects According to Housing Conditions

The rearing and socio-sexual environment of male ruminants exerts a decisive influence on reproductive behavior and performance observed during adulthood. It has been reported that males raised in continuous contact with females, particularly during the prepubertal period, exhibit more favorable developments in testicular volume, testosterone levels, and mating motivation. This effect is associated with the enhancement of neuroendocrine development through early intersexual interactions (Damián et al., 2018).

Rams and bucks reared in constant contact with females prior to puberty have been found to possess larger testicular volumes and stronger mating drives (Illius et al., 1976a; Katz et al., 1988). In fact, a study investigating the effects of rearing isolation from females on adult reproductive behavior reported that bucks raised in the presence of females exhibited higher frequencies of courtship behavior, as well as greater rates of ejaculation and mounting, compared to those reared in isolation. Therefore, the lack of contact with females during the rearing period negatively affects the reproductive performance of bucks, and this detrimental effect persists even when they are later exposed to estrous females (Lacuesta et al., 2018).

Similarly, males raised in isolation from females may display weakened sexual behaviors, reduced mating motivation, and, in some cases, a tendency toward homosexual behavior (Zenchak et al., 1981; Ungerfeld et al., 2013; Lacuesta et al., 2018). Hence, rearing practices that allow males to be exposed to auditory, olfactory, and visual stimuli from females provide a reproductive advantage by enhancing the reproductive capacity of male animals.

3.2 Behavioral, Hormonal, and Testicular Responses

In male ruminants, the highest reproductive activity is typically observed during the autumn months, when day length decreases. At the onset of this period, gonadotropin (LH, FSH) and testosterone concentrations reach their peak levels, while spermatogenesis, ejaculate volume, and sperm quality are higher compared to other periods of the year (Chemineau et al., 1992; Delgadillo et al., 2022).

The female effect is defined as the phenomenon whereby olfactory (pheromonal), visual, auditory, and behavioral signals emitted by females stimulate the neuroendocrine system of males, enhancing reproductive activity. This effect can elicit endocrine and behavioral responses sufficient to alter the seasonal reproductive rhythm of males (Giriboni et al., 2017; Ungerfeld, 2007).

Seasonal reproductive rhythm can be modulated by socio-sexual signals produced by individuals of the same or opposite sex (Ungerfeld, 2007). Direct or indirect exposure to females activates the hypothalamic–pituitary–gonadal (HPG) axis in males, stimulating GnRH and LH secretion. This, in turn, results in a rapid increase in testosterone levels and a marked rise in testicular fluid volume (Perkins et al., 1992; Walkden-Brown et al., 1994; Ungerfeld and Fila, 2012). These hormonal increases have been reported to enhance libido, mating behavior, and ejaculation frequency (Fahey et al., 2012).

Furthermore, brief exposure of rams to estrous females prior to semen collection significantly improves ejaculate volume, sperm concentration, and motility (Fahey et al., 2012; Caraty and Fabre-Nys, 2020). Under conditions of prolonged physical contact with females, increases in testicular volume and testosterone concentration have been observed, accompanied by intensified reproductive and aggressive behaviors (Illius et al., 1976b; Carrillo et al., 2014).

In a study on Gabon goats, bucks exposed to estrous females through chemical (pheromonal), visual, and auditory cues exhibited higher testicular activity, superior ejaculate quality, and increased intratesticular fluid volume compared to isolated males (Giriboni et al., 2017). These findings demonstrate that female stimulation can directly modulate testicular function in males.

Similarly, prepubertal male kids raised in contact with sexually mature females showed earlier and stronger physiological responses in terms of testicular development, testosterone levels, and libido compared to those

raised in complete isolation from females (Lacuesta et al., 2015). This suggests that early exposure to females has a programming effect on the development of the male reproductive system.

Additionally, in red deer, continuous social contact with females increased fecal testosterone metabolite concentrations and improved sperm quality in males (Villagrán and Ungerfeld, 2013). Collectively, these findings support the notion that female stimulation positively influences male reproductive physiology through similar neuroendocrine mechanisms across different species.

3.3 Behavioral Disorders Observed in Isolated Male Groups

Male ruminants raised in complete isolation from females frequently exhibit social and sexual behavioral abnormalities. Upon reaching adulthood, these males may display low sexual interest in females, reduced mating motivation, or tendencies toward homosexual behavior (Zenchak et al., 1981; Ungerfeld et al., 2013; Lacuesta et al., 2018). The homosexual behaviors observed in isolated males are often not merely temporary; they are considered a form of "misdirected sexual motivation" that develops into long-lasting behavioral patterns due to social and sexual experience deficits (Zenchak et al., 1981; Carrillo et al., 2014).

Conversely, males subjected to prolonged female isolation can gradually regain normal sexual responses when later re-exposed to females. Early interaction with females supports both sexual learning and the appropriate development of neuroendocrine sensitivity in males (Hulet et al., 1964; Mattner et al., 1973; Lacuesta et al., 2018). These findings highlight the critical role of social experience and female presence in the permanent shaping of male libido and mating behavior.

Reproductive failures observed in groups composed solely of male individuals are suggested to arise not only from the frequency of homosexual behavior but also from persistent social attachments formed with other males (Price and Smith, 1984; Ungerfeld et al., 2013). Such attachments can suppress sexual interest toward females and constrain the sexual behavior repertoire.

Recent studies indicate that complete isolation of males from females during early life can induce lasting changes in testosterone secretion, GnRH/LH dynamics, testicular development, and libido levels (Ungerfeld and Silva, 2022; Delgadillo et al., 2022). These physiological differences are associated with lower reproductive success compared to males raised in regular contact with females.

In conclusion, the presence and stimulation of females exert a strong biostimulatory effect in males by enhancing neuroendocrine activity, promoting testicular development, and strengthening the sexual behavior repertoire. Accordingly, the controlled management of female stimulation is considered

a natural, effective, and low-cost approach to improving male reproductive performance in farm animals (Lacuesta et al., 2015; Ungerfeld et al., 2013).

4. CONCLUSIONS AND RECOMMENDATIONS

The role of female stimulation (female effect) in enhancing reproductive performance in male farm animals has significant implications from both biological and management perspectives. Current research demonstrates that female presence induces strong neuroendocrine activation of the hypothalamic-pituitary-gonadal axis in males, leading to substantial increases in testosterone secretion, testicular volume, spermatogenesis, and libido (Carrillo et al., 2014; Giriboni et al., 2017; Lacuesta et al., 2018). Specifically, visual, auditory, or pheromone-based olfactory cues from females have been shown to elevate LH pulse frequency and testosterone peaks in males, thereby sustaining sexual behavior (Hernández et al., 2021).

Housing conditions and social environment are critical determinants of the magnitude of this effect. Males raised in prolonged isolation from females may exhibit reduced sexual motivation, delayed ejaculation, insufficient courtship behavior, and even behaviors resembling homosexual orientation (Zenchak and Anderson, 1980; Ungerfeld et al., 2013; Lacuesta et al., 2018; Bedos et al., 2022). Conversely, males exposed to brief, controlled contact with females during puberty or pre-adult stages show superior testicular development, sperm quality, and mating eagerness (Illius et al., 1976b; Fernández et al., 2019). These findings clearly indicate that female stimulation is a critical environmental factor for the development of healthy reproductive capacity in male animals.

However, maintaining continuous co-housing of males and females under farm conditions may lead to uncontrolled mating, difficulties in pedigree tracking, and errors in selection of breeding stock. Therefore, female stimulation should be implemented as a controlled biostimulation strategy. The optimal approach involves providing males with short-term visual, auditory, and pheromone exposure to females while preventing physical contact. This strategy not only stimulates testosterone secretion but also enhances pre-breeding sexual activity in males, thereby improving insemination success (Rodríguez-De Lara et al., 2010; Bedos et al., 2022).

In conclusion, female stimulation represents a natural, cost-effective, and welfare-friendly biostimulation method for enhancing male reproductive performance in farm animals. Future research should aim to elucidate the physiological mechanisms, optimal timing, and interspecies differences associated with this method. Moreover, objective assessment of female stimulation effects using biotechnological monitoring systems (e.g., behavioral sensors, pheromone analyses) will facilitate its integration into modern herd management programs.

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Chapter 2

2030 FORECAST OF AGRICULTURAL MACHINERY UTILIZATION OF SİVAS PROVINCE WITH DATA FROM THE PAST YEARS (2014-2024)

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INTRODUCTION

Agricultural mechanization constitutes a fundamental pillar of sustainable agricultural development and economic transformation. It encompasses the utilization of mechanical power and advanced technologies in the execution of various agricultural operations, including soil preparation, sowing, irrigation, crop management, harvesting, and post-harvest processing. The level of mechanization within a country is a key indicator of its agricultural efficiency, productivity, and technological progress. A higher degree of mechanization is generally associated with enhanced labor productivity, reduced dependency on manual labor, improved timeliness of farm operations, and increased crop yields. Moreover, mechanization contributes to resource optimization, cost reduction, and the overall modernization of rural economies.

In contrast, low mechanization levels often constrain agricultural growth, particularly in developing countries where traditional farming practices remain prevalent. Such limitations may lead to inefficiencies in land use, labor shortages during peak agricultural seasons, and slower adaptation to climate-resilient production systems. Therefore, assessing the level of agricultural mechanization at the national or regional scale is essential for identifying technological gaps, formulating effective policy interventions, and promoting sustainable rural development. By understanding the dynamics of mechanization, governments and development agencies can design targeted programs to enhance equipment accessibility, strengthen the agricultural machinery industry, and ultimately ensure food security and economic resilience.

Sivas, located in the heart of Central Anatolia, is one of Türkiye's largest provinces in terms of area and has long been recognized for its rich agricultural potential. The province's geography, climate, and historical significance have shaped its agricultural structure, creating a landscape where conventional practices meet modern development. Agriculture remains one of the most important economic sectors in Sivas, supporting rural livelihoods and contributing to the province's overall socio-economic fabric. Sivas's agricultural structure is deeply influenced by its diverse topography and continental climate. The province is characterized by vast plateaus, fertile plains, and mountain ranges, with elevations ranging from 900 to over 2000 meters. The continental climate brings cold, snowy winters and hot, dry summers, conditions that determine the types of crops cultivated and the timing of agricultural activities. The dominant feature of Sivas agriculture is field crop production, which occupies the largest portion of cultivated land. Wheat and barley are the primary crops, forming the backbone of the province's agricultural output. Lentils, chickpeas, and other legumes are also important, both for domestic consumption and for maintaining soil fertility through crop rotation. In recent years, Sivas has diversified its agricultural portfolio with increased attention to industrial crops such as sugar beet,

sunflower, and potato. These crops are supported by modern irrigation systems and cooperative-based marketing networks. In this study, it is aimed to determine the agricultural mechanization projection of Sivas province until 2030 and these values will guide the mechanization plans in the region.

MATERIAL AND METHOD

The province of Sivas is located in the middle of the Anatolian peninsula, in the Yukarıkızılırmak section of the Central Anatolia Region. Located between 36° and 39° east longitudes and 38° and 41° north latitudes, the province is the second largest province in Türkiye after Konya in terms of land area, with a surface area of 28,488 km^2. Erzincan is located in the east of Sivas, Malatya and Kahramanmaraş in the south, Kayseri in the southwest, Yozgat in the west, Tokat and Ordu in the north, and Giresun in the northeast (Figure 1). The continental climate prevails in the part of the province that enters the Kızılırmak Basin, the Black Sea climate prevails in the part that enters the Yeşilırmak Basin, and the Eastern Anatolian climate prevails in the part that enters the Euphrates Basin. (Altuntaş ve Aslan, 2009; Anonim, 2011; Bulut, 2016).

Figure 1. Sivas province map

As is seen in Figure 2, 41% of Sivas province's land is agricultural, 27% is meadow-pasture, 13% is forest and shrubland, and 19% is non-agricultural areas (Anonim, 2017; Şahin et al., 2024).

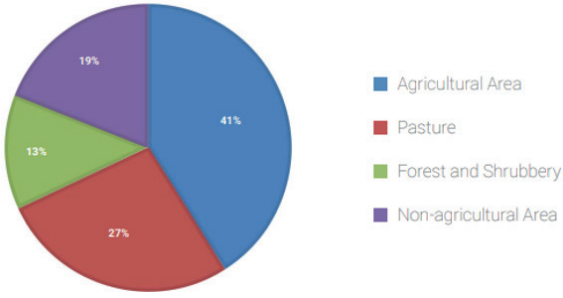

Figure 2. Land distribution of Sivas province

According to 2024 data, 55585.4 hectares of land in the province was allocated to grains and other plant products, while 230297.5 hectares were allocated to fallow land (Anonim, 2025a). According to 2024 data, the most cultivated crops in the province are shown in Table 1. (Anonim, 2025a).

Table 1. *Agricultural production quantities of major crops in Sivas province*

Crop	Production quantities (tons)
Sugar beet	1035924
Wheat	658824
Potato	560398
Barley	339970
Clover	177726
Oat	143504
Maize	125841
Tritikale	81845
Sunflower	40679

The material of the study consisted of the agricultural machinery data of the Turkish Statistical Institute for the years 2014-2024 for the province of Sivas (Anonymous 2025b). This data is used to determine the percentage ratios, either an increase or a decrease, for every agricultural tools and machinery by analyzing the covering years. After that, taking into account the 10-year usage amounts of agricultural machines, the percentage rates of increase and decrease in their numbers were calculated, and the average coefficients of these percentage rates were determined. By using the coefficients determined based on the data of previous years, the projections of agricultural tools and machines widely used in Sivas until 2030 are calculated using the same method in cited studies (Demir and Kuş 2016; Akbaş, 2019; Baran et al., 2019; Baran 2021; Ertop et al., 2021; Baran and Kaya, 2021; Gül et al., 2023; Turgut, 2023a; Turgut 2023b)

RESULTS AND DISCUSSIONS

In Sivas province, where conventional tillage is widely practiced, the increase in the number of rotary tillers is noteworthy. However, the fact that the increase in the number of moldboard ploughs is close to zero is an indication of this. It has been calculated that 24.33% of water erosion in Sivas province occurs in agricultural lands, the total erosion amount in agricultural lands is 4091354.68 tons $year^{-1}$ and the unit erosion amount is 4.04 tons ha^{-1} $year^{-1}$ (Anonim, 2020). Therefore, it is important to adopt conservation soil tillage methods throughout the province. As seen in Table 2, the highest projection coefficient with positive percent of 19.70 value is occurred in case of rotary tiller among those taken into consideration. Subsoiler, rotary cultivator, disc type tractor plough, disc harrow, stubble plough (moldboard type), land roller, arc opening plow, cultivator, disc type stubble plough (one

way), and moldboard type tractor plough are followed rotary tiller with positive projection coefficient value of 9.88%, 4.83%, 2.62%, 2.26%, 1.86%, 1.75%, 1.55%, 1.42%, 1.26% and 0.85% respectively.

Table 2. *Projection of Some Soil Tillage Tools and Machines Widely Used in Sivas Province*

Years	Moldboard type tractor plough	Stubble plough (moldboard type)	Disc type tractor plough	Disc type stubble plough (one way)	Arc opening plow	Cultivator	Disc harrows	Rotary Tiller	Rotary cultivator	Subsoiler	Land roller
2014	21824	1265	4081	518	356	18265	2949	45	491	149	2928
2015	22109	1330	4121	543	367	18397	3052	61	518	162	3033
2016	22221	1361	4132	534	379	18741	3088	134	583	190	3189
2017	22422	1383	4214	544	383	18885	3153	134	592	206	3237
2018	22805	1416	4213	542	320	19239	3246	134	602	223	3238
2019	23023	1444	4941	538	316	19984	3193	141	602	241	3221
2020	23482	1480	5075	561	348	20501	3373	178	712	319	3329
2021	23503	1494	5095	573	358	20521	3390	182	723	333	3346
2022	23206	1506	5179	579	358	20655	3514	184	745	350	3407
2023	23469	1502	5190	583	375	20784	3581	189	757	361	3441
2024	23743	1519	5229	586	405	21010	3681	197	776	372	3478
Years	**PERCENTAGE CHANGE**										
2014-2015	1.31	5.14	0.98	4.83	3.09	0.72	3.49	35.56	5.50	8.72	3.59
2015-2016	0.51	2.33	0.27	-1.66	3.27	1.87	1.18	119.67	12.55	17.28	5.14
2016-2017	0.90	1.62	1.98	1.87	1.06	0.77	2.10	0.00	1.54	8.42	1.51
2017-2018	1.71	2.39	-0.02	-0.37	-16.45	1.87	2.95	0.00	1.69	8.25	0.03
2018-2019	0.96	1.98	17.28	-0.74	-1.25	3.87	-1.63	5.22	0.00	8.07	-0.53
2019-2020	1.99	2.49	2.71	4.28	10.13	2.59	5.64	26.24	18.27	32.37	3.35
2020-2021	0.09	0.95	0.39	2.14	2.87	0.10	0.50	2.25	1.54	4.39	0.51
2021-2022	-1.26	0.80	1.65	1.05	0.00	0.65	3.66	1.10	3.04	5.11	1.82
2022-2023	1.13	-0.27	0.21	0.69	4.75	0.62	1.91	2.72	1.61	3.14	1.00
2023-2024	1.17	1.13	0.75	0.51	8.00	1.09	2.79	4.23	2.51	3.05	1.08
Projection Coefficient	**0.85**	**1.86**	**2.62**	**1.26**	**1.55**	**1.42**	**2.26**	**19.70**	**4.83**	**9.88**	**1.75**
Years	**PROJECTIONS**										
2025	23945	1491	5366	593	411	21307	3764	236	813	409	3539
2026	24148	1463	5507	601	418	21609	3849	282	853	449	3601
2027	24354	1436	5651	608	424	21915	3936	338	894	494	3664
2028	24561	1409	5799	616	431	22225	4025	404	937	542	3728
2029	24769	1383	5951	624	437	22540	4116	484	982	596	3793
2030	24980	1357	6107	632	444	22859	4209	579	1030	655	3860

As seen in Table 3, the highest projection coefficient with positive percent of 13.51 value is occurred in case of among those taken into consideration. The agricultural soils of Sivas province, like those throughout our country, are poor in organic matter. Although animal husbandry is intensive throughout the province, animal manure is not fully utilized. However, the increase in the number of manure spreading machinery shows that there is positive progress in this regard. Stubble drill, pneumatic precision drill, universal seed drill, combined seed drill, chemical fertilizer spreader, tractor-drawn seed drill are followed manure spreading machinery with positive projection coefficient value of 10.93%, 9.09%, 8.22%, 5.56%, 5.16%, 2.65% respectively. In the province, the broadcast sowing method is being replaced by machine sowing. Farmers in the province prefer to use stubble drill and pneumatic precision drill, especially in the cultivation of wheat and corn. In the 2030 projection, it is predicted that the largest number of tractor-drawn seed drill will be in the province.

Table 3. *Projection of Some Sowing-Planting Fertilizer Machines Widely Used in Sivas Province*

Years	Tractor-drawn seed drill	Combined seed drill	Pneumatic precision drill	Stubble drill	Universal seed drill	Manure spreading machinery	Chemical Fertilizer Spreader
2014	5367	4349	239	16	156	109	3290
2015	5864	4417	255	18	168	142	3417
2016	5943	4589	271	23	175	169	3553
2017	5974	4658	331	22	209	206	3637
2018	6536	4987	341	26	214	275	3794
2019	6599	6469	351	27	219	263	4311
2020	6625	6864	472	31	280	305	4923
2021	6656	6880	486	40	293	322	4939
2022	6782	7032	510	43	310	349	5229
2023	6831	7124	532	43	326	357	5281
2024	6934	7270	549	43	335	366	5389
Years	**PERCENTAGE CHANGE**						
2014-2015	9.26	1.56	6.69	12.50	7.69	30.28	3.86
2015-2016	1.35	3.89	6.27	27.78	4.17	19.01	3.98
2016-2017	0.52	1.50	22.14	-4.35	19.43	21.89	2.36
2017-201	9.41	7.06	3.02	18.18	2.39	33.50	4.32
2018-2019	0.96	29.72	2.93	3.85	2.34	-4.36	13.63
2019-2020	0.39	6.11	34.47	14.81	27.85	15.97	14.20
2020-2021	0.47	0.23	2.97	29.03	4.64	5.57	0.33
2021-2022	1.89	2.21	4.94	7.50	5.80	8.39	5.87
2022-2023	0.72	1.31	4.31	0.00	5.16	2.29	0.99
2023-2024	1.51	2.05	3.20	0.00	2.76	2.52	2.05
Projection Coefficient	**2.65**	**5.56**	**9.09**	**10.93**	**8.22**	**13.51**	**5.16**

Years	PROJECTIONS						
2025	7118	7675	599	48	363	415	5667
2026	7306	8102	653	53	392	472	5959
2027	7500	8552	713	59	425	535	6267
2028	7698	9028	778	65	460	608	6590
2029	7902	9531	848	72	497	690	6930
2030	8112	10061	926	80	538	783	7287

Horticulture and has an important place in Sivas province. Apricots, apples, cherries, pears, plums and walnuts are grown in significant amounts. Especially knapsack sprayer is widely used in these areas. It is seen that knapsack sprayers and PTO driven sprayers are appearing to be the most abundant. On the other hand, it is seen that dusters (5.42%) increased more than these. Dusters are followed by PTO driven sprayers, engine driven sprayers, knapsack sprayers, barrow dusters and combine sprayers and atomizers respectively, with positive percentage coefficient value of 4.47%, 2.80%, 2.01%, 0.97% and 0.58% respectively (Table 4).

Table 4. *Projection of Spraying Machines Widely Used in Sivas Province*

Years	Knapsack sprayer	Barrow duster and combine sprayer	PTO driven sprayer	Engine driven sprayer	Atomizer	Duster
2014	1824	184	1120	484	701	43
2015	1903	187	1209	502	709	50
2016	2209	191	1273	535	717	58
2017	2270	194	1310	553	718	63
2018	2241	198	1489	562	711	69
2019	1886	186	1517	563	702	62
2020	1941	190	1557	574	708	63
2021	1960	194	1573	587	719	68
2022	2015	200	1598	604	727	70
2023	2026	203	1629	621	742	70
2024	2163	202	1723	637	742	71

Years	PERCENTAGE CHANGE					
2014-2015	4.33	1.63	7.95	3.72	1.14	16.28
2015-2016	16.08	2.14	5.29	6.57	1.13	16.00
2016-2017	2.76	1.57	2.91	3.36	0.14	8.62
2017-201	-1.28	2.06	13.66	1.63	-0.97	9.52
2018-2019	-15.84	-6.06	1.88	0.18	-1.27	-10.14
2019-2020	2.92	2.15	2.64	1.95	0.85	1.61
2020-2021	0.98	2.11	1.03	2.26	1.55	7.94
2021-2022	2.81	3.09	1.59	2.90	1.11	2.94
2022-2023	0.55	1.50	1.94	2.81	2.06	0.00
2023-2024	6.76	-0.49	5.77	2.58	0.00	1.43
Projection Coefficient	**2.01**	**0.97**	**4.47**	**2.80**	**0.58**	**5.42**
Years	**PROJECTIONS**					
2025	2206	204	1800	655	746	75
2026	2251	206	1880	673	751	79
2027	2296	208	1964	692	755	83
2028	2342	210	2052	711	759	88
2029	2389	212	2144	731	764	92
2030	2437	214	2239	752	768	97

Harvesting machines commonly used in Sivas province are given in Table 5. It can be observed that a positive projection coefficient of 9.11% for the baler, 8.61% for the corn forage harvester, 7.43% for the beet lifter, 6.59% for the potato digger, 6.30% for the straw machine, 3.44% for the combine harvester, 2.20% for the tractor drawn mover and 0.66% for the straw conveyor and unloader respectively. Thresher has negative projection coefficient with a percent of 3.06. Combine harvesters with straw chopping and hay making units are increasing day by day in the region. Despite this increase, there is a noticeable increase in the number of balers in Sivas province, where animal husbandry has an important place.

Table 5. *Projection of Harvest-Threshing Machines Widely Used in Sivas Province*

Years	Combine harvester	Thresher	Beet lifter	Straw conveyor and unloader	Straw machine	Corn forage harvester	Baler	Tractor drawn mower	Potato digger
2014	34	8253	454	682	150	279	511	4029	268
2015	35	8280	505	626	169	308	543	4139	313
2016	33	7655	550	657	177	368	581	4228	354
2017	34	7625	599	667	194	371	615	4282	381
2018	21	6533	658	688	205	459	813	4277	386

2019	22	6241	665	674	198	482	859	4578	387
2020	23	6131	670	687	219	537	999	4648	425
2021	29	6097	694	698	236	556	1020	4674	447
2022	32	5998	856	710	251	597	1089	4872	480
2023	38	5984	901	719	260	609	1135	4966	503
2024	41	5984	914	724	274	623	1189	4999	501
Years	**PERCENTAGE CHANGE**								
2014-2015	2.94	0.33	11.23	-8.21	12.67	10.39	6.26	2.73	16.79
2015-2016	-5.71	-7.55	8.91	4.95	4.73	19.48	7.00	2.15	13.10
2016-2017	3.03	-0.39	8.91	1.52	9.60	0.82	5.85	1.28	7.63
2017-201	-38.24	-14.32	9.85	3.15	5.67	23.72	32.20	-0.12	1.31
2018-2019	4.76	-4.47	1.06	-2.03	-3.41	5.01	5.66	7.04	0.26
2019-2020	4.55	-1.76	0.75	1.93	10.61	11.41	16.30	1.53	9.82
2020-2021	26.09	-0.55	3.58	1.60	7.76	3.54	2.10	0.56	5.18
2021-2022	10.34	-1.62	23.34	1.72	6.36	7.37	6.76	4.24	7.38
2022-2023	18.75	-0.23	5.26	1.27	3.59	2.01	4.22	1.93	4.79
2023-2024	7.89	0.00	1.44	0.70	5.38	2.30	4.76	0.66	-0.40
Projection Coefficient	**3.44**	**-3.06**	**7.43**	**0.66**	**6.30**	**8.61**	**9.11**	**2.20**	**6.59**
Years	**PROJECTIONS**								
2025	42	5801	982	729	291	677	1297	5109	534
2026	44	5624	1055	734	310	735	1416	5221	569
2027	45	5452	1133	738	329	798	1545	5336	607
2028	47	5285	1218	743	350	867	1685	5454	647
2029	49	5123	1308	748	372	941	1839	5574	689
2030	50	4967	1405	753	395	1022	2006	5696	735

CONCLUSIONS

The analysis of agricultural machinery utilization in Sivas Province reveals that the region possesses a moderate but steadily improving level of mechanization within the context of Turkish agriculture. However, the mechanization level in Sivas remains below that of highly developed agricultural regions, reflecting both structural and economic constraints such as farm fragmentation, limited investment capacity, and variations in terrain and climate conditions.

Despite these limitations, the province exhibits considerable potential for further mechanization, particularly through the modernization of its existing machinery fleet and the adoption of energy-efficient and precision agriculture technologies. Continued government support programs, cooperative models for machinery sharing, and training initiatives for rural farmers can significantly enhance the effectiveness of machinery use. Strengthening local access to agricultural engineering services and credit mechanisms will also be vital for sustaining progress.

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Chapter 3

DETERMINATION OF BUMBLEBEE SPECIES AND THEIR ASSOCIATED FLORA IN KAYSERI PROVINCE[1]

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INTRODUCTION

The role of bees in pollination within agricultural areas and natural ecosystems is significant (Free, 1970). Another critical factor in pollination is the role of bumblebees, which are considered key pollinators in natural ecosystems (Williams, 1998; Benton, 2000; Aslan et al., 2017). Bumblebees (*Bombus* spp.) are among the most important pollinators of many plant species (Kırpık & Durdu, 2017). Several factors enhance the importance of bumblebees in the fertilization of greenhouse, cultivated, and wild plants: their large colony populations, relatively hairy and large body size, ability to forage under low temperatures and light intensities, and long tongues, which enable them to visit long-tubed flowers (Free, 1993; Gösterit & Gürel, 2005; Aslan et al., 2017). Bees play a crucial role in sustaining the survival of wild flowering plants (Corbet et al., 1992; Aslan et al., 2017). Bumblebees, in particular, are of great economic importance as pollinators in the cross-pollination of both wild and cultivated plants (Free, 1970; Loken, 1973; Özbek, 1976; Aslan et al., 2017).

Bumblebees visit a wide range of plants, including industrial crops, forage and pasture plants, fruit trees (stone fruits, pome fruits, berries, citrus, etc.), vegetables, medicinal and aromatic plants, as well as numerous wild and cultivated species in tree, shrub, and maquis forms (Aytekin & Çağatay, 1999; Özbek, 2011). Due to their critical role in pollinating many wild and cultivated plants, extensive research has been conducted on bumblebees, and they have been mass-reared commercially for use in pollination, particularly under protected cultivation (Free, 1993; Hines et al., 2006). The pollination efficiency of bumblebees in greenhouse crops, such as tomatoes, peppers, eggplants, and strawberries, has facilitated their widespread use in greenhouses, starting in 1987 in the Netherlands and subsequently in Belgium, France, and Germany (Aslan et al., 2017). In recent years, bumblebees have also been increasingly used in greenhouse and protected cultivation systems in countries such as Israel, the USA, Japan, Spain, and the United Kingdom (Cameron et al., 2007). The introduction of bumblebees into enclosed systems, such as greenhouses, has been considered a crucial step toward transitioning to organic farming. Their role has become even more crucial in the pollination of crops such as tomatoes, cucumbers and peppers, particularly in winter and early spring-when honeybees and other wild bees are less effective (Gürel et al., 2001).

In Turkey, bumblebees, supported by the Ministry of Agriculture as part of good agricultural practices, have recently become one of the most prominent areas of agricultural innovation. Their use as a natural alternative to hormones in crop production is encouraged to promote the transition to hormone-free fruit and vegetable production. Owing to its favourable topographic and climatic conditions, Turkey is particularly rich in bumblebee fauna (Reining, 1968, 1971; Özbek, 1983; Aslan et al., 2017). The high pollination efficiency

of bumblebees and the widespread presence of their natural populations in Mediterranean countries have led to their collection from the wild and large-scale export abroad since 1987 (Özbek, 1993). However, the destruction of nests, overharvesting from natural habitats, and the indiscriminate use of agrochemicals have caused severe declines in bumblebee populations in recent years.

Given the economic significance of bumblebees in the pollination of wild and cultivated plants, as well as their essential role in organic farming and their potential to reduce the ecological damage caused by hormones and similar practices, this study aimed to identify the bumblebee species found in Kayseri Province, determine their habitats, and examine their relationships with plants.

General Characteristics of Bumblebees

The most distinctive features that differentiate bumblebees from other bee species are their robust appearance and colourful hair. These relatively large bees usually measure more than 20 mm in length. Unlike many other bee species, their hindwings lack a jugal lobe (Aslan, 1997). Due to their long tongues, bumblebees are capable of pollinating a greater variety of plants compared to other bees. They typically build their nests underground. The lifespan of a colony is typically one year, and only mated females survive the winter (Aslan, 1997). In the spring, these mated females begin constructing nests, and the first eggs they lay develop into worker bees. Workers perform all colony tasks except egg-laying: they expand the nest, collect and store food, and prepare nectar pots to feed the larvae. Toward the end of summer, males and new queens emerge. At this stage, the colony declines, and the old queen dies (Alford, 1978; Borror et al., 1981).

Morphological Characteristics of Bumblebees

In the subfamily Bombinae, the head is either long or its longitudinal and transverse dimensions are approximately equal. On both sides, close to the lateral regions of the head, there is a well-developed pair of compound eyes (Aslan, 1997). Between the upper parts of the compound eyes, there are three simple eyes called ocelli (Figure 1).

A pair of antennae arises near the middle of the compound eyes. In females and workers, the antennae consist of 12 segments, while in males they have 13 segments and are generally longer (Prys-Jones & Corbet, 1987). The area between the compound eyes and the mandibles is referred to as the malar space. Below the antennal sockets is a structure called the clypeus. Just below the clypeus is a pair of pointed or flattened structures known as the labral tubercles, and immediately beneath these is the labrum lamella (Aslan, 1997).

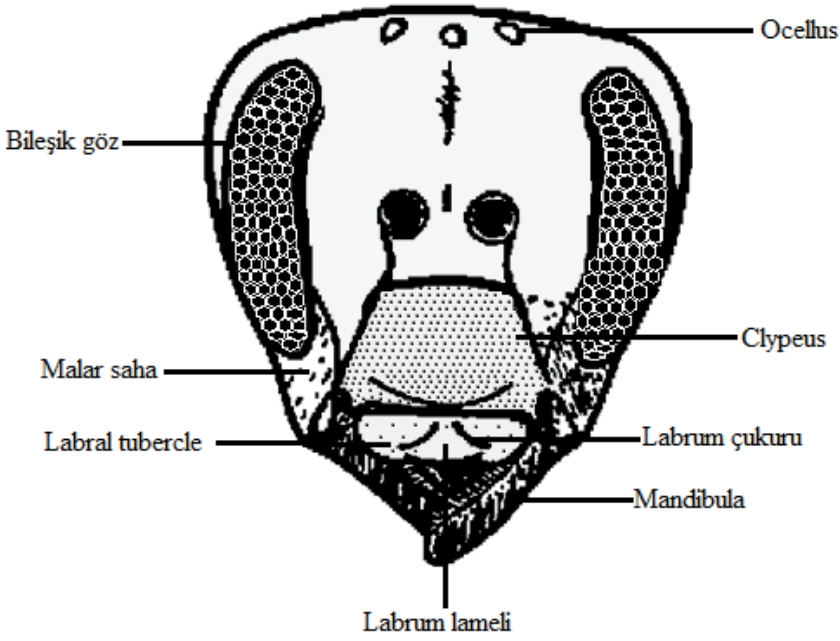

Figure 1. Head structure of bumblebees (modified from Stephen et al., 1969)

The thorax, near the head, consists of the collar, followed by structures called the interal band and scutellum. The abdomen is composed of six segments in females and workers, and seven segments in males, which are used for sex differentiation (Figure 2).

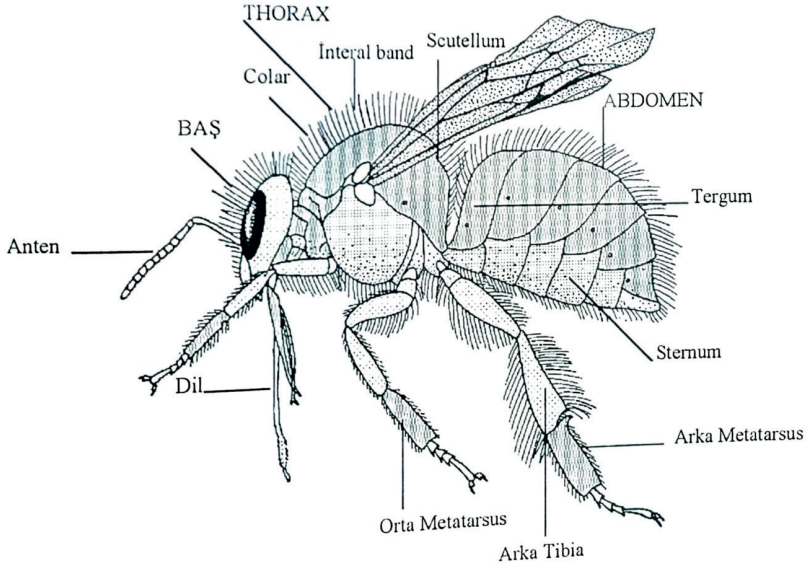

Figure 2. General body structure of bumblebees (modified from Hagen, 1994)

Determination of Bumblebee Species and Their Associated Flora in Kayseri Province

In this study conducted in Kayseri Province, a total of 232 bumblebees were collected, representing seven species and six subspecies across six subgenera within the subfamily Bombinae (Figure 5). The identified bumblebee species and subspecies were: *Bombus argillaceus*, *B. armeniacus*, *B. fragrans*, *B. humilis*, *B. incertus*, *B. melanurus*, *B. niveatus*, *B. persicus eversmaniellus*, *B. ruderarius simulatilis*, *B. subterraneus latreillellus*, *B. sylvarum daghestanicus*, *B. terrestris* subsp. *dalmatinus* and *B. zonatus apicalis*. The distribution areas of these species throughout Kayseri Province are presented in (Figure 4).

The host plants of these species and subspecies were determined to include: *Anchusa* sp., *Campsis* sp., *Carduus* sp., *Consolida* sp., *Cucurbita pepo*, *Echium italicum*, *Helianthus annuus*, *Impatiens balsamina*, *Jurinea* sp., *Lavandula angustifolia*, *Medicago sativa*, *Ononis spinosa*, *Phaseolus vulgaris*, *Prunus avium*, *Salvia* sp., *Sideritis* sp., *Stachys byzantina*, *Tilia* sp., *Trifolium pratense* and *Zinnia elegans* (Table 1, Figure 3).

Figure 3. Some of the plants visited by bumblebee species: a) Cucurbita pepo, b) Lavandula angustifolia, c) Echium italicum

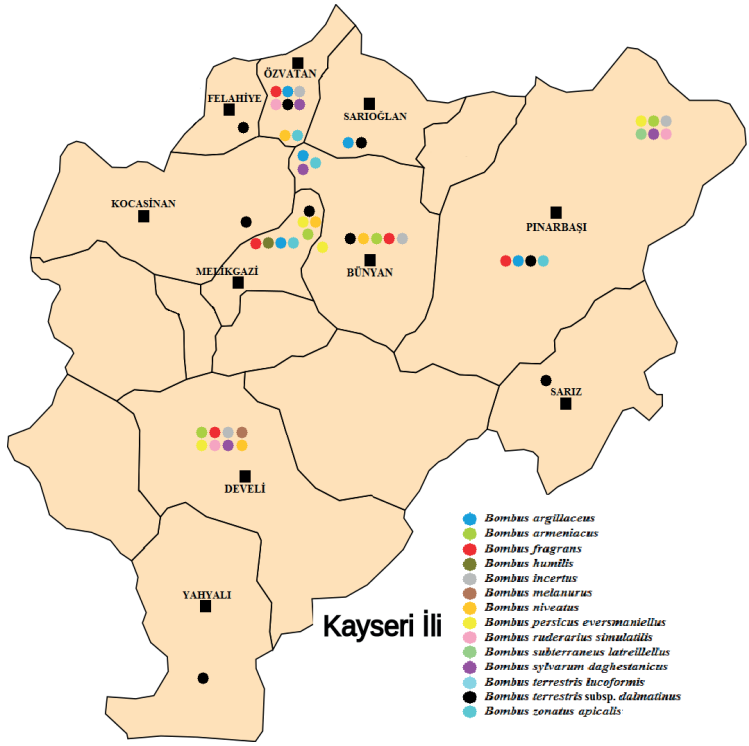

Figure 4. Distribution areas of bumblebee species across Kayseri Province (1140-2290 m)

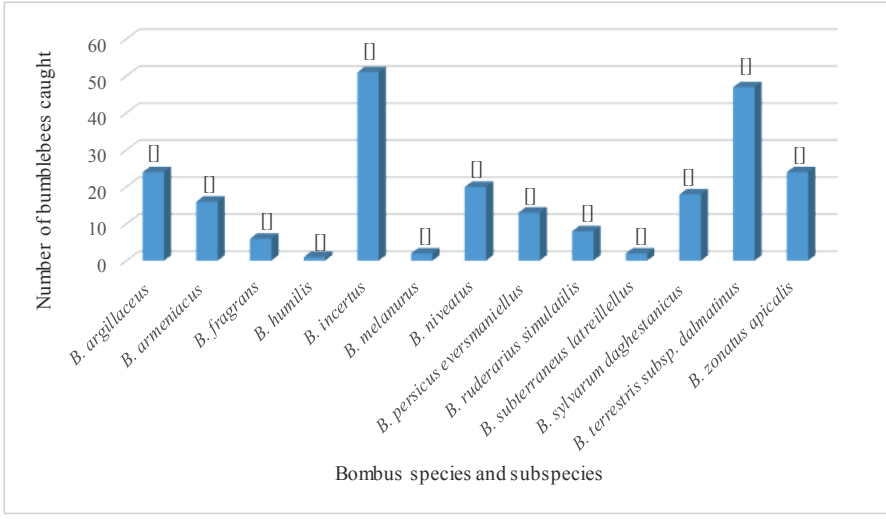

Figure 5. Distribution of the number of bumblebees captured by species

Table 1. Bumblebee species recorded in Kayseri Province and their visited host plants

Bombus Bee Species	*B. argillaceus*	*B. armeniacus*	*B. fragrans*	*B. humilis*	*B. incertus*	*B. melanurus*	*B. niveatus*	*B. persicus eversmaniellus*	*B. ruderarius simulatilis*	*B. subterraneus latreillellus*	*B. sylvarum daghestanicus*	*B. terrestris* subsp. *dalmatinus*	*B. zonatus apicalis*
Asteraceae													
Carduus sp.	-	+	-	-	+	-	-	+	+	+	+	-	-
Helianthus annuus	+	-	-	-	-	-	-	-	-	-	-	+	+
Jurinea sp.	-	-	-	-	+	-	-	-	-	-	-	-	-
Zinnia elegans	-	-	-	-	-	-	-	-	-	-	-	+	-
Balsaminaceae													
İmpatiens balsamina	-	-	-	-	-	-	-	-	-	-	-	+	-
Bignoniaceae													
Campsis sp.	-	-	-	-	-	-	-	-	-	-	-	+	-
Boraginaceae													
Anchusa sp.	+	+	+	-	+	+	+	+	+	-	+	-	+
Echium italicum	+	-	-	+	-	-	+	-	-	-	-	+	+
Cucurbitaceae													
Cucurbita pepo	+	-	-	-	-	-	-	-	-	-	-	+	-
Fabaceae													
Medicago sativa	+	-	-	-	-	-	-	-	-	-	-	-	-
Ononis spinosa													+
Phaseolus vulgaris	-	-	-	-	-	-	-	-	-	-	-	+	-
Trifolium pratense	+	-	-	-	-	-	-	-	-	-	-	+	-
Lamiaceae													
Lavandula angustifolia	-	-	-	-	-	-	-	-	-	-	-	+	-
Salvia sp.	+	+	+	-	+	-	+	-	-	-	-	+	+
Sideritis sp.	-	-	-	-	+	-	-	-	-	-	-	-	-
Stachys byzantina	-	-	-	-	-	-	-	-	-	-	-	-	+
Malvaceae													
Tilia sp.	-	-	-	-	-	-	-	-	-	-	-	+	-
Ranunculaceae													
Consolida sp.	+	-	-	-	-	-	-	-	-	-	-	+	+
Rosaceae													
Prunus avium	+	-	-	-	-	-	-	-	-	-	-	-	-
Toplam Konukçu Sayısı	9	3	2	1	5	1	3	2	2	1	2	12	7

(+):var,(-): yok

Bumblebee Species and Subspecies Found in Kayseri Province *Bombus* (*Megabombus*) *argillaceus* (Scopoli, 1763)

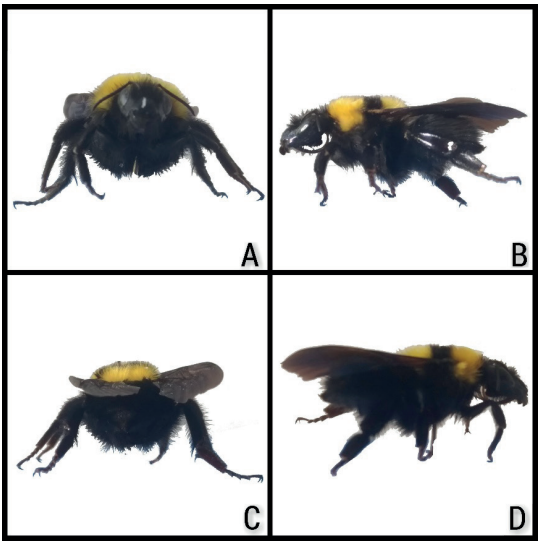

Figure 6. Bombus (Megabombus) argillaceus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: The body length ranges from 20 to 23 mm. The head hairs and vertex are covered with black hairs. On the thorax, the collar is broad and yellow, the interal band is black, and the scutellum is covered with yellow hairs. The lateral sides of the thorax are black. On the abdomen, the lateral sides of the first segment are yellow, while the central part is covered with black hairs. The other segments are covered with black hairs, although white hairs may appear on the fourth segment.

The longitudinal dimension of the head is much greater than the transverse. The clypeus is long and convex, with a depression extending from the upper to the middle region, marked with dense punctures. The malar space is very long, and the labrum depression is deep and wide. The wings are dark brown, and the legs are black.

Worker: The body length ranges from 13 to 16 mm. The head and thorax are similar in colouration and structure to the queen's. The first abdominal segment is yellow with a few black hairs. The second and third segments are black; the upper part of the fourth segment features a thin black band, with the remaining part white. The fifth segment is white, and the sixth segment is covered with black hair.

Male: The body length ranges from 14 to 17 mm. The head bears a mixture of black and yellow hairs, with black hairs being longer. On the thorax, the dorsal and lateral parts of the collar are yellow, the interal band is black, and the scutellum is covered with yellow hairs. On the abdomen, the first segment

is yellow, the second and third segments are black, the fourth and fifth segments are white, and the sixth segment is white with some black hairs. The last segment is black; the vertex is yellow with some black hairs interspersed. The leg hairs are black.

Examined material: Kayseri-Melikgazi-Turan, 2 females, 18.05.2021, 19.05.2021; Kayseri-Sarıoğlan, 1 female, 13.06.2021; Kayseri-Melikgazi-Sarımsaklı, 1 female, 23.06.2021; Kayseri-Melikgazi-Subaşı, 1 female, 03.07.2021; Kayseri-Bünyan-Koramaz Mountain, 8 workers, 11.07.2021; Kayseri-Bünyan-Karahıdırlı, 3 workers, 13.07.2021; Kayseri-Özvatan-Kermelik, 3 workers, 13.07.2021; Kayseri-Özvatan, 3 workers, 13.07.2021; Kayseri-Pınarbaşı, 1 female, 10.08.2021; Kayseri-Melikgazi-Ağırnas, 1 female, 18.08.2021.

Bombus (*Thoracobombus*) *armeniacus* **Radoszkowski, 1877**

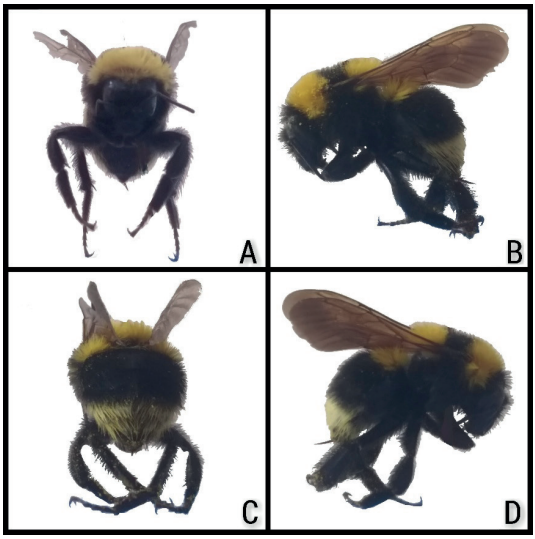

Figure 7. Bombus (Thoracobombus) armeniacus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 17 to 20 mm. The head is covered with black hair. On the thorax, the collar is broad and yellow, the interal band is black, and the scutellum and lateral sides are yellow. The first three segments of the abdomen are dirty yellow, the fourth and fifth segments are yellow, and the last segment is black.

The longitudinal dimension of the head exceeds its transverse dimension. The clypeus is prominently curved and covered with small punctures. The malar space is longer than its width and smooth. The labrum depression is deep and very wide, and the labral tubercles are pointed and angular. The area between the lateral ocellus and the compound eye is narrow; the region near the compound eye is punctured, while the remaining part is smooth. This area is more than twice the diameter of the lateral ocellus.

Worker: Body length ranges from 11 to 14 mm. Other characteristics are similar to those of the queen.

Male: Body length ranges from 13 to 16 mm. The head is covered with black hair interspersed with a few strands of dirty white hair. The vertex is black with a few mixed dirty white hairs. On the thorax, the interal band is narrow and black, while the collar and scutellum, along with their dorsal, lateral, and ventral surfaces, are dirty white. The first three abdominal segments are light yellow, and the remaining four segments have brownish-yellow hairs. The lateral sides of the last segment bear black hairs. The femora are dirty white.

Examined material: Kayseri-Melikgazi-Subaşı, 1 queen, 1 worker, 1 male, 03.07.2021, 11.06.2021, 03.07.2021; Kayseri-Bünyan-Koramaz Mountain, 7 workers, 11.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 3 workers, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 3 queens, 12.07.2021.

Bombus (*Subterraneobombus*) *fragrans* **Pallas, 1771**

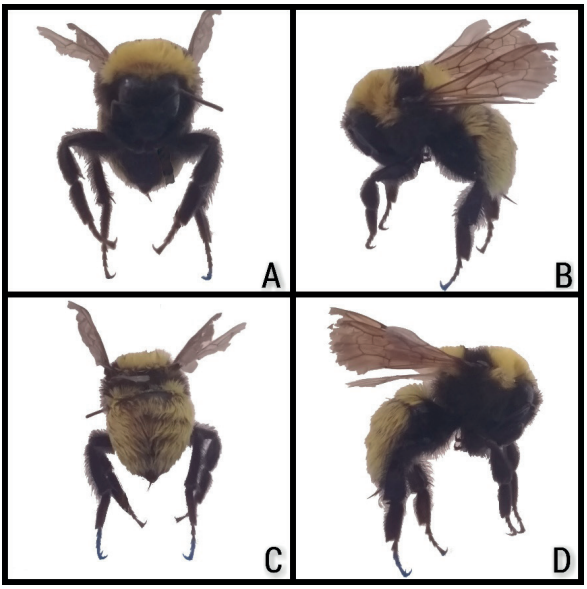

Figure 8. Bombus (Subterraneobombus) fragrans: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 28 to 31 mm. The head is covered with black hair, and the vertex has a yellowish hue. On the thorax, the interal band is broad and black, the collar is yellow, and the scutellum is covered with yellow hairs. The first five abdominal segments are yellow, and the last segment bears black hairs.

The longitudinal dimension of the head exceeds its transverse dimension. The clypeus is broad and densely punctured. The malar space is slightly longer than its distal width, and the labrum depression is broad and deep. The lateral

sides of the malar space are finely punctured. The surface of the last abdominal segment is rough, and the legs are black.

Worker: Body length ranges from 17 to 21 mm, with other characteristics similar to the queen.

Male: Body length ranges from 18 to 22 mm, with characteristics similar to those of the queen and worker. The seventh abdominal segment is black.

Examined material: Kayseri-Melikgazi-Turan, 2 males, 15.06.2021, 06.08.2021; Kayseri-Bünyan-Koramaz Mountain, 2 workers, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 1 queen, 12.07.2021; Kayseri-Özvatan, 1 worker, 13.07.2021.

Bombus (*Thoracobombus*) *humilis* **Illiger, 1806**

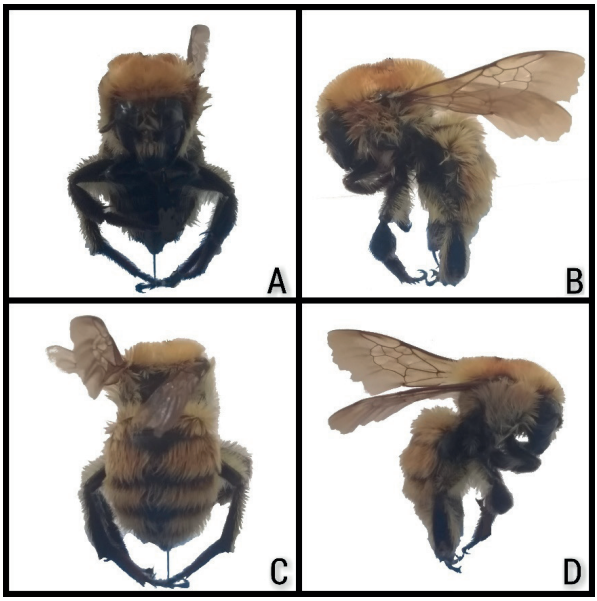

Figure 9. Bombus (Thoracobombus) humilis: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 16 to 18 mm. The head is covered with short black hair. The hairs on the sixth tergite are black, while the hairs on the abdominal sterna are reddish.

The longitudinal dimension of the head is longer than the transverse. The bare area lateral to the lateral ocellus, separated from the compound eye by a band of punctures, is of medium size. The labrum depression is broad and deep, and the labral tubercles are sparsely punctured and pointed. The longitudinal dimension of the clypeus exceeds its transverse dimension, and its surface has both fine and large dense punctures. The length of the malar space is twice its width, with a sparsely punctuated surface.

Worker: Body length ranges from 7 to 10 mm, with other characteristics

similar to the queen.

Male: Body length ranges from 9 to 11 mm. The longitudinal dimension of the head slightly exceeds its transverse dimension. The thorax lacks an interal band. The longitudinal dimension of the clypeus is nearly equal to its transverse dimension. The malar space is 1.5 times as long as wide and has small punctures. The hairs on abdominal segments 1–6 are lemon yellow, the sixth segment is black, and the hairs on the abdominal sternum are lemon yellow.

Examined material: Kayseri-Melikgazi-Turan, 1 worker, 15.08.2021.

Bombus (*Melanobombus*) *incertus* **Morawitz, 1881**

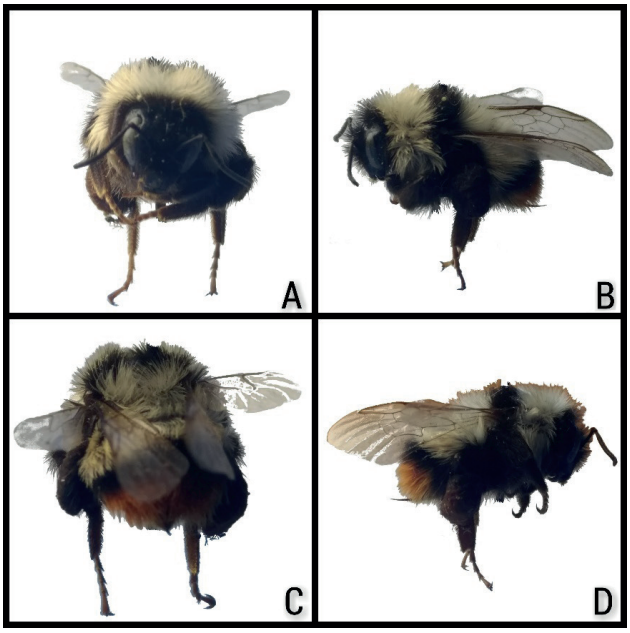

Figure 10. Bombus (Melanobombus) incertus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 15 to 22 mm. The head is covered with black hair, and the vertex is black. On the thorax, the interal band is black, while the collar, scutellum, and lateral sides of the thorax are covered with white hairs. The first and second abdominal segments are white, the third segment is black, the fourth and fifth segments are reddish-brown, and the sixth segment bears light reddish hairs. The leg hairs are black.

The transverse dimension of the head is shorter than its longitudinal dimension. The clypeus is broad and laterally flattened, with a finely punctured surface. The labrum depression is broad and deep, and the labral tubercles are angular with pointed tips. The labrum lamella is broad and thickens towards the distal end. The distal width of the malar space slightly exceeds its length. The sixth abdominal segment has a prominent raised structure with large

punctures.

Worker: Body length ranges from 9 to 13 mm, with other characteristics similar to the queen.

Male: Body length ranges from 11 to 16 mm. The head hairs are white, and the hairs on the hind tibiae are brown. The remaining body characteristics are similar to those of the queen and worker.

Examined material: Kayseri-Bünyan-Koramaz Mountain, 29 workers, 11.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 13 workers, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 3 queens, 1 worker, 12.07.2021; Kayseri-Özvatan, 5 workers, 13.07.2021.

Bombus (*Subterraneobombus*) *melanurus* **Lepeletier 1836**

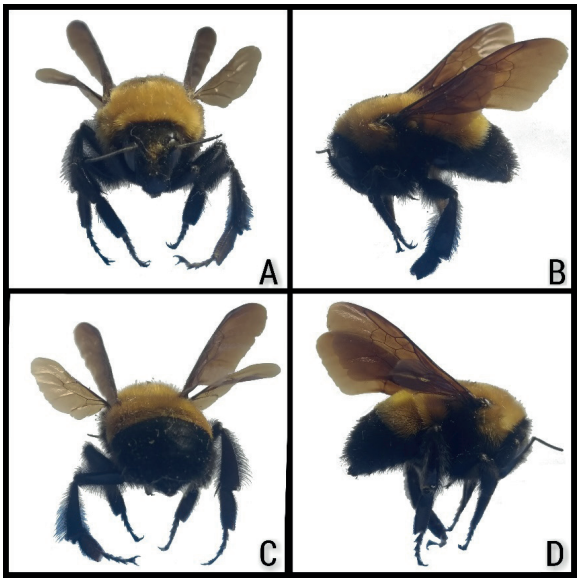

Figure 11. Bombus (Subterraneobombus) melanurus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 28 to 30 mm. The head is covered with black hair, and the vertex is black. The thorax lacks an interal band; the entire thorax is brownish-yellow, with lateral sides yellow, and the legs are black. On the abdomen, the first and second segments are brownish-yellow, while the remaining segments are covered with black hairs.

The longitudinal dimension of the head is much greater than its transverse dimension. The surface of the clypeus has small punctures, the labrum depression is broad and deep, and the malar space is longer than its width with a finely punctured surface. The surface of the last abdominal segment is wrinkled.

Worker: Body length ranges from 16 to 19 mm, with other characteristics similar to the queen.

Male: Body length ranges from 18 to 24 mm. The head bears black hairs mixed with yellow hairs. The thorax is brownish-yellow. On the abdomen, the first and second segments are brownish-yellow, while the remaining five segments are covered with black hairs.

Examined material: Kayseri-Develi-Erciyes Mountain, 1 queen, 1 worker, 12.07.2021.

Bombus (*Sibiricobombus*) *niveatus* **Kriechbaumer, 1870**

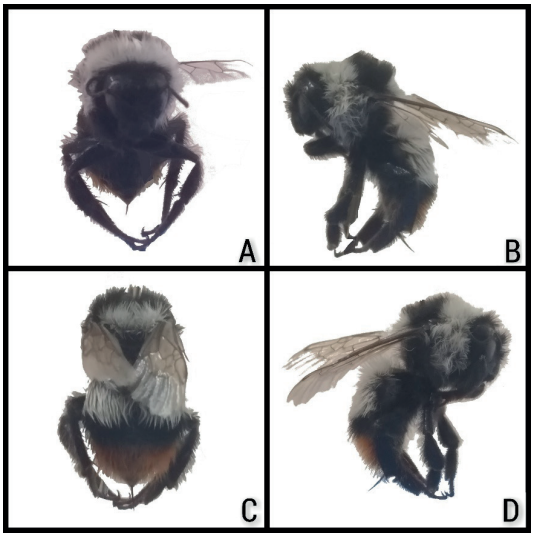

Figure 12. Bombus (Sibiricobombus) niveatus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 16 to 21 mm. The head hairs are black, and the vertex is black. On the thorax, the interal band is black, while the collar, scutellum, lateral, and dorsal surfaces are white. The first two abdominal segments are white, the third segment is black, and the remaining three segments are reddish-brown. The leg hairs are black.

The longitudinal dimension of the head exceeds its transverse dimension. The clypeus is distinctly long and convex, with a punctured surface; the apex has slightly flattened, large punctures. The labrum depression is narrow and deep. The labral tubercles are pointed on the inner side, and the labrum lamella is narrow and thickened at the tip. The malar space is much longer than its distal width and punctured. The area between the compound eye and lateral ocellus is narrow, slightly less than twice the ocellus diameter. The surface of the last abdominal segment is very rough and matte.

Worker: Body length ranges from 10 to 15 mm, with other characteristics similar to the queen.

Male: Body length ranges from 13 to 17 mm. The clypeus hairs are white, and around the antennal sockets, a mixture of white and black hairs occurs. The vertex hairs are white in the centre and black on the sides. Thorax and abdomen hairs are similar to those of the queen. Leg hairs and dorsal surface are black, ventral surface is white, and tibial hairs are brownish.

Examined material: Kayseri-Bünyan-Koramaz Mountain, 2 queens, 13 workers, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 2 workers, 12.07.2021; Kayseri-Özvatan-Kermelik, 1 worker, 13.07.2021; Kayseri-Melikgazi-Güzelköy, 2 workers, 14.07.2021, 17.07.2021.

Bombus (*Thoracobombus*) *persicus eversmanniellus* **Skorikov, 1922**

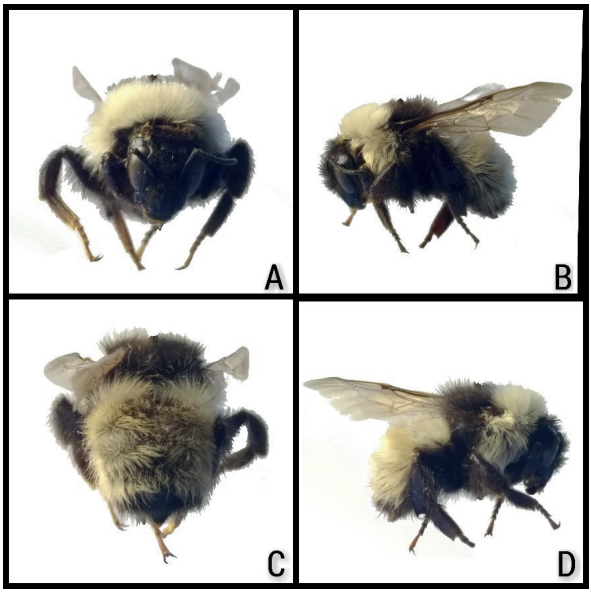

Figure 13. Bombus (Thoracobombus) persicus eversmanniellus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 19 to 23 mm. The head hairs and vertex are black. On the thorax, the collar is broad and white, the lateral sides are white, and there is no interal band; the remaining thorax and lateral parts are black. On the abdomen, the first four segments are white, but the second segment bears orange hairs. The fifth and sixth segments are black, with white hairs on the lateral and ventral parts of the fifth segment. The legs are black.

The longitudinal dimension of the head slightly exceeds its transverse dimension. The surface of the clypeus is sparsely punctured. The malar space is slightly longer than its width. The labrum lamella is broad and of moderate depth. The labral tubercles are flat and without angles.

Worker: Body length ranges from 12 to 15 mm, with other characteristics similar to the queen.

Male: Body length ranges from 14 to 16 mm. The hairs on the head and thorax are similar to those of the queen and worker. The first four abdominal segments have white and light orange hairs, while the remaining three segments are covered with black hairs.

Examined material: Kayseri-Bünyan, 1 queen, 1 worker, 01.07.2021; Kayseri-Melikgazi-Subaşı, 2 queens, 1 worker, 2 males, 03.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 1 worker, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 5 queens, 12.07.2021.

Bombus (*Thoracobombus*) *ruderarius simulatilis* **(Muller, 1776)**

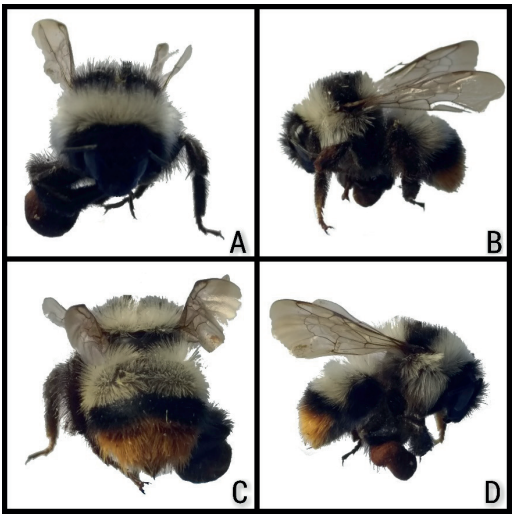

Figure 14. Bombus (Thoracobombus) ruderarius simulatilis: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 16 to 19 mm. The head is covered with black hair, and the vertex is black. On the thorax, the collar is broad and smoky white, the interal band is black, and the scutellum, as well as the lateral and ventral sides of the thorax, are smoky white. The first and second abdominal segments are smoky white; the third segment is black with reddish-brown hairs on the ventral, lateral, and central parts. The remaining three segments are reddish-brown. The labrum lamella is thick, the labral tubercles are flat, and the labrum depression is wide. The coxa and leg hairs are black. The surface of the last abdominal segment is coarsely punctured and white.

Worker: Body length ranges from 10 to 14 mm, with other characteristics similar to the queen.

Male: Body length ranges from 13 to 15 mm. The head bears a mixture of black and white hairs. Leg hairs are black, and the remaining body features are similar to those of the queen and worker.

Examined material: Kayseri-Pınarbaşı-Ziyarettepesi, 1 worker, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 3 queens, 2 workers, 12.07.2021; Kayseri-Özvatan, 2 workers, 13.07.2021.

Bombus (*Subterraneobombus*) *subterraneus latreillellus* **Kirby, 1802**

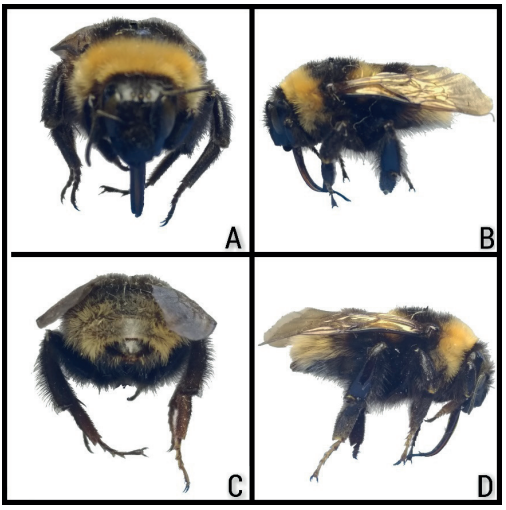

Figure 15. Bombus (Subterraneobombus) subterraneus latreillellus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 19 to 22 mm. The head is covered with black hair interspersed with yellow hair. On the thorax, the interal band is wide, and the hairs outside this band are yellow. The scutellum is smoky white, and the lateral and ventral sides of the thorax are smoky white. On the abdomen, the first segment has dense yellow hairs on the sides and sparse black hairs in the centre; the second segment has apical yellow, long, dense hairs, while the remaining parts are black, short, and sparse. The third, fourth, and fifth segments are white or dirty white, with some black hairs at the base of the third segment. The last segment is black.

The longitudinal dimension of the head exceeds the transverse dimension. The middle of the clypeus is flat and shiny, while the sides are coarsely punctured. The malar space is longer than its width. The labrum depression is deep and wide. The surface of the last abdominal segment is granular.

Worker: Body length ranges from 13 to 16 mm, with other characteristics similar to the queen. In some individuals, the first and second abdominal segments may bear black hairs.

Male: Body length ranges from 15 to 17 mm. The head has a mix of black and yellow hairs, with the yellow hairs shorter and highly branched. The thorax is yellow dorsally and laterally outside the interal band. On the abdomen, the middle of the sixth and seventh segments is black, the sides are yellow, and the

other segments are yellow, though black hairs are present among the yellow hairs on the second and third segments; in some individuals, black hairs are also present on the fourth and fifth segments.

Examined material: Kayseri-Pınarbaşı-Ziyarettepesi, 2 workers, 11.07.2021.

Bombus (*Thoracobombus*) *sylvarum daghestanicus* **(L., 1761)**

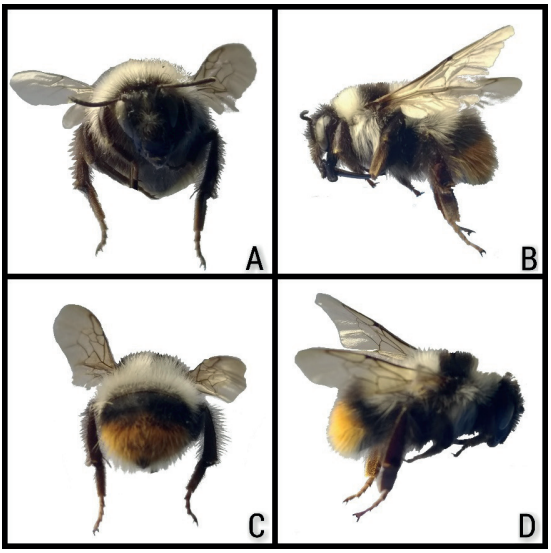

Figure 16. Bombus (Thoracobombus) sylvarum daghestanicus: A) Anterior view, B) Lateral view, C) Posterior view, D) Lateral view

Queen: Body length ranges from 16 to 18 mm. The head is covered with black hair interspersed with white hair. On the thorax, the collar is broad and smoky white, the interal band is black, the scutellum is smoky white, and the lateral and ventral sides of the thorax are smoky white. The first and second abdominal segments are smoky white; the third segment is black with reddish-brown hairs on the ventral, lateral, and central parts. The remaining three segments are reddish-brown.

The longitudinal dimension of the head is slightly longer than the transverse dimension. The clypeus is shorter than its width, with small punctures scattered among larger punctures. The malar space is slightly longer than its distal width. The labrum lamella is sharp, the labral tubercle is prominent, and the labrum depression is deep. The surface of the last abdominal segment is coarsely punctured and white.

Worker: Body length ranges from 8 to 13 mm, with other characteristics similar to the queen.

Male: Body length ranges from 10 to 14 mm. The head hairs are white, with some black hairs near the antennal sockets. The seventh abdominal

segment is reddish-brown, and the tibia bears reddish hairs. Other features are similar to those of the queen and worker.

Examined material: Kayseri-Pınarbaşı-Ziyarettepesi, 1 queen, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 10 queens, 3 workers, 12.07.2021; Kayseri-Bünyan-Karahıdırlı, 3 workers, 13.07.2021; Kayseri-Özvatan, 1 worker, 13.07.2021.

Bombus (*Bombus*) *terrestris* subsp. *dalmatinus* **Dalla Torre, 1882**

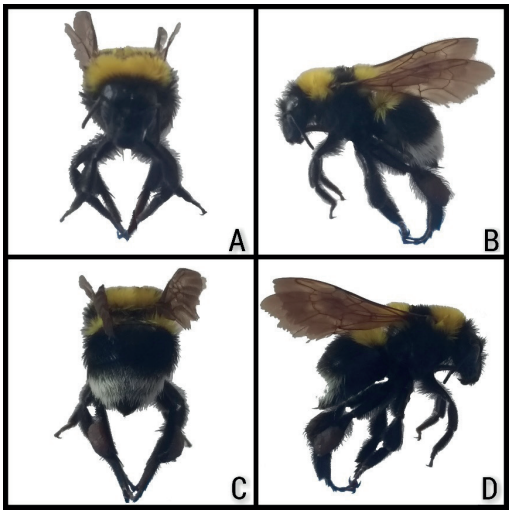

Figure 17. Bombus (Bombus) terrestris subsp. *dalmatinus A) Anterior, B) Lateral, C) Posterior, D) Lateral view*

Queen: Body length ranges from 17 to 23 mm. The head has a mix of black and dark brownish-black hairs; the vertex is black. Thorax with a broad lemon-yellow collar extending laterally, an interal band and a scutellum black. Abdomen: first segment black, second segment lemon-yellow with black hairs ventrally, third segment black, fourth and fifth segments white, sixth segment black with few white hairs. Legs black.

Worker: Body length ranges from 9 to 16 mm; other characters are similar to the queen.

Male: Body length ranges from 12 to 17 mm. Head with mixed yellow and black hairs; vertex black with few scattered yellow hairs. Thorax with lemon-yellow collar extending ventrally; interal band and scutellum black. Abdomen: first segment black with yellow hairs on sides and middle, second segment yellow, third segment black, fourth, 5th, and sixth segments yellowish-white, seventh segment with mixed black and white hairs.

Examined material: Kayseri-Melikgazi-Sarımsaklı, 1 worker, 2 workers, 1 worker, 1 male, 1 male, 1 worker, 1 male, 1 worker, 23.06.2021, 04.07.2021, 08.07.2021, 08.07.2021, 01.08.2021, 02.08.2021, 02.08.2021, 07.08.2021; Kayseri-

Melikgazi-Turan, 1 male, 1 worker, 1 worker, 3 workers, 2 workers, 2 workers, 18.05.2021, 16.06.2021, 07.07.2021, 18.07.2021, 15.08.2021, 24.08.2021; Kayseri-Melikgazi-Subaşı, 2 workers, 3 workers, 11.06.2021, 03.07.2021; Kayseri-Melikgazi-Güzelköy, 2 workers, 1 worker, 1 male, 18.06.2021, 14.07.2021, 17.07.2021; Kayseri-Yahyalı, 2 workers, 2 workers, 21.08.2021, 22.08.2021; Kayseri-Pınarbaşı, 3 workers, 10.08.2021; Kayseri-Melikgazi-Gesi, 2 workers, 10.06.2021; Kayseri-Melikgazi-Ağırnas, 2 workers, 18.08.2021; Kayseri-Kocasinan-Çavuşağa, 2 workers, 22.06.2021; Kayseri-Sarız, 2 workers, 11.08.2021; Kayseri-Kocasinan-Gömeç, 1 worker, 06.07.2021; Kayseri-Bünyan, 1 worker, 02.07.2021; Kayseri-Sarıoğlan, 1 worker, 13.06.2021; Kayseri-Felahiye, 1 worker, 15.06.2021.

Bombus (*Thoracobombus*) *zonatus apicalis* **Moravitz, 1875**

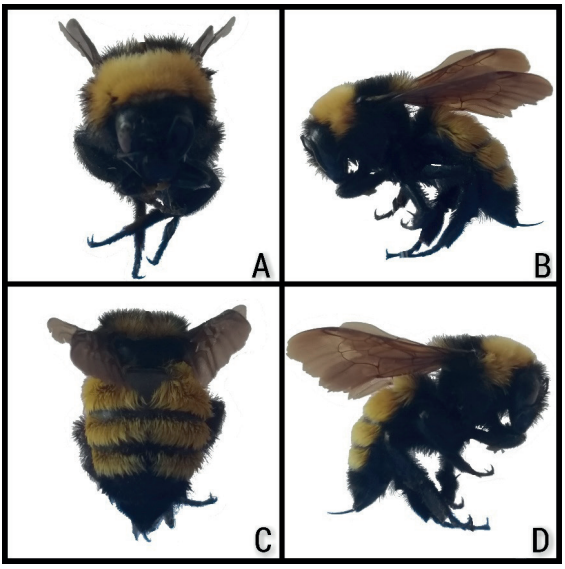

Figure 18. Bombus (Thoracobombus) zonatus apicalis A) Anterior, B) Lateral, C) Posterior, D) Lateral view

Queen: The body size ranges between 17 and 19 mm. The head bears a mix of yellow and black hairs, and the vertex is black. On the thorax, the collar is extensive and yellow, the interal band is black, and the scutellum is very narrow, yellow with a few black hairs. The first four abdominal segments are yellow, while the remaining two segments are covered with black hairs. The longitudinal section of the head is slightly longer than its width. The clypeus surface is dotted with small and large punctures on the sides and shiny in the middle. The malar area's length slightly exceeds its distal width. The labrum cavity is narrow and moderately deep. The labral tubercle is slightly raised with very large punctures on its surface.

Worker: Body size varies between 12 and 14 mm, with other features similar to the queen.

Male: Body size ranges between 12 and 15 mm. The thorax is similar to that of the queen and worker. The first five abdominal segments are yellow, the sixth segment is black with yellow hairs on the sides, and the seventh segment is black.

Examined material: Kayseri-Melikgazi-Turan, 1 female, 1 worker, 07.07.2021; Kayseri-Pınarbaşı, 1 female, 10.08.2021; Kayseri-Bünyan-Koramaz Dağı, 1 female, 9 workers, 11.07.2021; Kayseri-Bünyan-Karahıdırlı, 1 female, 8 workers, 13.07.2021; Kayseri-Özvatan, 1 worker, 13.07.2021; Kayseri-Özvatan-Kermelik, 1 worker, 13.07.2021.

As a result of this study, 13 bumblebee species visiting 20 plant species belonging to 10 different plant families were identified.

Subgenus: *Megabombus Dalla* Torre, 1880

Species: *Bombus argillaceus* (Scopoli, 1763)

Occurrence Plants: *Anchusa* sp. L., *Consolida* sp. Gray, *Cucurbita pepo* L., *Echium italicum* L., *Helianthus annuus* L., *Medicago sativa* L., *Prunus avium* L., *Salvia* sp. L., *Trifolium pratense* L.

Altitude: 1140-1525 m

Localities: Kayseri-Melikgazi-Turan, 2 specimens, 18.05.2021, 19.05.2021; Kayseri-Sarıoğlan, 1 specimen, 13.06.2021; Kayseri-Melikgazi-Sarımsaklı, 1 specimen, 23.06.2021; Kayseri-Melikgazi-Subaşı, 1 specimen, 07.03.2021; Kayseri-Bünyan-Koramaz Dağı, 8 specimens, 07.11.2021; Kayseri-Bünyan-Karahıdırlı, 3 specimens, 07.13.2021; Kayseri-Özvatan-Kermelik, 3 specimens, 07.13.2021; Kayseri-Özvatan, 3 specimens, 07.13.2021; Kayseri-Pınarbaşı, 1 specimen, 08.10.2021; Kayseri-Melikgazi-Ağırnas, 1 specimen, 08.18.2021.

Subgenus: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus armeniacus* Radoszkowski, 1877

Occurrence Plants: *Anchusa* sp. L., *Carduus* sp. L., *Salvia* sp. L.

Altitude: 1375-2290 m

Localities: Kayseri-Melikgazi-Subaşı, 3 specimens, 03.07.2021; Kayseri-Bünyan-Koramaz Dağı, 7 specimens, 11.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 3 specimens, 11.07.2021; Kayseri-Develi-Erciyes Dağı, 3 specimens, 12.07.2021.

Subspecies: *Subterraneobombus* Vogt, 1911

Species: *Bombus fragrans* Pallas, 1771

Occurrence Plants: *Anchusa* sp. L., *Salvia* sp. L.

Altitude: 1300-2200 m

Locations: Kayseri-Melikgazi-Turan, 2 specimens 15.06.2021, 06.08.2021; Kayseri-Bünyan-Koramaz Mountain, 2 specimens 11.07.2021; Kayseri-Develi-Erciyes Mountain, 1 specimens 12.07.2021; Kayseri-Özvatan, 1 specimens 13.07.2021.

Subspecies: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus humilis* Illiger, 1806

Occurrence Plants:*Echium italicum* L.

Altitude: 1300 m

Locations: Kayseri-Melikgazi-Turan, 1 specimen, 15.08.2021.

Subspecies: *Melanobombus* Dalla Torre, 1880

Species: *Bombus incertus* Morawitz, 1881

Occurrence Plants: *Anchusa* sp. L., *Carduus* sp. L., *Jurinea* sp. Cass., *Salvia* sp. L., *Sideritis* sp. L.

Altitude: 1420-2200 m

Locations: Kayseri-Bünyan-Koramaz Dağı, 29 specimens, 11.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 13 specimens, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 4 specimens, 12.07.2021; Kayseri-Özvatan, 5 specimens, 13.07.2021.

Subspecies: *Subterraneobombus* Vogt, 1911

Species: *Bombus melanurus* Lepeletier, 1836

Occurrence Plants: *Anchusa* sp. L.

Altitude: 2135-2200 m

Locations: Kayseri-Develi-Erciyes Mountain, 2 specimens, 12.07.2021.

Subspecies: *Sibiricobombus* Vogt, 1911

Species: *Bombus niveatus* Kriechbaumer, 1870

Occurrence Plants:*Anchusa* sp. L., *Salvia* sp. L., *Echium italicum* L.

Altitude: 1320-2200 m

Locations: Kayseri-Bünyan-Koramaz Mountain, 15 specimens, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 2 specimens, 12.07.2021; Kayseri-Özvatan-Kermelik, 1 specimens, 13.07.2021; Kayseri-Melikgazi-Güzelköy, 2 specimens, 14.07.2021, 17.07.2021.

Subspecies: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus persicus eversmaniellus* (Skorikov, 1922)

Occurrence Plants: *Anchusa* sp. L., *Carduus* sp. L.

Altitude: 1325-2290 m

Locations: Kayseri-Bünyan, 2 specimens, 01.07.2021; Kayseri-Melikgazi-Subaşı, 5 specimens, 03.07.2021; Kayseri-Pınarbaşı-Ziyarettepesi, 1 specimen, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 5 specimens, 12.07.2021.

Subspecies: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus ruderarius simulatilis* Muller, 1776

Occurrence Plants: *Anchusa* sp. L., *Carduus* sp. L.

Altitude: 1420-2200 m

Locations: Kayseri-Pınarbaşı-Ziyarettepesi, 1 specimen, 11.07.2021; Kayseri-Develi-Erciyes Dağı, 5 specimens, 12.07.2021; Kayseri-Özvatan, 2 specimens, 13.07.2021

Subspecies: *Subterraneobombus* Vogt, 1911

Species: *Bombus subterraneus latreillellus* Kirby, 1802

Occurrence Plants: *Carduus* sp. L.

Altitude: 1800 m

Locations: Kayseri-Pınarbaşı-Ziyarettepesi, 2 specimens, 11.07.2021.

Subspecies: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus sylvarum daghestanicus* (L., 1761)

Occurrence Plants: *Anchusa* sp. L., *Carduus* sp. L.

Altitude: 1190-2200 m

Locations: Kayseri-Pınarbaşı-Ziyarettepesi, 1 specimen, 11.07.2021; Kayseri-Develi-Erciyes Mountain, 13 specimens, 12.07.2021; Kayseri-Bünyan-Karahıdırlı, 3 specimens, 13.07.2021; Kayseri-Özvatan, 1 specimens, 13.07.2021.

Subgenus: *Bombus* Latreille, 1802

Species: *Bombus terrestris* subsp. *dalmatinus* Dalla Torre, 1882

Occurrence Plants: *Campsis* sp. Lour., *Consolida* sp. Gray, *Cucurbita pepo* L., *Echium italicum* L., *Helianthus annuus* L., *Phaseolus vulgaris* L., *Impatiens balsamina* L., *Lavandula angustifolia* Mill., *Salvia* sp. L., *Tilia* sp. L., *Trifolium pratense* L., *Zinnia elegans* Jacg.

Altitude: 1150-1575 m

Locations: Kayseri-Melikgazi-Turan, 10 specimens, 18.05.2021, 16.06.2021, 07.07.2021, 18.07.2021, 15.08.2021, 24.08.2021; Kayseri-Melikgazi-Gesi, 2

specimens, 10.06.2021; Kayseri-Melikgazi-Subaşı, 5 specimens, 11.06.2021, 03.07.2021; Kayseri-Sarıoğlan, 1 specimens, 13.06.2021, Kayseri-Felahiye, 1 specimens, 15.06.2021; Kayseri-Melikgazi-Güzelköy, 4 specimens, 18.06.2021, 14.07.2021, 17.07.2021; Kayseri-Kocasinan-Çavuşağa, 2 specimens, 22.06.2021; Kayseri-Melikgazi-Sarımsaklı, 9 specimens, 23.06.2021, 04.07.2021, 08.07.2021, 01.08.2021, 02.08.2021, 07.08.2021; Kayseri-Bünyan, 1 specimens, 02.07.2021; Kayseri-Kocasinan-Gömeç, 1 specimens, 06.07.2021; Kayseri-Pınarbaşı, 3 specimens, 10.08.2021; Kayseri-Melikgazi-Ağırnas, 2 specimens, 18.08.2021; Kayseri-Yahyalı, 4 specimens, 21.08.2021 and 22.08.2021.

Subspecies: *Thoracobombus* Dalla Torre, 1880

Species: *Bombus zonatus apicalis* Moravitz, 1875

Occurrence Plants: *Anchusa* sp. L., *Consolida* sp. Gray, *Echium italicum* L., *Helianthus annuus* L., *Ononis spinosa* L., *Salvia* sp. L., *Stachys byzantina* K.Koch

Altitude: 1140-1525 m

Locations: Kayseri-Melikgazi-Turan, 2 specimens, 07.07.2021; Kayseri-Bünyan-Koramaz Dağı, 10 specimens, 11.07.2021; Kayseri-Bünyan-Karahıdırlı, 9 specimens, 13.07.2021; Kayseri-Özvatan, 1 specimen, 13.07.2021; Kayseri-Özvatan-Kermelik, 1 specimen, 13.07.2021; Kayseri-Pınarbaşı, 1 specimen, 10.08.2021.

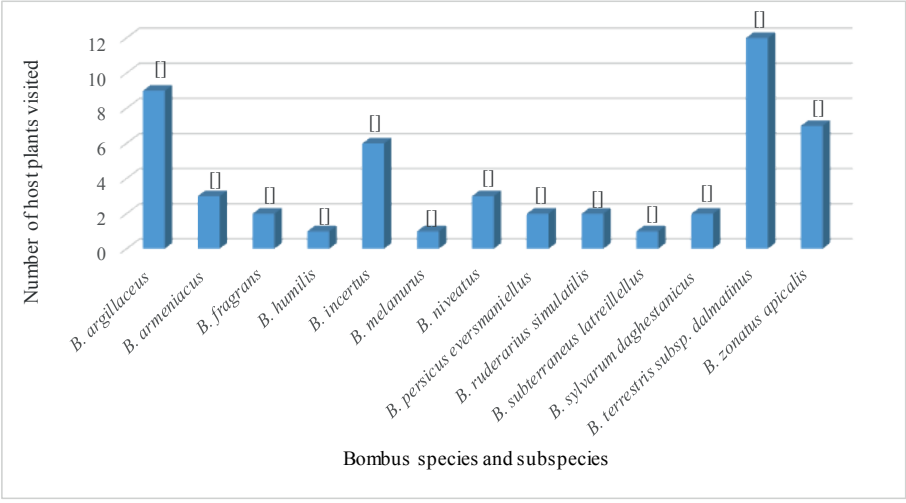

Figure 19. Number of host plant species visited by Bombus bee species captured in Kayseri province

When Figure 19 is examined, it was determined that the host plants visited by *Bombus* bee species belong to 10 plant families and cover 20 different host plant species belonging to these families. It was found that *Bombus* bee species

visiting the host plant species of the identified plant families varied. *Bombus* bee species were mostly captured on plants belonging to the Boraginaceae family and least on plants belonging to the Balsaminaceae, Bignoniaceae, Malvaceae, and Rosaceae families. The plant species on which *Bombus* bee species were most frequently captured was found to be *Anchusa* sp.

As a result of this study, when the altitudes of *Bombus* species were examined; *Bombus argillaceus* was found at an altitude of 1140-1525 m, while in other studies conducted in different areas; Aliev (2005) 2000 m, Aliyev (2019) 900-1300 m, Aslan (1997) 1000-1900 m, Aslan (2017) 600-1400 m, Boustani (2020) 230-2332 m, Monfared (2007) 1207-2800 m, and Özbek (2002) 1100-1600 m. *B. armeniacus* was found at an altitude of 1375-2290 m, while in other studies conducted in different areas; Aliev (2005) 1600-1900 m, Aliyev (2019) 1000-1300 m, Aslan (1997) 1000-1800 m, Monfared (2007) 1937-2600 m, Özbek (2002) 1200 m, and Williams (2011) 950-2000 m. *B. fragrans* was found at an altitude of 1300-2200 m, while in other studies conducted in different areas; Aliev (2005) 2400-3000 m, Aslan (1997) 1500-1600 m, Monfared (2007) 1937-2730 m, Özbek (2002) 1500 m, and Özgişi (2020) 799 m. *B. humilis* was found at an altitude of 1300 m, while in other studies conducted in different areas; Monfared (2007) 1800-2594 m, and Williams (2011) 800 m. *B. incertus* was found at an altitude of 1420-2200 m, while in other studies conducted in different areas; Aliev (2005) 2300 m, Aslan (1997) 1400-1800 m, Aslan (2017) 1000-1200 m, and Monfared (2007) 1937-2594 m. *B. melanurus* was found at an altitude of 2135-2200 m, while in other studies conducted in different areas; Aliev (2005) 2400 m, Aslan (1997) 1500-1600 m, Boustani (2020) 1815-3000 m, and Williams (2011) 2030 m. *B. niveatus* was found at an altitude of 1320-2200 m, while in other studies conducted in different areas; Aslan (1997) 1300-1900 m, Aslan (2017) 1000-1500 m, Monfared (2007) 1950-3000 m, and Özgişi (2020) 1780 m. *B. persicus eversmanniellus* was found at an altitude of 1325-2290 m, while in another study conducted in different areas; Aslan (1997) 1600-1900 m. *B. ruderarius simulatilis* was found at an altitude of 1420-2200 m, while in another study conducted in different areas; Aslan (1997) 1350-1800 m. *B. subterraneus latreillellus* was found at an altitude of 1800 m, while in another study conducted in different areas; Aliev (2005) 1600 m. *B. sylvarum daghestanicus* was found at an altitude of 1190-2200 m, while in other studies conducted in different areas; Aslan (1997) 1300-1700 m, and Aslan (2017) 1200-1400 m. *B. terrestris subsp. dalmatinus* was found at an altitude of 1150-1575 m, and there is no sufficient study for this species. *B. zonatus apicalis* was found at an altitude of 1140-1525 m, while in other studies conducted in different areas; Aliev (2005) 1600-2000 m, Aslan (1997) 1000-1600 m, and Aslan (2017) 800-1200 m.

Table 2. Bombus Bee Species Found in Kayseri Province and Their Locations and Altitude

Location	Altitude (m)	Bombus Species												
		B. argillaceus	*B. armeniacus*	*B. fragrans*	*B. humilis*	*B. incertus*	*B. melanurus*	*B. niveatus*	*B. persicus eversmaniellus*	*B. ruderarius simulatilis*	*B. subterraneus latreillellus*	*B. sylvarum daghestanicus*	*B. terrestris* subsp. *dalmatinus*	*B. zonatus apicalis*
Ağırnas-Melikgazi	1325	+	-	-	-	-	-	-	-	-	-	-	+	-
Bünyan	1335	-	-	-	-	-	-	-	+	-	-	-	+	-
Çavuşağa-Kocasinan	1150	-	-	-	-	-	-	-	-	-	-	-	+	-
Erciyes dağı-Develi	2290	-	+	-	-	-	-	-	+	-	-	-	-	-
Erciyes dağı-Develi	2200	-	+	+	-	+	+	+	+	+	-	+	-	-
Erciyes dağı-Develi	2135	-	-	-	-	+	+	-	-	-	-	-	-	-
Felahiye	1300	-	-	-	-	-	-	-	-	-	-	-	+	-
Gesi- Melikgazi	1250	-	-	-	-	-	-	-	-	-	-	-	+	-
Güzelköy-Melikgazi	1325	-	-	-	-	-	-	+	-	-	-	-	+	-
Gömeç- Kocasinan	1140	-	-	-	-	-	-	-	-	-	-	-	+	
Karahıdırlı-Bünyan	1190	+	-	-	-	-	-	-	-	-	-	+	-	+
Karahıdırlı-Bünyan	1140	-	-	-	-	-	-	-	-	-	-	-	-	+
Kermelik-Özvatan	1320	-	-	-	-	-	-	+	-	-	-	-	-	-
Kermelik-Özvatan	1140	+	-	-	-	-	-	-	-	-	-	-	-	+
Koramaz dağı-Bünyan	1440	+	+	+		+		+	-	-	-	-	-	+
Özvatan	1560	-	-	-	-	+	-	-	-	-	-	-	-	-
Özvatan	1420	+	-	+	-	+	-	-	-	+	-	+	-	+
Pınarbaşı	1525	+	-	+	-	-	-	-	-	-	-	-	+	+
Saraycık-Develi	1670	-	-	-	-	-	-	-	-	-	-	-	-	-
Sarımsaklı-Melikgazi	1175	+	-	-	-	-	-	-	-	-	-	-	+	-
Sarıoğlan	1150	+	-	-	-	-	-	-	-	-	-	-	+	-
Sarız	1575	-	-	-	-	-	-	-	-	-	-	-	+	-
Subaşı-Melikgazi	1375	+	+	-	-	-	-	-	+	-	-	-	+	-
Turan-Melikgazi	1300	+	-	+	+	-	-	-	-	-	-	-	+	+
Yahyalı	1250	-	-	-	-	-	-	-	-	-	-	-	+	-
Ziyarettepesi-Pınarbaşı	1800	-	+	-	-	+	-	-	+	+	+	+	-	-

(+):var,(-): yok

CONCLUSION

In this study, the *Bombus* bee species present in Kayseri Province and the vegetation types they inhabit were determined. According to the findings, 7 species and 6 subspecies belonging to 6 subgenera of the subfamily Bombinae were found to utilize 20 plant species from 10 different plant families as hosts.

The *Bombus* species identified in the study are *Bombus argillaceus*, *B. armeniacus*, *B. fragrans*, *B. humilis*, *B. incertus*, *B. melanurus*, *B. niveatus*, *B. persicus eversmaniellus*, *B. ruderarius simulatilis*, *B. subterraneus latreillellus*, *B. sylvarum daghestanicus*, *B. terrestris subsp. dalmatinus*, and *B. zonatus apicalis*. The host plant species visited by these bees include *Anchusa sp.*, *Campsis sp.*, *Carduus sp.*, *Consolida sp.*, *Cucurbita pepo*, *Echium italicum*, *Helianthus annuus*, *Impatiens balsamina*, *Jurinea sp.*, *Lavandula angustifolia*, *Medicago sativa*, *Ononis spinosa*, *Phaseolus vulgaris*, *Prunus avium*, *Salvia sp.*, *Sideritis sp.*, *Stachys byzantina*, *Tilia sp.*, *Trifolium pratense*, and *Zinnia elegans*.

Among the captured *Bombus* species and subspecies, the widest host plant range was observed in *B. terrestris subsp. dalmatinus* with 12 plant species, while the narrowest range, with only a single host plant, was observed in *B. humilis*, *B. melanurus*, and *B. subterraneus latreillellus*. Additionally, the most frequently visited host plant was *Anchusa sp.*, visited by 10 *Bombus* species. The observed *Bombus* species were recorded at altitudes ranging from 1140 to 2290 meters. *B. sylvarum daghestanicus* was observed across a wide altitude range of 1190-2200 m, whereas *B. subterraneus latreillellus* was recorded only at 1800 m in Pınarbaşı-Ziyarettepesi.

The results indicate that the recorded *Bombus* species exhibit an overall distribution between 1140 and 2290 meters in elevation. The bees displayed selectivity in their choice of host plants, which is influenced by the diversity of plant families and feeding preferences among coexisting *Bombus* species at the same altitudes. However, *B. humilis*, *B. melanurus*, and *B. subterraneus latreillellus* were found to prefer only a single plant species specifically.

As a result, the *Bombus* species present in Kayseri Province and their associated vegetation have been documented, providing a foundation for future studies. A global decline in *Bombus* populations has been reported, and it is believed that a similar decline may be occurring in Kayseri. This study also shows that *Bombus* bees inhabit limited areas and visit a restricted number of plant species. The destruction of these limited habitats, indiscriminate use of pesticides, stubble burning, and the loss of plant species in these areas pose a significant threat to the selective *Bombus* species, potentially leading to their decline and eventual extinction over time.

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Chapter 4

PREDATORY INSECT ORIUS SPP. (HEMIPTERA: ANTHOCORIDAE) IN COTTON FARMING IN SOUTHEASTERN ANATOLIA REGION AND SOME BIOLOGICAL CHARACTERISTICS OF (ORIUS ALBIDIPENNIS (REUTER)[1]

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INTRODUCTION

Cotton (*Gossypium hirsutum*) is a strategic crop of great importance both in our country and globally. The harvested seed cotton is an indispensable raw material for various industries: ginning for processing, the textile industry for its fiber, and the oil and feed industries for its seed.

Turkey ranks 11th in the world in terms of cotton cultivation area, 5th in fiber yield per unit area, 7th in cotton production volume, 4th in cotton consumption, and also 4th in cotton imports (Özüdoğru, 2023).

In Turkey, suitable regions for cotton cultivation include the Southern Mediterranean coastal areas such as Antalya, Çukurova, and Hatay; the Southeastern region including Gaziantep, Kahramanmaraş, Diyarbakır, Şanlıurfa, and Mardin; and western provinces such as Muğla, Denizli, Aydın, İzmir, and Balıkesir (Keskinkılıç, 2014).

During the 2021/22 cotton production season in Turkey, cotton was cultivated over an area of 432,000 hectares. The Southeastern Anatolia Region accounted for over 60% of the country's total cultivation area with 262,000 hectares. In comparison, Çukurova had 68,000 ha, the Aegean Region 98,000 ha, and Antalya 4,000 ha (Özüdoğru, 2023).

Throughout its growth period from planting to harvest, the cotton plant is exposed to many harmful pests. The unconscious and incorrect use of chemical pesticides in these areas poses threats to human and environmental health and, more importantly, disrupts the natural balance among living organisms. However, in Southeastern Anatolia, natural enemies have shown promising potential in suppressing pest populations, both in terms of species diversity and population density (Karaat et al., 1987; Büyük et al., 2002).

Studies conducted in the Southeastern Anatolia Region have found that predators such as *Chrysoperla carnea* Steph., *Orius* spp., *Nabis* spp., *Deraeocoris* spp., *Geocoris* spp., *Campylomma divesicornis* Reut., and *Aelothrips collaris* Priesner are commonly and frequently encountered in cotton fields (Göven & Efil, 1994; Büyük et al., 2002; Özpınar & Yücel, 2002).

Previous studies in the GAP (Southeastern Anatolia Project) region have identified three species of *Orius* (Heteroptera: Anthocoridae): *Orius minutus* (L.), *Orius horvathi* (Reut.), and *Orius niger* Wolf. However, no specific information was provided about which of these species was the most dominant or abundant (Karaat et al., 1986; Göven & Özgür, 1990; Uygun et al., 1993).

Pesticides used in plant protection are among the major threats to the survival and activity of beneficial organisms. Therefore, when pesticide use is necessary, either selective pesticides or those with minimal side effects on beneficial species should be preferred.

With the implementation of the GAP project in Southeastern Anatolia, irrigation opportunities have increased, leading to a rise in diseases, pests, and weeds, and consequently a significant increase in pesticide usage. To preserve

the natural balance in the region and prevent unconscious pesticide use, it is essential that cotton producers are able to correctly identify predatory insects in cotton, understand their relationship with plant phenology and hosts, receive training on pest management methods, and that national integrated pest management projects are carried out (Karaat et al., 1987; Göven & Özgür, 1990; Büyük et al., 2002).

Studies conducted in the region have shown that the predatory species *Chrysoperla carnea* Steph., *Orius* spp., *Nabis* spp., *Deraeocoris* spp., *Geocoris* spp., *Campylomma divesicornis* Reut., and *Aelothrips collaris* Priesner are commonly and frequently found in cotton cultivation areas (Göven & Efil, 1994; Büyük et al., 2002; Özpınar & Yücel, 2002).

Karaat et al. (1986) reported that among the beneficial species found in Southeastern Anatolia cotton fields, the most common predators were *Campylomma* spp., *Nabis* spp., and *Deraeocoris* spp. from the Heteroptera order, *Chrysoperla carnea* from Neuroptera, and *Orius niger* and *Orius horvathi* from the Anthocoridae family. These researchers also determined that *Orius* species were present in cotton fields from mid-June until the first week of October, with their population density peaking in August (35 individuals per 10 sweeps of 25 plants).

Özpınar and Yücel (2002) identified 16 predator species in cotton fields within the GAP (Southeastern Anatolia Project) area, most of which were generalist predators. They found that *Coccinellidae*, *Chrysopidae*, and *Nabidae* were present at low densities, while *Orius minutus* and *Aelothrips intermedius* Bagnall were recorded in higher numbers.

The objective of this study is to highlight the importance of *Orius* species—considered significant predators in controlling pest populations that cause yield losses in cotton production. The study aims to evaluate their population densities, certain biological characteristics, and propose measures to support and conserve these beneficial insects.

In integrated pest management (IPM) programs, it is essential to consider the presence and activity of these predators when planning pesticide applications. Doing so can help preserve the natural balance in the ecosystem and promote more sustainable cotton farming by enhancing the effectiveness of natural enemies.

1. Taxonomic Position and Importance of *Orius* Species

Orius species belong to the family Anthocoridae, which includes around 600 species and is part of the superfamily Cimicoidea within the order Hemiptera. Members of this family range in size from 1.4 to 4.5 mm and can be found in a variety of habitats around the world (Lattin, 1999).

Although some species in the Anthocoridae family feed on pollen and plant material (exhibiting zoophytophagous behavior), most are predatory

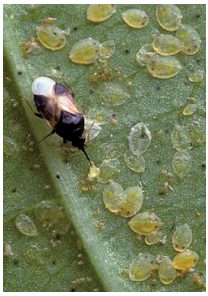
(Önder, 1982). Their prey includes a wide range of small arthropods such as thrips, scale insects, aphids, psyllids, bark beetles, as well as small Lepidoptera larvae, insect eggs, and mites (Pericart, 1972; Lattin, 1999).

According to Lodos (1986), members of the Anthocoridae family are commonly known as "minute pirate bugs" or "flower bugs." Both nymphs and adults are predators, typically found on flowers, where they feed on soft-bodied insects such as aphids, scale insects, psyllids, mites, thrips, leafhoppers, whiteflies, and similar pests.

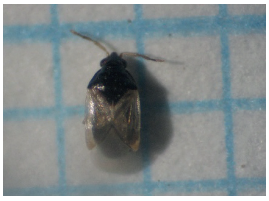
Species of the *Orius* genus have a flattened, oval, and elongated body shape, with the upper surface of the wings usually colored brownish or black and white (Figure 1). The head is extended forward, eyes are large, and antennae are composed of four segments (Önder, 1982; Lodos, 1986).

Both adults and nymphs, with few exceptions, exhibit zoophagous feeding behavior. They prey on members of the families Thysanoptera, Psyllidae, Aphididae, and Tetranychidae, as well as the eggs of Lepidoptera and Coleoptera species (Önder, 1982; Lodos, 1986).

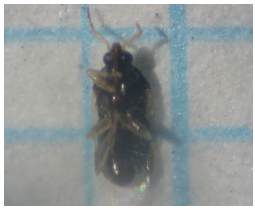
Taxonomic information for the predatory insect genus *Orius* is given below.



Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Suborder: Heteroptera
Family: Anthocoridae
Genus: *Orius* Wolff, 1811



♂ Dorsal



♂ Ventral

♀ Dorsal

♀ Ventral

Figure 1. Dorsal and ventral views of male and female individuals of the Orius genus

Önder (1982) reported in his taxonomic and faunistic research on the Anthocoridae fauna of Turkey that there are a total of 8 species belonging to the genus *Orius*: *O. pallidicornis* (Reut.), *O. niger* (W.), *O. laevigatus* (Fieb.), *O. majusculus* (Reut.), *O. horvathi* (Reut.), *O. minutus* (L.), *O. vicinus* (Rib.), and *O. laticollis* (Reut.).

2. Predatory *Orius* Species Founded in Cotton Cultivation Areas of the Southeastern Anatolia Region

The predatory *Orius* species founded in cotton cultivation areas of the Southeastern Anatolia Region are shown in (Figure 1) and in Table 1.

Figure 1. Turkey map and Southeast Anatolian Region and locations where the studies have done

Order	Family	Supergenus	Species
Hemiptera	Anthocoridae	Dimorphella	*Orius albidipennis* (Reuter)*
		Heterorius	*Orius horvathi* (Reuter) *Orius vicinus* (Ribaut)
		Orius s.str.	*Orius laevigatus* (Fieber) *Orius niger* Wolff

**It was found as a new record for the fauna of Türkiye*

Table 1. Predatory insect Orius species founded in cotton cultivation areas of the Southeastern Anatolia Region

As shown in Table 1, studies conducted in the cotton cultivation areas of the Southeastern Anatolia Region between 2005 and 2007 identified three subgenera and five species belonging to the genus *Orius*. Among these, *O. albidipennis* was identified as the most abundant species and was recorded as a new species for the Turkish fauna (Büyük and Kazak, 2009). In previous studies carried out in the cotton fields of the region, the species *O. minutus*, *O. horvathi*, and *O. niger* were reported (Göven and Özgür, 1990; Uygun et al., 1993).

In studies conducted in the cotton-growing areas of the Southeastern Anatolia Region, it was determined that among predatory bugs belonging to the order Heteroptera, *Campylomma diversicornis*, *Orius horvathi*, *O. niger*, and *O. minutus* accounted for the largest share (60%), and that the populations of these predators increased and reached their peak during the cotton maturation period (early September) (Göven and Özgür, 1990).

In a faunistic study conducted in the GAP area, it was also reported that among predatory heteropterans in cotton cultivation areas, species belonging to the family Anthocoridae, genus *Orius* namely *O. minutus*, *O. horvathi*, and *O. niger* were present (Uygun et al., 1993). Images showing *Orius* species commonly found on cotton flowers are given in Figure 2.

Figure 2. Images of predatory insect Orius species on cotton flowers, where they are commonly found.

3. Abundance Rates of *Orius* Species in Cotton Fields

In studies conducted on the abundance rates of *Orius* species in cotton cultivation areas of the Southeastern Anatolia Region, a total of 1,074 adult *Orius* individuals were collected in 2005 233 from Şanlıurfa Central, 267 from Harran, 278 from Diyarbakır Central, and 296 from Çınar. In 2006, a total of 1,140 adult *Orius* individuals were collected — 285, 284, 301, and 270 individuals respectively from the same locations. These specimens were identified and classified according to their diagnostic features, and the abundance ratios of the species are presented in Figure 3.

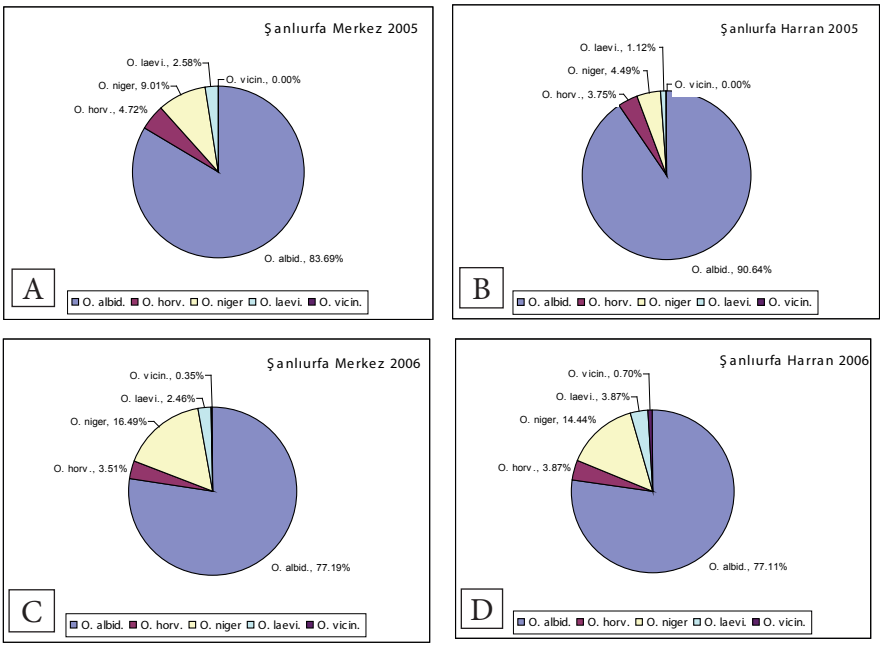


Figure 3. Abundance ratios of Orius species collected in the villages of Çekçek (Şanlıurfa-Central) and Tahılalan (Harran) during 2005–2006

As shown in Figure 3 A, among the 233 adult *Orius* individuals collected in 2005 from Çekçek village, Şanlıurfa Central, 195 were identified as *O. albidipennis*, 21 as *O. niger*, 11 as *O. horvathi*, and 6 as *O. laevigatus*. Accordingly, the abundance ratios of these species were 83.69%, 9.01%, 4.72%, and 2.58%, respectively. The species *O. vicinus* was not detected.

From Tahılalan village in Harran district (Şanlıurfa), a total of 267 adult *Orius* individuals were collected, of which 242 were *O. albidipennis*, 12 were *O. niger*, 10 were *O. horvathi*, and 3 were *O. laevigatus*. The abundance ratios were 90.64%, 4.49%, 3.75%, and 1.12%, respectively. The species *O. vicinus* was not found (Figure 1B).

In Figure 3 C, for 2006, among the 285 adult *Orius* individuals collected in Çekçek village, Şanlıurfa Central, 220 were identified as *O. albidipennis*, 47 as *O. niger*, 10 as *O. horvathi*, 7 as *O. laevigatus*, and 1 as *O. vicinus*. The respective abundance ratios were 77.19%, 16.49%, 3.51%, 2.46%, and 0.35%.

From Tahılalan village, Harran district (Şanlıurfa), 284 adult *Orius* individuals were collected in 2006. Of these, 219 were *O. albidipennis*, 41 were *O. niger*, 11 were *O. horvathi*, 11 were *O. laevigatus*, and 2 were *O. vicinus*. The abundance ratios were determined as 77.11%, 14.44%, 3.87%, 3.87%, and 0.70%, respectively (Figure 3 D).

Of the samples collected in 2006, all three specimens belonging to the *O. vicinus* species were found in Şanlıurfa, one in the central district, and

the other two in Harran. The occurrence rates of *Orius* species in Diyarbakır province are given in Figure 4.

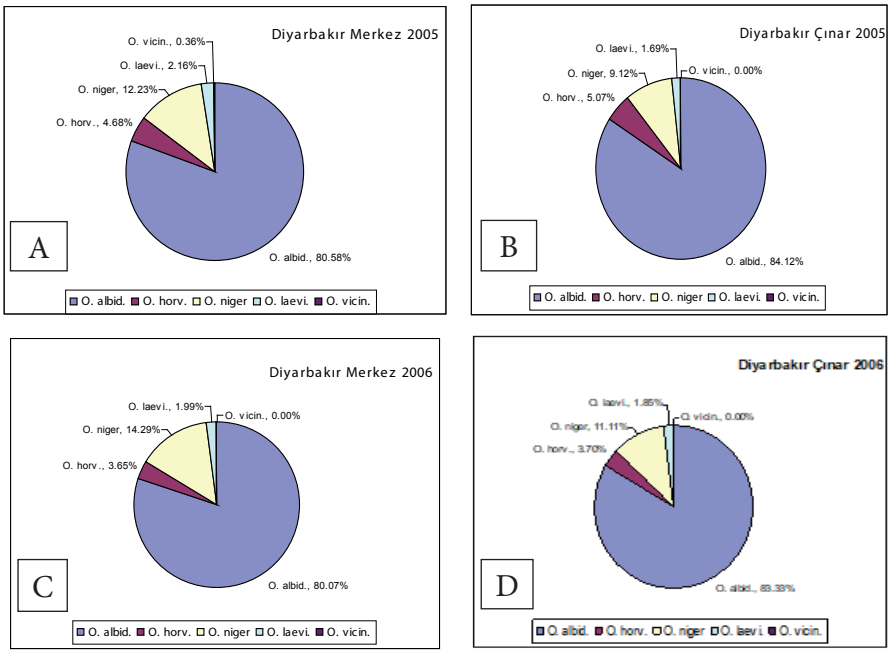


Figure 4. Abundance ratios of Orius species collected in the villages of Yukarı Nasırlı (Diyarbakır-Central) and Beşpınar (Çınar) during 2005–2006.

As shown in Figure 4 A, among the 278 adult *Orius* individuals collected in 2005 from Yukarı Nasırlı village, Diyarbakır Central district, 224 were identified as *O. albidipennis*, 34 as *O. niger*, 13 as *O. horvathi*, 6 as *O. laevigatus*, and 1 as *O. vicinus*. The respective abundance ratios were 80.58%, 12.23%, 4.68%, 2.16%, and 0.36%.

In Beşpınar village of Çınar district (Diyarbakır), among the 296 adult *Orius* individuals collected, 249 were identified as *O. albidipennis*, 27 as *O. niger*, 15 as *O. horvathi*, and 5 as *O. laevigatus*. The abundance ratios for these species were 84.12%, 9.12%, 5.07%, and 1.69%, respectively (Figure 4 B).

As shown in Figure 4 C, among the 301 adult *Orius* individuals collected in 2006 from Yukarı Nasırlı village, Diyarbakır Central district, 241 were identified as *O. albidipennis*, 43 as *O. niger*, 11 as *O. horvathi*, and 6 as *O. laevigatus*. The respective abundance ratios were 80.06%, 14.29%, 3.65%, and 1.99%.

In Beşpınar village of Çınar district (Diyarbakır), among the 270 adult *Orius* individuals collected, 225 were *O. albidipennis*, 30 were *O. niger*, 10 were *O. horvathi*, and 5 were *O. laevigatus*. The abundance ratios were 83.33%, 11.11%, 3.70%, and 1.85%, respectively.

Among the specimens collected in 2005, a single individual belonging to the species *O. vicinus* was found in Yukarı Nasırlı village, Diyarbakır Central district (Figure 4D).

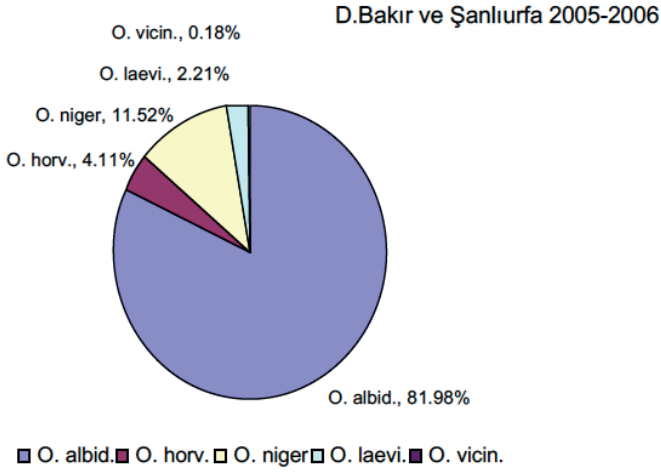


Figure 5. Abundance ratios of Orius species collected in Diyarbakır and Şanlıurfa provinces during 2005 and 2006.

As a result of the two-year study, a total of 2,214 adult *Orius* individuals were collected periodically from the time they were first observed in nature until harvest in both provinces. Among these, 81.98% were *O. albidipennis*, 11.52% were *O. niger*, 4.11% were *O. horvathi*, 2.21% were *O. laevigatus*, and 0.18% were *O. vicinus* (Figure 5).

In previous studies conducted in the cotton cultivation areas of the Southeastern Anatolia Region, it was reported that among the beneficial predatory heteropterans, *O. niger* and *O. horvathi* were the most commonly found species (Karaat et al., 1986; Göven and Özgür, 1990). It was also determined that, among the predatory bugs of the order Heteroptera found in the region's cotton fields, *C. diversicornis*, *O. horvathi*, *O. niger*, and *O. minutus* constituted the largest proportion (60%) and that their populations increased gradually, reaching a peak during the cotton maturation period (early September).

Pericart (1972) stated that *O. albidipennis* is a species widely distributed in the Mediterranean Basin and the Atlantic Region of Western Europe. Another study reported that *O. albidipennis* requires higher temperatures for successful development, which is related to the geographical origin of the species (Zaki, 1989). It was noted that this species may not be recommended against early-season pests but could be a good alternative for controlling late-season pests.

4. Some Biological Characteristics of *Orius albidipennis* (Reuter)

The following information presents certain biological characteristics of *Orius albidipennis*, the most abundant species (81.98%) found in cotton

cultivation areas of the Southeastern Anatolia Region, obtained under controlled laboratory conditions.

4.1. Egg Incubation Periods

The egg incubation period of *O. albidipennis* was monitored for 54 eggs, with minimum and maximum durations determined as 3.0–6.0 days, and the average incubation period calculated as 4.14 ± 0.75 days. Wright (1994) reported that females of *Orius* species lay slender, hardly visible eggs inside plant tissues about 2–3 days after mating, and that the eggs usually hatch within 3–5 days. Cocuzza et al. (1997b), in their study examining the effects of three different temperatures on the development and reproduction of *O. albidipennis*, reported an egg incubation period of 3.8 ± 0.1 days at 25°C.

Hodgson and Aveling (1988) stated that *Orius* species deposit their eggs into the epidermis of host plants where prey are present, leaving the white operculum exposed (Figure 6 A, B, C). They generally prefer younger plant tissues and can lay approximately 200 eggs.

Büyük and Kazak (2010) reported that the predatory bug *Orius albidipennis* is an important predator adapted to warm climate zones and is commonly distributed in countries neighboring the Mediterranean. They also noted that its presence and identification in Turkey were first determined in 2007 through a study conducted in cotton fields in the Southeastern Anatolia Region. They emphasized that the short duration of both pre-oviposition and pre-adult developmental periods, together with high egg production and hatching rates, are the most favorable traits of this predator, which remains abundant from the flowering stage of cotton until harvest.

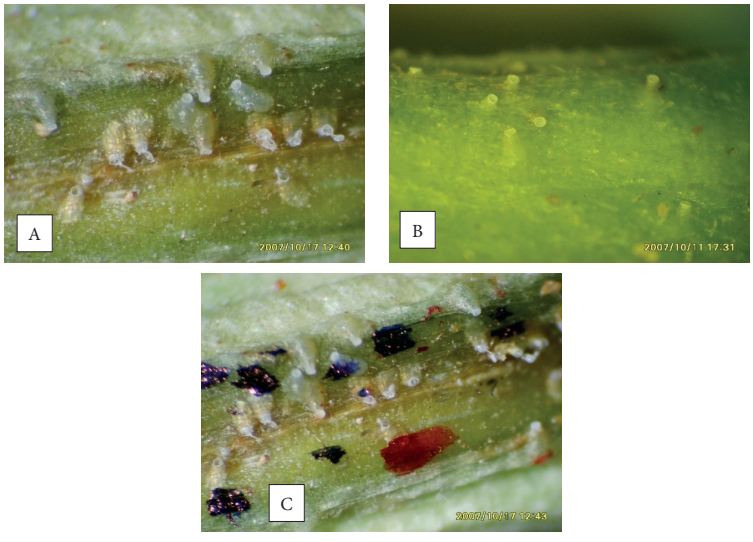


Figure 6. Appearance of O. albidipennis eggs within plant tissues hatched and unhatched eggs (A, B), and eggs laid at different times marked with colored pencils (C)

4.2. Pre-adult Developmental Periods

Table 2. Nymphal development durations (days) of Orius albidipennis

		Nymph Stages					
		(N_1)	(N_2)	(N_3)	(N_4)	(N_5)	Sum
(n)	Average	2.98	2.43	2.24	2.43	4.18	13.98
37	Min.-Max.	(2.0-4.0)	(2.0-3.0)	(2.0-3.0)	(2.0-3.0)	(3.0-5.5)	(11.5-16.0)
	Standard error of the mean	2.98±0.60	2.43±0.39	2.24±0.34	2.43±0.25	4.18±0.83	13.98±1.28

As shown in Table 2, the average nymphal development durations of 37 individuals reared and observed through all nymphal stages were determined as 2.98 ± 0.6, 2.43 ± 0.39, 2.24 ± 0.34, 2.43 ± 0.25, and 4.18 ± 0.83 days, respectively, with a total average of 13.98 ± 1.28 days. Accordingly, the shortest nymphal development period occurred during the third instar (2.24 ± 0.34 days), while the longest occurred during the fifth instar (4.18 ± 0.83 days).

Wright (1994) reported that *Orius* species pass through five nymphal stages and, under favorable conditions, it takes at least 20 days from egg to adult. Cocuzza et al. (1997b), in their study on the effects of three different temperatures on the development and reproduction of *O. albidipennis*, found that at 25°C, the egg incubation period was 3.8 ± 0.1 days, and the nymphal development durations were 3.1 ± 0.1, 2.6 ± 0.1, 2.2 ± 0.09, 2.0 ± 0.06, and 3.2 ± 0.1 days, with a total development period of 13.2 ± 0.2 days. They also reported that *O. albidipennis* females lived for 23.5 days at 25°C, and the highest reproduction occurred again at 25°C, with an average of 71.1 eggs per female.

Fritsche and Tamo (2000), in a study on the effects of two different diets on the biology and development of *O. albidipennis*, reported that when the predator was fed only on cowpea leaves, the nymphal stage duration was prolonged (17.6 days) compared to the dual diet (14.8 days), and nymphal mortality reached a high rate of 78.6%. They also reported that female predators fed on *M. sjostedti* larvae had an average daily egg production of 6.8 eggs, a total of 61.1 eggs, and an average lifespan of 13.5 days.

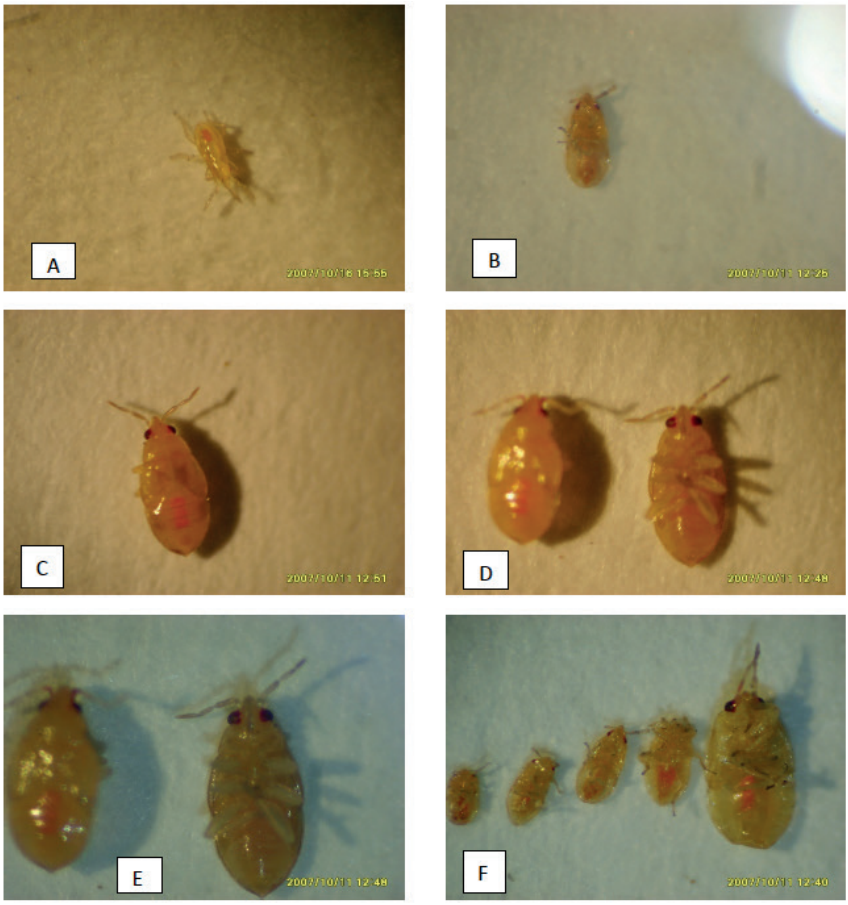


Figure 7. Different biological stages of O. albidipennis: newly hatched 1st instar nymph (A), 2nd instar nymph (B), 3rd instar nymph (C), 4th instar nymph (D), 5th instar nymph (E), and appearance of all five instars together (F)

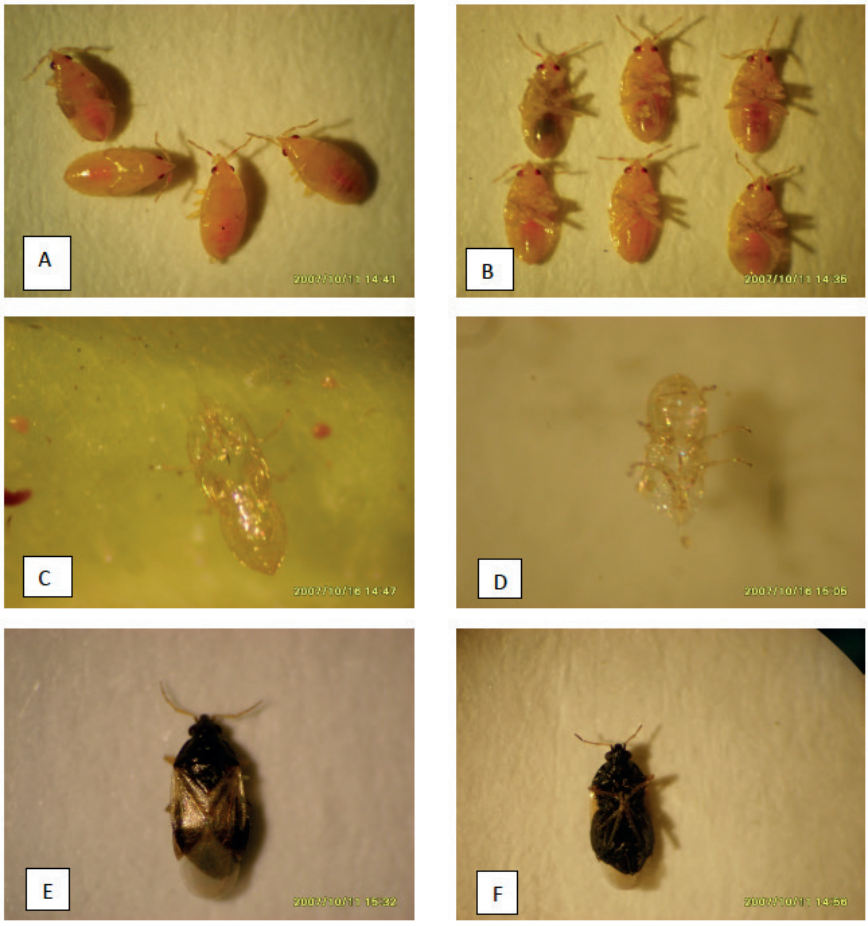


Figure 8. Dorsal and ventral views of final instar nymphs of O. albidipennis (A, B); dorsal and ventral exuviae of final instars (C, D); and dorsal and ventral views of adult individuals (E, F)

4.3. Pre-oviposition Period

To determine the pre-oviposition period of *O. albidipennis*, newly emerged adults were placed in oviposition containers, with two males and one female in each, and provided with fresh bean pods and eggs of the flour moth (*Ephestia kuehniella*). The study was conducted with 38 replications, and the results are presented in Table 3.

Table 3. Pre-oviposition periods (days) of O. albidipennis

Adult number (n)	mean	Min.- Max.	Standard error of the mean
38	3.72	2.5-5.5	3.72±0.81

As shown in Table 3, the pre-oviposition periods of *O. albidipennis* were completed in 38 female adults, with minimum and maximum values of 2.5–5.5 days, and the average pre-oviposition period was determined as 3.72 ± 0.81 days. Cocuzza et al. (1997a) reported that the pre-oviposition period of *Orius albidipennis* fed on *E. kuehniella* eggs was 3.2 ± 0.2 days.

4.4. Oviposition, Post-oviposition Periods

Studies on the above-mentioned biological stages were conducted with 30–37 replications, and in 27 replications, all developmental stages were successfully completed. The obtained data are presented in Table 4.

Table 4. Oviposition period, total and average number of eggs laid, egg hatch rates, and post-oviposition periods of O. albidipennis

Female Number	Mean Min.- Max	Oviposition. Duration (Day)	Total Number of Eggs (Number/ individual)	Average Number of Eggs (Number/ Day)	Number of Eggs Hatched (Number	Egg Hatching Rate (%)	Postovipos. Duration (Day)
(n)	Mean	26.22	85.07	3.25	58.81	69.01	7.37
27	Min.- Max.	21-30	65-104	2.64-3.90	43-78	53.93-78.04	(4-9.5)
	Standard error of the mean)	26.22 ±2.88	85.07 ±10.64	3.25 ±0.33	58.81 ±9.81	69.01 ±6.29	7.37 ±1.39

As shown in Table 4, among the 27 individuals that completed the biological stages described above, the minimum–maximum oviposition period was 21–30 days, with an average of 26.22 ± 2.88 days. During the oviposition period, the minimum–maximum number of eggs laid per individual ranged from 65 to 104, with an average of 85.07 ± 10.64 eggs per individual. The average number of eggs laid per day was determined as 2.64–3.90, with an average of 3.25 ± 0.33 eggs per day. The egg hatching rate of the laid eggs varied between 53.93% and 78.04%, with an average of 69.01 ± 6.29%. The post-oviposition period of the predator was determined to range from 4.0 to 9.5 days, with an average of 7.37 ± 1.39 days

Wright (1994) reported that female *Orius* individuals laid an average of 129 eggs during their approximately 35-day lifespan, and that they could produce several generations per season.

Cocuzza et al. (1997a), in a study investigating the effects of three different diets on the development and reproduction of *O. albidipennis*, used *Ephestia kuehniella* eggs, eggs + pollen, and pollen alone as food sources. They found that the oviposition period lasted 35.3 ± 1.7 days, and the fecundity was 109.8 ± 9.3 eggs per female. They also reported that fecundity increased by 40% (to 152.3 eggs per female) when *E. kuehniella* eggs + pollen were provided.

Cocuzza et al. (1997b) reported that at 25°C, the egg incubation period of *O. albidipennis* was 3.8 ± 0.1 days, and the nymphal development durations were 3.1 ± 0.1, 2.6 ± 0.1, 2.2 ± 0.09, 2.0 ± 0.06, and 3.2 ± 0.1 days, with a total development period of 13.2 ± 0.2 days. They also noted that *O. albidipennis* females lived for 23.5 days at this temperature, and the highest reproduction occurred again at 25°C, with an average of 71.1 eggs per female.

Adult Female Longevity

Data on the longevity of adult females were obtained by summing the minimum–maximum and average durations of the pre-oviposition, oviposition, and post-oviposition periods. The calculated values are presented in Table 5.

Table 5. Adult female longevity (days) of O. albidipennis

Dişi sayısı (n)	Preovipozisyon (Gün)	Ovipozisyon (Gün)	Postovipozisyon (Gün)	Ergin Dişi Ömrü (Gün)
38	3.72±0.81			
27		26.22±2.88	7.37±1.39	37.31±1.79

As shown in Table 5, the pre-oviposition period of adult females was 3.72 ± 0.81 days, the oviposition period was 26.22 ± 2.88 days, and the post-oviposition period was 7.37 ± 1.39 days, resulting in a total adult female lifespan of 37.31 ± 1.79 days. Wright (1994) reported that female *Orius* individuals have an approximate lifespan of 35 days.

Male–Female Ratio

Data obtained from 50 adults that completed the nymphal stage and reached adulthood were used to determine the sex ratio. The results are presented in Table 6.

Table 6. Male–female ratio of O. albidipennis

Ergin Sayısı (n)	Erkek Sayısı (Adet)	Dişi Sayısı (Adet)	Oran (%)
50	21.0	29.0	1:1.38

Among the individuals obtained from egg to adult emergence, a sex determination study conducted on 50 adults revealed that 21 were males and 29 were females. Accordingly, the male-to-female ratio, calculated through simple proportional analysis, was 0.42:0.58. Based on the equation $0.42 = 1 \rightarrow 0.58 = X$, the value of X was determined as 1.38, and thus, the **sex** ratio was found to be 1:1.38 (male:female).

Conclusion

Among the predatory insects found in the cotton cultivation areas of the Southeastern Anatolia Region, the *Orius* species are the most significant and the most abundant from the beginning of flowering to the end of harvest. The richness of species diversity, density, and their long-term presence within the cotton ecosystem represent a valuable ecological resource.

Considering this, special attention should be paid to the population of this predatory bug during chemical control operations, particularly against late-season pests in cotton fields.

It is recommended to avoid chemical applications in fields where the predator is abundant. Since this predator is highly mobile and can easily move away from treated areas, strip spraying should be practiced to minimize its exposure to pesticides and to allow its population to recover rapidly to normal levels.

Findings from this study, as well as reports from the literature, indicate that the predator adapts better to high temperature conditions (30–35°C). Therefore, in order to increase its population in other cultivated plants, necessary protective measures should be taken, pollen-producing plants should be encouraged in and around fields, and if necessary, mass rearing and release programs should be implemented. Finally, the presence and population dynamics of this beneficial predator should also be investigated in other crop ecosystems.

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Chapter 5

LIFE HISTORY OF ALMOND SEED WASP, *Eurytoma amygdali* Enderlein (HYMENOPTERA: EURYTOMIDAE) IN TURKEY

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INTRODUCTION

Almond (*Prunus dulcis* Mill.) belongs to the Rosaceae family and is among the important nut species due to its high nutritional value, aromatic properties, and rich food content. The almond originates from Central and Western Asia. In Türkiye, almond cultivation can be carried out in all regions except for the coastal parts of the Black Sea region and the high plateaus. It is a fruit species with low soil selectivity.

Almonds are widely used not only as a snack and in the food industry both globally and in Türkiye, but also in various other sectors such as cosmetics and pharmaceuticals. In Türkiye, almonds are consumed both as shelled nuts and as fresh green almonds (locally known as çağla). In addition to their pleasant taste, almonds are considered high-quality products. Once shelled, they are commonly used in the pastry industry – in cakes, sweets, and Turkish delights. Due to their nutritional content, almonds have antioxidant properties and are known to reduce the risk of cardiovascular diseases.

According to statistical data on almond trees in Türkiye (TÜİK, 2023), there are 13.616.290 fruit-bearing trees, 7.670.190 non-fruit-bearing trees, and a total of 21.286.480 almond trees.

In almond cultivation, various insect pests and disease agents can cause yield and quality losses at different levels depending on plant variety, pest species, pathogens, and environmental factors. In Türkiye, almond-growing areas are expanding day by day, with a noticeable transition from traditional farming systems to high-input intensive agricultural systems. This shift in cultivation practices increases the frequency and spread of pests and diseases, which limits profitability.

Flower and fruit drop in almond trees varies depending on climatic conditions, physiological factors, disease agents, and the extent of damage caused by harmful insect species. Particularly, harmful insects are among the main factors causing flower and fruit drop, and they significantly reduce yields in later stages due to the damage they inflict.

Many studies have been conducted on almond pests in Türkiye. Some of these studies include: Nizamlıoğlu (1961), Ekici & Günaydın (1969), Maçan (1986), Bolu & Çınar (2005), Bolu et al. (2005), Bolu & Özgen (2005), Bolu (2006), Bolu et al. (2006a), Bolu et al. (2006b), Bolu & Kara (2006), Bolu (2007), Bolu et al. (2007), Bolu & Özgen (2007a), Bolu & Özgen (2007b), Bolu & Özgen (2007c), Bolu & Legalov (2008), Bolu & Özgen (2009), Bolu & Özgen (2010), Bolu & Özgen (2011), Bolu (2012), Bolu (2016a), Bolu (2016b), Bolu & Maral (2016), Tolga (2018), Yiğit et al. (2020), Usanmaz (2020), Usanmaz & Aslan (2023), Koç et al. (2024), Cebeci et al. (2024), Özgen & Topdemir (2024), Özgen et al. (2025).

Maçan (1986), in his studies conducted between 1978 and 1980 in almond-growing areas of Adıyaman, Diyarbakır, Mardin, Siirt, and Şanlıurfa, identified a total of 25 harmful insect species: 11 from the order Coleoptera, 6 from Lepidoptera, 3 each from Hymenoptera and Homoptera, and 2 from Heteroptera. Among these, *Monosteira lobulifera, M. unicostata, Brachycaudus helichrysi, Hyalopterus amygdali, Diloba caeruleocephala, Recurvaria nanella, Anarsia lineatella, Rhynchites smyrnensis, Coenorrhinus aequatus, Anthonomus amygdali, A. rubripes, A. baudueri, Eurytoma amygdali, Caliroa limacina, and Cimbex quadrimaculata* were reported to cause significant damage.

Between 2002 and 2005, Bolu et al. (2005) conducted studies in the provinces of Diyarbakır, Elazığ, and Mardin and identified 244 insect species, 2 mite species, and 34 spider species on almond trees. Of these, 124 were found to be harmful, with 12 species classified as economically significant pests. These include: *Eurytoma amygdali, Anthonomus amygdali, Polydrosus roseiceps, Tatianaerhynchites aequatus, Epirhynchites smyrnensis, Agrilus roscidus, Capnodis carbonaria, C. tenebricosa, Monosteira lobulifera, M. unicostata, Cimbex quadrimaculata*, and *Diloba caeruleocephala*.

Usanmaz (2020) conducted research in almond production areas of Gaziantep (Şahinbey, Şehitkamil, Oğuzeli), Kahramanmaraş (Pazarcık), and Adıyaman (Besni) and identified 68 genera/species belonging to 28 families across 4 insect orders as pests damaging almond trees.

Yiğit et al. (2020), in their study conducted in Malatya between 2017 and 2018, investigated host preferences and adult emergence times of a particular pest species on various almond cultivars, including Ferragnes, Ferraduel, Nonpareil, Drake, Cristomorto, and Garrigues. Observations revealed the lowest damage rate (81%) in the Ferragnes cultivar and the highest (97%) in the Nonpareil cultivar. In 2017, 89.3% of the adults emerged, while 10.6% of the population transitioned to the next generation. Adult emergence began at the end of April when the maximum temperature reached 25 °C and the daily average exceeded 15 °C. The study emphasizes the importance of variety selection and climate data in effective control of almond fruit borer.

The taxonomic classification, damage, and control strategies of the species are presented below.

Scientific name: *Eurytoma amygdali* End. Common name (Turkish): Badem İçkurdu

Order: Hymenoptera Family: Eurytomidae Common names (English): Almond seed wasp

Distribution: Found in the former Russia, the Balkans, Cyprus, Syria, Israel, and Türkiye.

In Türkiye: Present in the Aegean, Eastern, and South-eastern Anatolia regions, as well as other almond-growing areas (Nizamlıoğlu, 1961; Ekici & Günaydın, 1969; Bolu et al., 2005; Tolga, 2018; Usanmaz, 2020).

Host plants: Feeds on sweet and bitter almond fruits.

Identification: The adult is black in colour. Only the tips of the femora and tibiae, as well as the entire tarsi, are yellow. The entire body is covered with erect, small, white hairs. In appearance, the adult closely resembles a fully winged ant (Figure 1).

Figure 1. *Lateral view of female and male individuals of Eurytoma amygdali.*

When viewed from above, the head is kidney-shaped. Its width is nearly twice its length. The surface is entirely covered with small pit-like punctures, each with a short, upright, colourless bristle emerging from the center. The antennae are located in a depression at the front center of the head, positioned vertically and slightly curved. There are three ocelli, brick-red in colour, arranged in an equilateral triangle on the top of the head. The antennae consist of 10 segments, and their structure and shape differ between males and females (Figure 2).

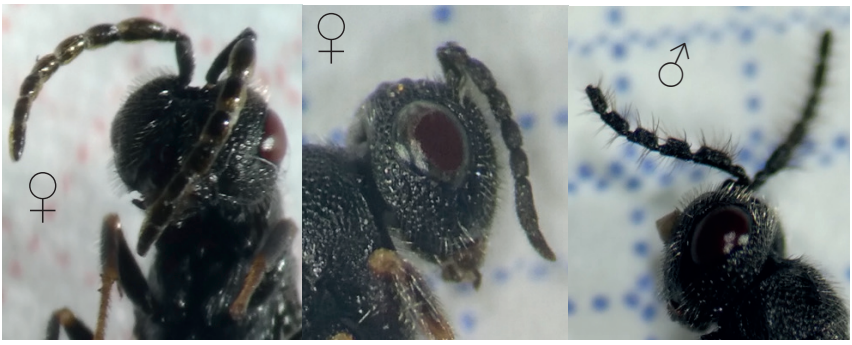

Figure 2. *Antennae of Eurytoma amygdali female (left and center) and male (right).*

The thorax is well-developed and connects to the head with a short, wedge-shaped segment (cervix). The prothorax is rectangular with slightly rounded edges. The mesothorax is the most developed part of the thorax (Figures 3-4). The metathorax is highly reduced, appearing as a narrow, curved strip.

The forewings are well-developed and nearly triangular in shape. They are transparent, colourless, with an oily sheen and a slightly brownish tint in the middle. Wing venation is very faint. The hindwings are almost kidney-shaped. The leading and distal edges of the forewings, as well as the distal and lower edges of the hindwings, have short, lateral hairs.

The legs are black, with yellowish joints between segments. They are covered with whitish hairs.

The abdomen consists of 10 segments, is black, and shiny. In females, it is spindle-shaped, laterally flattened, tapering towards the end, and slightly curved upward. The ovipositor is located on the 8th segment and is reddish-brown in colour. In males, the abdomen is oval-shaped, less flattened laterally compared to females, and does not taper at the end.

The average body length of the female wasp is 7.1 mm (ranging from 6.5 to 7.7 mm), while the male is 5.3 mm (ranging from 4.7 to 6.0 mm).

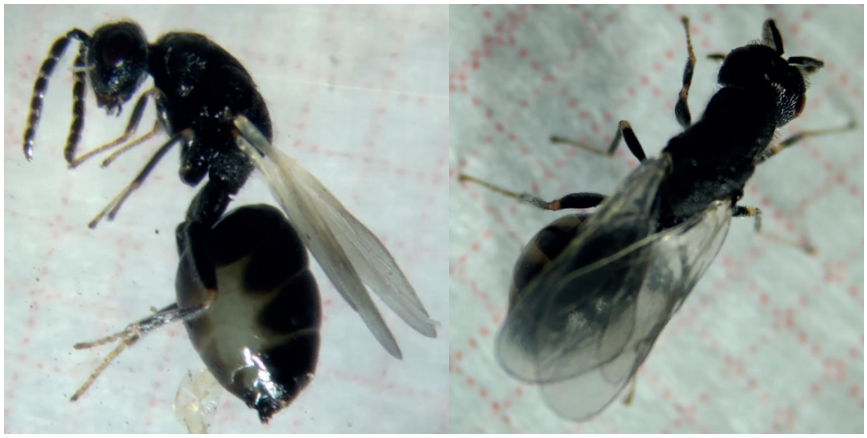

Figure 3. *Lateral and dorsal view of a newly emerged female individual from the pupa, with the antennal sheath still attached.*

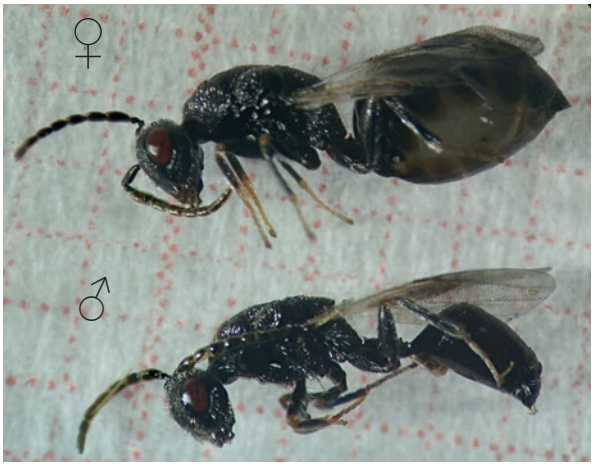

Figure 4. *Lateral view of newly emerged female and male individuals from the pupa, with the antennal sheath still attached.*

The larva is milky white, legless, slightly curved, and has a plump body. Its head is translucent white. The body consists of 13 segments, clearly separated by deep grooves. Sparse hairs, similar in colour to the body, are present on the surface. The mandibles are quite prominent (Figure 5). The average length of the mature larva is 6.7 mm (ranging from 6.0 to 8.1 mm).

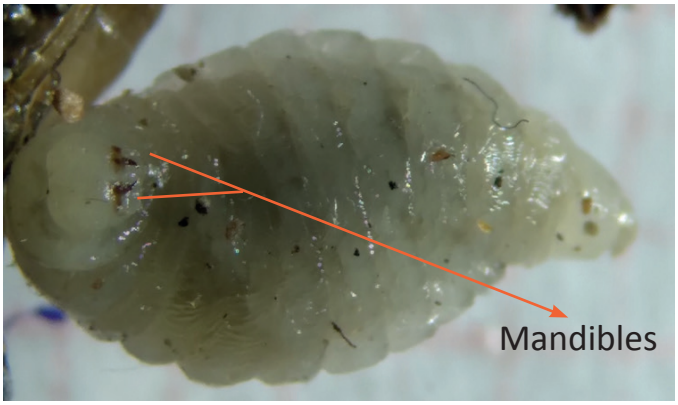

Figure 5. *Larva of Eurytoma amygdali.*

Prepupal and pupal stages: A free pupal stage is observed. With the onset of the prepupal stage, darkening begins from the head and gradually spreads to cover the entire body in the following days (Figures 6-7).

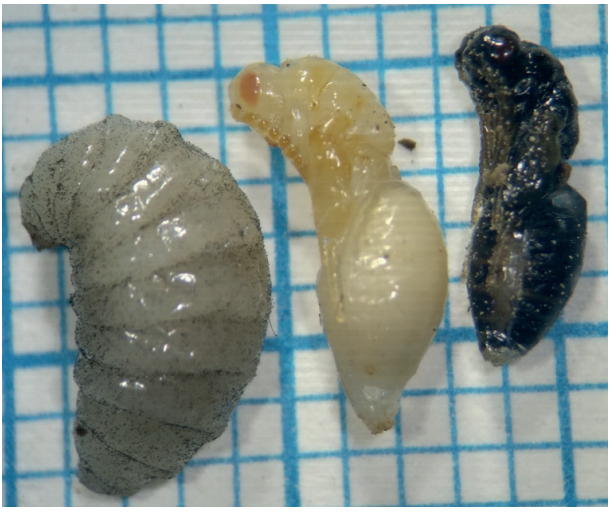

Figure 6. *Larval, prepupal, and pupal stages of Eurytoma amygdali.*

Figure 7. *Prepupal and pupal stages of Eurytoma amygdali.*

Biology, Ecology, and Type of Damage

The pest overwinters in the larval stage inside the fruit and pupates there. Although it may vary by year, adult emergence typically begins in March (Figure 8). After mating, females lay one egg per fruit. To prevent other females from laying eggs in the same fruit, each infested fruit is marked with a pheromone by the female. The species completes one generation per year.

Figure 8. *Seed consumed by the larva of Eurytoma amygdali (left) and adult emergence from the fruit (right).*

The larva initially partially, then completely, consumes the inside of almond fruits. The pest completes its development within a single fruit. Damaged fruits dry out and change colour more quickly than healthy ones (Figure 9). The light green colour of the outer hull turns yellowish-brown and becomes fully brown during the winter months (Figure 10). The typical shine observed on the shells of healthy fruits is absent in infested almonds. These damaged fruits do not fall from the tree throughout the year and remain firmly attached.

Figure 9. *Fruits on the tree infested with Eurytoma amygdali larvae.*

Figure 10. *Fruits infested with Eurytoma amygdali larvae (Overwintering on the tree).*

According to Talhouk (1977), the damage caused by this pest to almond fruits in Lebanon ranges between 8% and 35%. The extent of damage varies significantly depending on climatic conditions and the botanical characteristics of the cultivated varieties. Ivanov (1968), citing information provided to Ahakondi, reported that *E. amygdali* caused up to 50% damage to almond fruits in Syria and Palestine. According to Klopperich, the pest led to 40-80% yield losses in almonds grown in Jordan and other Mediterranean countries. The same author noted that in Bulgaria, *E. amygdali* infests approximately 25% of almond fruits each year. According to Ekici and Günaydın (1969), *E. amygdali* caused a 51.4% yield loss in almonds in Elazığ province in 1964.

In a study conducted by Bolu and Özgen (2007), it was reported that the almond seed wasp is widely distributed in the provinces of Diyarbakır, Elazığ, and Mardin. The overall infestation rate ranged from 30% to 60%. The highest infestation was recorded in 2003 in Elazığ (Gezin), with a rate of 58.86%, while the lowest was observed in Mardin (Ömerli), at 31.66%.

Tolga (2018), in a study conducted in Muğla province, reported the lowest fruit infestation rate as 0.10% in Orchard No. 2 (Sarnıç), located in Akhisar district in 2016. The highest infestation rate was recorded as 86.30% in Orchard No. 4 (Temel), located in Fethiye district in 2014. Usanmaz and Aslan (2023) determined that *Eurytoma amygdali* Enderlein (Hymenoptera: Eurytomidae), which causes significant yield losses in almond orchards, had an infestation rate ranging from 24.26% to 47.33% in the orchards surveyed across the provinces of Gaziantep, Kahramanmaraş, and Adıyaman during the years 2016-2017.

It is important to distinguish the damage caused by the almond seed wasp from that of other pests feeding on almond fruits. Differentiating *Eurytoma amygdali* from Rhynchitidae species such as *Epirhynchites (Colonnellinius) smyrnensis* and *Tatianaerhynchites aequatus* (L.) is relatively easy.

While the almond seed wasp lays only one egg per almond fruit, Rhynchitidae species lay more than one egg (typically 3-7). The larvae of *Eurytoma amygdali* are milky white, legless, slightly curved, and have plump bodies. In contrast, Rhynchitidae larvae also have plump and curved bodies and are legless, but they are light yellowish-white in color with a brown head capsule (Figure 11).

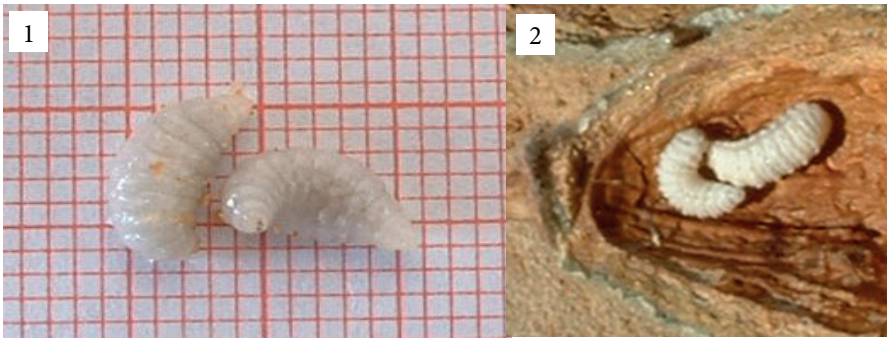

Figure 11. *Larvae of the almond seed wasp (Eurytoma amygdali) and Rhynchitidae species.*

While fruits infected with almond seed wasp larvae remain on the tree without reaching their normal size and falling, colour fading is observed, fruits infected with Rhynchitidae larvae do not reach their normal size, shrink and fall (Figure 12).

Figure 12. *Fruits infested with almond seed wasp (left) and Rhynchitidae larvae (right).*

While almond seed wasp larvae feed on the inside of the seed, Rhynchitidae larvae consume the entire seed (Figure 13).

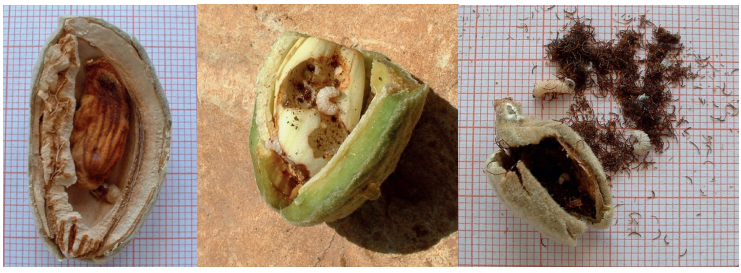

Figure 13. *Damage to the seed caused by almond seed wasp (left) and Rhynchitidae larvae (center and right).*

Control Methods

Natural Enemies Özgen and Bolu (2007) identified, for the first time in Türkiye, three parasitoid species as natural enemies of the pest. These species are:

Adontomerus amygdali (Boucek, 1958) (Hymenoptera: Torymidae) (Figure 14)

Aprostocetus bucculentus (Kostjukov) (Hymenoptera: Eulophidae) (Figure 15)

Gugolzia bademia Doğanlar (Hymenoptera: Pteromalidae) (Figure 16)

Among these, *G. bademia* is a newly described species for the global insect fauna.

When the parasitism rates of these parasitoids were examined, *A. amygdali* was found only in Ergani and exhibited a very low parasitism rate. This species overwinters inside the fruit in the larval stage and emerges in June of the following year. It completes one generation per year. On average, four individuals emerge from each fruit.

The other two parasitoids were found in Gezin and Sivrice, and they also showed low parasitism rates. *A. bucculentus* also overwinters as a larva inside

the fruit and has one generation per year. On average, 14 individuals were recorded to emerge per fruit.

G. bademia, first described by Doğanlar and Bolu (2004) as a new species to science, differs from the other two species by overwintering in the adult stage. It also has one generation per year, but only one individual was obtained per fruit.

In conclusion, although *E. amygdali* has three natural enemies, their parasitism rates are too low to effectively suppress the pest population.

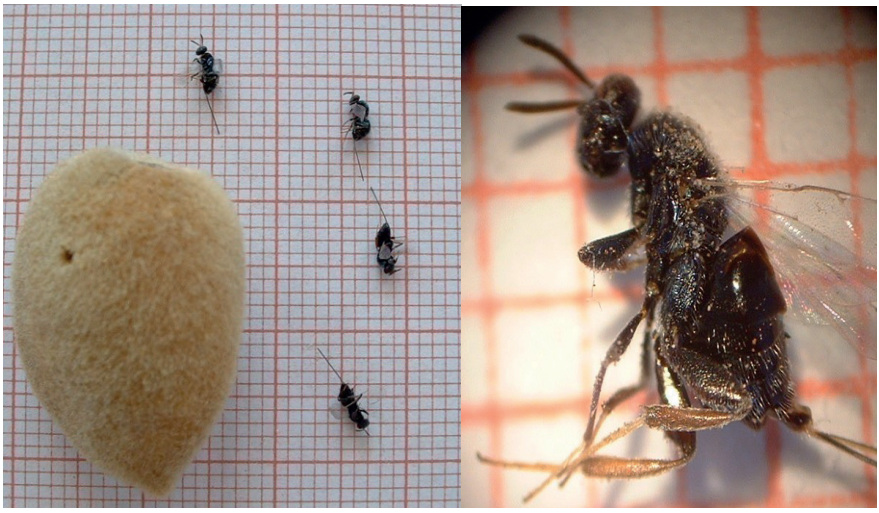

Figure 14. *Female of Adontomerus amygdali, a parasitoid of Eurytoma amygdali.*

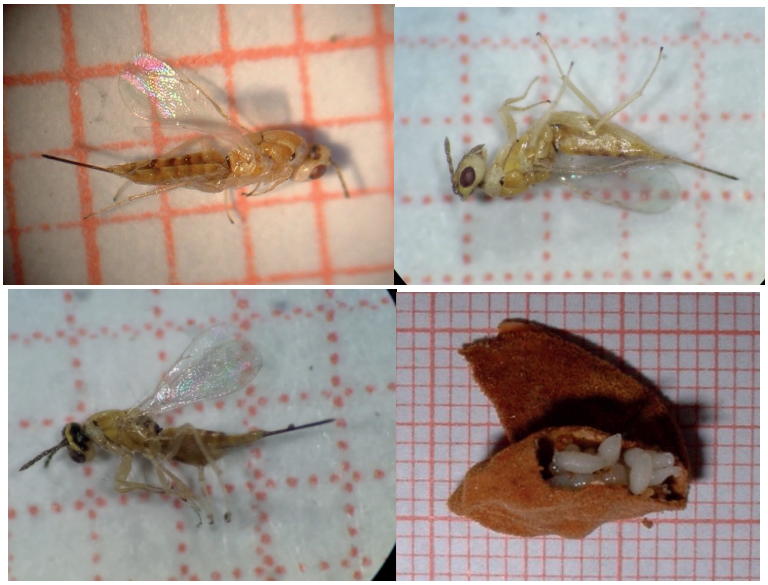

Figure 15. *Adult Aprostocetus bucculentus and its larvae inside the seed.*

Figure 16. *Male (top) and female (bottom) individuals of Gugolzia bademia, a parasitoid of Eurytoma amygdali.*

Usanmaz and Aslan (2023) identified the parasitoids of *Eurytoma amygdali* in Gaziantep, Kahramanmaraş, and Adıyaman provinces during 2016–2017. Within the study area, the parasitoid species *Adontomerus amygdali* (Boucek, 1958) (Hymenoptera: Torymidae), *Aprostocetus bucculentus* (Kostjukov) (Hymenoptera: Eulophidae), and *Gugolzia bademia* (Doğanlar) (Hymenoptera: Pteromalidae) were identified. However, they reported that the population density of these parasitoids was not sufficient to control the pest effectively.

Mechanical Control

Although the fruits infested with the pest resemble healthy fruits in appearance, they have a yellowish hue and remain on the tree without falling

during harvest. The outer hull does not split open. Farmers can easily identify these fruits during harvesting. However, instead of collecting and destroying the infested fruits after separating them from the healthy ones, they often leave them inside the orchard or along its edges (Figure 17). In fact, burning and properly disposing of these infested fruits would significantly reduce the pest population for the following year.

Figure 17. *Fruits infested with Eurytoma amygdali larvae left behind in the orchard.*

Chemical Control

Chemical treatment against the almond seed wasp is effective when targeting the adult stage. The goal is to keep the trees covered with insecticide during the period of adult emergence, thereby eliminating them before they can mate and lay eggs. For this reason, accurately determining the timing of the first adult emergence is critical.

In early spring, just after flowering when the young almonds (çağla) begin to form, infested fruits from the previous year are collected and placed in fine-mesh wire cages, which are then hung on a few trees. When the first adult emergence is observed, an appropriate insecticide should be applied to the trees.

In summary:

After harvest, if there are darkened or discoloured fruits still hanging on the trees, this indicates the presence of the almond seed wasp. However, to determine whether an area requires treatment, the fruits should be cracked open to check for larvae. If infestation is confirmed, treatment should be carried out.

The aim of insecticide application is to eliminate the adults before they can reproduce. Therefore, both the start and duration of adult emergence must be accurately monitored.

In early spring, after flowering when the young almonds become visible, at least 200 infested fruits should be placed into each of three fine-mesh wire cages. One cage is hung on an outer branch of a tree on the southwest side of the orchard. The second is placed on the ground in the same location. The third cage is taken to the relevant institution for daily monitoring under natural conditions.

Taking into account regional climate variations, the cages are checked daily around the expected emergence period. The first adult emergence is recorded, and adults are counted daily by sex until emergence ends. When the first adult females are observed, the first insecticide application should be carried out.

General Conclusions and Recommendations:

This review has identified host preferences of the almond seed wasp (*Eurytoma amygdali* Enderlein) across different almond varieties and documented adult emergence times in Malatya province. The results show that the pest causes significant damage across all varieties, with infestation rates ranging from 81% (Ferragnes) to 97% (Nonpareil).

Adult emergence begins in late April, when the daily average temperature exceeds 15 °C and the maximum reaches 25 °C. In 2017, 89.3% of the population emerged as adults, while 10.6% transitioned to the next generation. Based on these findings, the following recommendations are made:

Variety Selection: Since damage levels vary by variety, newly established orchards should prioritize less-preferred varieties such as Ferragnes and Cristomorto.

Phonological Monitoring: As adult emergence is influenced by climatic conditions, emergence forecasts based on temperature data (especially in late April) should guide the timing of control measures.

Mechanical Control: After harvest, all dried, hollowed, and darkened fruits remaining on the trees must be collected and destroyed. This significantly reduces next year's pest population.

Chemical Control: Control efforts should begin with the emergence of adult individuals, using appropriate insecticides. Early warning systems such as the cage method are recommended to monitor emergence.

Natural Enemies: Biological control options to enhance the effectiveness and population density of natural parasitoid species should be explored. Integrated pest management (IPM) strategies that support ecological balance should be promoted.

These findings provide a valuable foundation for developing integrated control strategies against *Eurytoma amygdali* and contribute to more effective pest management in almond orchards.

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Chapter 6

THE BIOLOGY, ECOLOGY AND PARASITOIDS OF *SESAMIA* SPP. (LEPIDOPTERA: NOCTUIDAE)

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1.Introduction

The genus Sesamia Guenee, 1852, known for species commonly referred to as maize stemborers, includes 29 species reported to be distributed primarily in Afrotropical regions (Kergoat et al., 2015; Hevin et al., 2024). However, the number of species in this genus is reported to be 49 in internet-based sources (Anonymous, 2025). The genus *Sesamia* is a group of noctuid moths known for their larval stages, which infest a variety of cereal crops, such as maize, sorghum, and sugarcane. These pests, commonly referred to as maize stemborers, cause significant yield losses through internal feeding on plant stems, cobs, and other vascular tissues. *Sesamia* species are distributed across the Afrotropical, Asian, and Mediterranean regions, where they are considered major agricultural pests (Le Rü et al., 2006).

This chapter provides an overview of the biology, ecology, damage, natural enemies, and management strategies associated with *Sesamia* species, with a particular focus on their role in crop damage and integrated pest management (IPM) approaches.

2. Distribution of *Sesamia* spp.

Sesamia species are found primarily in the Afrotropical, Asian, and Mediterranean regions of Palearctic region. In these areas, they are particularly destructive to staple crops like maize, sorghum, and sugarcane.

Afrotropical Region: *Sesamia* species are widespread across sub-Saharan Africa, where they are especially problematic for maize and sorghum cultivation. Some common species include *Sesamia nonagrioides*, *Sesamia inferens*, and *Sesamia calamistis* (Sagnon et al., 2013).

Asia: Several *Sesamia* species also occur in parts of West, South and Southeast Asia, where they infest maize and sugarcane fields. Important species include *Sesamia inferens* and *Sesamia cretica*, which affect crops in India and Southeast Asia.

Mediterranean Region: In the Mediterranean, *Sesamia nonagrioides* is the most prevalent species affecting maize, sorghum, and sugarcane crops. *Sesamia cretica* does occur in some areas but is less widespread and important compared to *Sesamia nonagrioides*. *S. nonagrioides* is the dominant and widespread species in Europe, eg., Grecee, Italy, France, Spain and Portugal, Türkiye. Specifically, in Türkiye this species, widely distributed throughout of the Southeastern Anatolia, Mediterranean and Aegean regions (Kayapınar and Kornoşor, 1990; Alexandri Tsitsipis, 1990; Kergoat et al., 2015)

3. Description

In Türkiye, the *Sesamia* species complex consists of three species: *S. cretica* L., *S. nanogrionides* Lef., and *S. calamistis* Hampton (Kornoşor, 1985).

Adults

The moths have a body length ranging from 12 to 17 mm, with a wingspan between 26 and 32 mm. The forewings of *S. cretica* and *S. calamistis* are straw yellow, whereas *S. nanogrioides* exhibits reddish-brown forewings. There are 5-6 black-brown spots arranged as stripes along the outer edge of the forewings, and a brown line runs along the veins in the middle. The hindwings are silvery white. The head, thorax, abdomen, and legs of *S. cretica* and *S. calamistis* are covered in light earth-colored or straw yellow scales. In contrast, *S. nanogrionides* has reddish-brown or reddish dark beige scales. Males have comb-like antennae (Figure1a), while females (Figure1b) possess thread-like antennae.

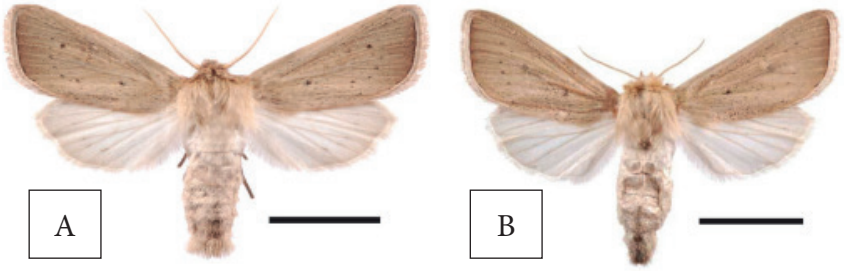

Figure 1. Adults of Sesamia nonagrioides a-Male, b-Female (Kergoat et al., 2015)

Eggs

The diameter of the egg is approximately 10 microns. The eggs are flattened, cylindrical, and slightly curved inward at both the top and bottom. Females typically lay their eggs in clusters. Initially, the eggs are cream-colored, but they darken through embryonal development over time (Figure 2a).

Larvae

The larvae are cream-colored with a slightly pinkish dorsal side and yellow ventral side. The head is reddish-brown, and the prothorax is dark yellow with brown spots. The mature larvae reach a size of 30-35 mm in length (Figure 2b and 2c).

Pupa

The pupa is encased in a white cocoon spun by the larva. It is reddish-brown and varies in size from 12 to 20 mm (Figure 2d).

Figure 2. Different biological stages of Sesamia nonagrioides a-egg, b-young larvae c-mature larvae, d-pupae

4-Biology

Adult moths emergence in April during the spring. The adults are nocturnal and seek concealment during diurnal periods. Following copulation, females oviposit their eggs in masses of varying densities of eggs between the leaf sheath and the stem of maize plants. A female's average longevity vary with temperature 17.3 days at 14 °C to 6.0 days 25 °C, fecundity ranging from 200 to 350 eggs, deposited across multiple cycles. The incubation period for the eggs is highly dependent on climatic conditions, varying from 8.4 days to 30 days (Kornoşor, 1985; Andreadis et al., 2013).

Upon emergence, the neonate larvae engage in feeding on the host plant's foliage for a few days before boring into the plant tissue. The larval entry point rapidly develops a pinkish discoloration. The larvae penetrate the stem multiple times, forming galleries as they consume the pith. Larval development progresses through 6–7 instars. During this period, larvae may migrate between adjacent plants. Larvae reaching the seventh instar typically cease feeding and transition into the prepupal stage within a constructed chamber inside the stem. The pupal duration spans 12–37 days depending on temperature ((Kornoşor, 1985; Andreadis et al., 2013).

The first adults from overwintering generation appear between early March. Adults of the second generation emerge in overlapping periods from mid-June through mid-July. These moths oviposit on a wide range of host plants, including maize (*Zea mays*), millet, rice (*Oryza sativa*), barnyard grass, wild millet species, common reed, and various other poaceous weeds (Kornoşor, 1985; Bayram et al., 2007).

Subsequent generations exhibit overlapping developmental stages; consequently, adults, eggs, larvae of all instars, and pupae can be found simultaneously in maize fields. Moths of the third generation emerge in late July to early August. They again oviposit on host plants, and the resulting larvae continue to feed until late October or even November. The pest overwinters as a mature or immature larval stages. Feeding activity may continue on suitable days throughout the winter. Pupation of the overwintered generation commences in early March, concluding the cycle (Kornoşor, 1985). The number of generations vary with ecological conditions between 2-5 generations.

3. Feeding Ecology and Damage of *Sesamia* spp.

The cryptic feeding behavior of *Sesamia* larvae is one of the primary factors contributing to their status as significant agricultural pests. These moths are known for their internal feeding strategy, which involves boring into the plant's stems, cobs, or other vital parts (Velasco et al., 2004). This behavior not only damages the plant physically but also disrupts its internal physiological functions (Askarianzadeh et al., 2008; Rodríguez et al., 2018). Upon hatching, the larvae of *Sesamia* spp. begin feeding internally by boring into the plant's stems or cobs (Bayram, 2003). This tunneling behavior makes it difficult to detect the larvae early, as they are hidden within the plant tissues. The larvae feed inside the stem of the plant, damaging the vascular tissues responsible for the transport of nutrients and water throughout the plant (Rodríguez et al., 2018). The physical act of boring into the plant weakens the plant's structural integrity, leading to potential lodging (plant collapse), reduced growth, and stunted development (Bayram, 2003). Feeding on the vascular tissues also disrupts the plant's nutrient flow, which reduces the overall health of the crop, leading to poor yield and sometimes death of the plant (Askarianzadeh et al., 2008).

The tunneling larvae not only remove valuable plant nutrients but also create pathways for secondary pathogens, such as fungi and bacteria, to enter the plant. This increases the susceptibility of the crop to secondary infections, which further diminishes its yield and quality. For example, the bored areas in the stems or cobs provide entry points for Fusarium and Aspergillus fungi, which can lead to the contamination of crops with mycotoxins (Avantaggiato, 2003; FAO, 2015). Larvae feeding is also led to nitrogen/protein deficiency in maize grain (Bayram, 2003)

Feeding Preferences: While *Sesamia* larvae are opportunistic feeders, preferring the softer tissues of the stem or cob, they exhibit a preference for young, tender plants, especially during early crop development. This preference makes early infestations particularly devastating as the larvae can significantly stunt plant growth before it matures.

4. Damage and Economic Impact

The damage is caused by the larvae, which are internal feeders that bore into the maize plant stalk and ears. Larvae penetrate the stalk and feed on the stem pith, creating frass-filled galleries. This internal damage weakens the plant structure, leading to stalk breakage (lodging) and interference with the translocation of metabolites (Bayram, 2003; Velasco et al., 2004a and 2004b; Rodríguez et al., 2018). In younger plants, tunneling in the growing point causes the central whorl of leaves to wilt and die, a symptom known as "deadheart" (Bayram, 2003). However, with generation coinciding the maize plants are reproduction phases, larvae infest older plants, damaging both stems and ears. Unlike the European corn borer (*Ostrinia nubilalis*), *S. nonagrioides* typically infests the ear through the shank (Velasco et al., 2004a and b). This causes kernel damage, ear malformation, and ear dropping, leading to significant yield reduction. Under heavy pest attacks along with improper chemical conditions *S. nonagrioides* damage can reach up to 100% (Bayram, 2003). Additionally, *S. nonagrioides* damage indirectly lead to the most critical consequence of its role in facilitating contamination by mycotoxigenic fungi, particularly those producing fumonisins (Rhee Rheeder et al., 2002; Avantaggiato et al., 2003; Santiago et al., 2013; Arias-Martín et al., 2021). The larvae act as both wound creators and vectors for fungal spores (primarily *Fusarium verticillioides* and *F. proliferatum*) (Avantaggiato et al., 2003; Arias-Martín et al., 2021). Larval boring creates essential entry points, and the larvae physically spread spores as they move and feed within the plant tissue (Avantaggiato et al., 2003; Arias-Martín et al., 2021).

Table1 Parasitic natural enemies of *Sesamia* spp.

Order	Family	Species	Host stage	Zoogeographic Region-	Reference
Hymenoptera	Chalcididae	*Brachymeria sesamiae*	L	Afrotropical	Polaszek et al., 1998.
	Braconidae	*Chelonus curvimaculatus*	L	Afrotropical	Mutamiswa et al., 2017
		Eichneumonidea sp.	L	Afrotropical	Mutamiswa et al., 2017
		Bracon testaceorufatus	L	Afrotropical	Mutamiswa et al., 2017
		Bracon sp.	L	Afrotropical	Mailafiya et al., 2009
		Bracon sesamiae	L	Afrotropical	Mailafiya et al., 2009
		Cotesia flavipes		Afrotropical	Getu et al., 2001; Mailafiya et al., 2009
		Cotesia sesamiae	L	Afrotropical	Getu et al., 2001
		Cotesia typhae	L	Afrotropical	Kaiser et al., 2017
		Cotesia ruficrus	L	Afrotropical and Palearctic	Sertkaya, 1999; Getu et al., 2001
		Gleptoapantelas africanus	L	Afrotropical	Awadalla et al., 2007
		Habrobracon hebetor	L	Palearctic	Bayram et al., 2007.
		Cotesia sp.	L	Afrotropical	Awadalla et al., 2007
		Apanteles sp.	L	Afrotropical	Awadalla et al., 2007
		Meteorus sp	L	Afrotropical	Awadalla et al., 2007
		Gyptomorrpha baetica	L	Palearctic	Beyarslan et al., 2006
	Ichneumonidae	*Cremastinae sp.*	L	Afrotropical	Polaszek et al., 1998.
		Syzeuctus sp.	L	Afrotropical	Polaszek et al., 1998.
		Venturia sp. A	L	Afrotropical	Polaszek et al., 1998.
		Gambroides nimbipennis	P	Afrotropical	Polaszek et al., 1998.
		Ichneumon rubriornatus	P	Afrotropical	Polaszek et al., 1998.
		Ichneumon unicinctus	L-P	Afrotropical	Polaszek et al., 1998.
		Procerochasmias nigromaculatus	P	Africa	Polaszek et al., 1998.
		Enicospilus sesamiae	L	Afrotropical	Polaszek et al., 1998
		Ichneumon sarcitorius caucasicus	P	Palearctic	Sertkaya, 1999; Bayram et al., 2007
		Pimpla spuria	P	Palearctic	Sertkaya, 1999; Bayram et al., 2007
		Pimpla hova	P	Afrotropical	Polaszek et al., 1998
		Pimpla sp. A	P	Afrotropical	Polaszek et al., 1998
		Xanthopimpla citrina	P	Afrotropical	Polaszek et al., 1998
		Xanthopimpla stemmator	P	Afrotropical	Polaszek et al., 1998
		Barichneumon sp.	P	Palearctic	Bayram et al., 2007
		Sinophorus turionum	L	Palearctic	Monetti et al., 2003
	Eulophidae	*Pediobius furvus*	P	Afrotropical	Mailafiya et al., 2009
		Tetrastichus atriclavus	L	Afrotropical	Polaszek et al., 1998
		Pediobius imbreus	L	Afrotropical	Polaszek et al., 1998
	Betylidae	*Goniozus indicus*	L	Afrotropical	Polaszek et al., 1998
		Norbanus sp.	L	Afrotropical	Mutamiswa et al., 2017
	Scelionidae	*Telenomus isis*	E	Afrotropical	Setamou and Schulthess, 1995
		Telenomus busseolae	E	Afrotropical, Palearctic	Sertkaya et al., 1994; Setamou and Schulthess, 1995
	Trichogrammatidae	*Trichogramma evanescens*	E	Palearctic	Bayram, 1999.
		Trichogramma turkestanica	E	Palearctic	Conti et al., 2003.
		Lathromeris ovicida	E	Afrotropical	Polaszek et al., 1998

Diptera	Tachinidae	*Siphona murina*	L	Afrotropical	Polaszek et al., 1998; Mutamiswa et al., 2017
		Exorista larvanum	L	Palearctic	Monetti et al., 2003
		Lydella thompsoni	L	Palearctic	Araujo and Figueiredo;1996; Monetti et al., 2003
		Peribaea tibialis	L	Palearctic	Monetti et al., 2003
		Nemorea pellucida	L	Palearctic	Monetti et al., 2003
		Metoposisyrops sesamiae	L	Afrotropical	Mailafıya et al. 2009
		Descampsina sesamiae	L-P	Afrotropical	Polaszek et al., 1998
		Lydella grisescens	L	Palearctic	Bayram et al., 2007
		Lydella sesamiae	L	Afrotropical	Polaszek et al., 1998
		Nemoraea discoidalis	P	Afrotropical	Polaszek et al., 1998
		Nemoraea bequaerti	L	Afrotropical	Polaszek et al., 1998
		Chromatophania picta	L	Afrotropical	Polaszek et al., 1998
		Dejeania bombylans	L	Afrotropical	Polaszek et al., 1998
		Pseudoperichaeta nigrolineata	L	Palearctic	Araujo and Figueiredo;1996
		Sturmiopsis parasitica	L-P	Afrotropical	Polaszek et al., 1998; Getu et al., 2001
	Sarcophagidae	*Sarcophaga benefactor?*	L	Afrotropical	Polaszek et al., 1998
		Atherigona (Acritochaeta) yorki	L	Afrotropical	Polaszek et al., 1998

E=egg, L=Larvae, P=Pupae

Among the natural enemy complex of *Sesamia* spp., parasitoids are the most effective. Among the 58 parasitoid species presented in Table 1, *Telenomus* spp. (*T. busseolae* and T. isis) are specialized egg parasitoids. In addition to the Afrotropical region, *Telenomus busseolae* occurs in the Palearctic region, specifically in the Mediterranean Basin (Alexandri and Tsitsipis, 1990; Kayapınar and Kornoşor, 1990; Kornoşor et al., 1992; Bayram, 2003; Bayram et al., 2004; Bayram et al., 2005). This specific parasitoid can be mass-reared and utilized against *Sesamia* spp. through inundative releases

5 Conclusion

Sesamia spp. are major agricultural pests, particularly in tropical and subtropical regions, where they cause significant damage to cereal crops. Their feeding ecology, including tunneling into plant stems and cobs, results in both direct and indirect damage to crops, leading to yield losses. An integrated pest management (IPM) approaches are essential for sustainable and effective control of Sesamia spp. As the impacts of climate change and globalization increase, the spread of *Sesamia* spp. to new areas may become more common, necessitating ongoing research and development of novel management strategies.

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