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# Periodic and annual changes in body weight and fat ratio of sunn pest, *Eurygaster maura* L. 1758 (Hemiptera: Scutelleridae)

Sünenin, *Eurygaster maura* L. 1758 (Hemiptera: Scutelleridae) vücut ağırlığında ve yağ oranında dönemsel ve yıllık değişimler

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A B S T R A C T

This study, which aims to predict the outbreaks of sunn pest; was carried out in two overwintering sites for six life cycles in 2013-2019. Three critical periods in each life cycle during the study; at the beginning of the estivation, hibernation and active life periods, the densities of the overwintering population, the fat ratios, weights, and the relationships between them were determined. It has been determined that the winter population of sunn pest varies in terms of both weight and fat depending on gender, life cycles and critical periods, and there is a positive relationship between body mass and fat ratios. Lipids ratio is an important indicator that we can use in estimates of sunn pest epidemic with appropriate climatic conditions and nutrient abundance. Especially in female individuals 27% and above, suitable for climatic conditions during active life; It has been demonstrated that in conditions where there is high temperature, low proportion humidity, wind speed and precipitation and proper nutrient abundance for 2 consecutive years, there is a significant increase in population size and pest can cause an epidemic.

## INTRODUCTION

The main pest of wheat, sunn pest (*Eurygaster* spp.), is widespread in the Near and Middle East, Northern and Eastern Europe and North Africa. The pest causes up to 100% damage in the quality and quantity of wheat by feeding on leaves, stems, and grains (Anonymous 2008, Özkan and Babaroğlu 2015, Babaroğlu et al. 2020). The life cycle of the sunn pest, which gives offspring once a year is divided into three main periods including aestivation, hibernation and active life periods. The aestivation period is from July to October-November following the harvest, the hibernation covers the period from October to November and from March to April of the following year. This period, which lasts about 8-9 months, is also called the passive life period, and during this period, it spends in obligatory diapause usually at 1200-1600 m altitude (overwintering site) without feeding. The passive period ends when the winter passes pest begins to fly from the overwintering site to the plains with the increase of the air temperature in the spring, and the active period, which is the breeding and development period, begins. Adults, who come to the plain in the active period, feed and mate for 1.5-2 months and lay eggs. At the end of this period, adults die. The eggs hatch within 2-3 weeks depending on the climatic conditions and nymphs show up. Nymphs that spend 5 periods within an average of one month become adult. Before returning to overwintering sites, adults are fed voraciously and store the necessary energy during hibernation, estivation, and active life periods a year later (Anonymous 2008, Özkan and Babaroğlu 2015, Babaroğlu et al. 2020).

In addition to appropriate climatic conditions and abundance of nutrients, the presence of physiologically strong individuals that have stored high amounts of nutrients is also an important factor in the occurrence of harmful outbreaks. Fats play a major role in pest's basic vital activities. In most insects, accumulated fat stores are of primary importance in diapause and post-diapause activities. Most insects end the diapause with a smaller amount of fat than at the beginning of diapause. This indicates that fats are the primary source used during diapause (Hahn and Denlinger 2011, Sinclair 2015, Wipking et al. 1995). Fat reserves are the most important resource used by diapause insects to meet their energy needs during their diapause (Hahn and Denlinger 2007, Estela and Soulages 2010, Sinclair 2015). In addition to the important role of fats in pest survival in the passive period (Fedotow et al. 1955, Popov 1979, 2002; Sinclair 2015, Williams et al. 2015a, Wipking et al. 1995), they also play an important role during migration from overwintering site to the plain (Beenakkers et al. 1984, Canavoso et al. 2003, Estela and Soulages 2010, Gade and Auerswald 2002, Kaufmann and Briegel 2004, Ziegler and Schulz 1986) and reproduction (Beenakkers et al. 1985, Briegel 1990, Troy et al. 1975, Van Handel 1993).

Increased body mass is associated with increased nutrient reserves. Therefore, individuals with larger bodies generally have more fat reserves than small ones (Sinclair and Marshall 2018, Williams et al. 2015b). Although there are some opposite examples, they usually show higher performance (survival rate, reproduction, spread) of large body individuals in diapause and post- diapause processes compared to small ones (Hahn and Denlinger 2007, Irwin and Lee 2003, Williams et al. 2015b).

Sunn pest causes great damage by creating periodic outbreaks. In pest control, it is very important to take the necessary precautions by predicting outbreaks that will occur. Demonstrating the usability of changes in the rate of sunn pest fat content in explaining the outbreak course has been discussed in this study.

## MATERIALS AND METHODS

The studies were carried out in Ekecik (Aksaray province) and TV tower (Kırşehir province) overwintering sites. To determine the body weights and fat ratios of the adult at the beginning of aestivation, hibernation, and active life periods from both overwintering sites during 6 life cycles in 2013-2019, adult males (3857) and females (4337) were collected and brought to the laboratory in the ice container, and initial body mass was determined by weighing individually. Weighed individuals were taken to the fat analysis as soon as possible without waiting. The determination of fat ratios is based on the Association of Official Analytical Chemists, Official Method 991.36. Firstly, sunn pests were kept in the desiccator at 105 °C for 4-5 hours, after their moisture was removing, they were ground and homogenized. 5-10 g sample was taken into the cartridge and placed in the extractor; the fats of the sunn pests were extracted for 5-6 hours (Anonymous 2000).

Meteorological data including temperature, proportional humidity, and wind speed were obtained from meteorological stations (IMETOS PRO 250) in the study sites.

*Statistical analysis*

Analysis of variance was used to determine if there were differences and, following Tukey test was used to determine significant differences according to their importance regression analysis was used to determine the relationships between the characters. Data were analyzed using SPSS 24 software.

## RESULTS AND DISCUSSION

*Fat ratio*

In the study, fat ratios in critical periods in the life cycle of the sunn pest were determined at first. From Ekecik (Aksaray province) and TV tower (Kırsehir province) overwintering sites, 6 life cycles (2013-2019) and 3 critical periods in each cycle. It has been determined that the fat content of male and female individuals collected at the beginning of aestivation, hibernation, and active life periods was 30.10% (19.92% - 43.00%) on average (Table 1).

As a result of the statistical analysis made considering life cycle, critical stage, and gender, no interaction was detected between the characters (F= 0.432; df= 10; P= 0.893), but the main characters; it has been determined that fat ratios differ according to the life cycle, critical period, and gender.

It was determined that female individuals (32.01%) have higher rates of fat than male individuals (28.18%) in both locations (F= 81.668; df= 1; P= 0.00). Similar to the results we obtained, it was also expressed by Fedotow (1945), Andreev (1963), Vinogradova (1969), Gospodinov (1973), Paulian et al. (1973), Mustatea et al. (1979), Paulian and Popov (1980), Kılınçer et al. (1987), Popov (2002), and Amiri et al. (2010) that females have a higher rate of fat than males.

**Table 1.** Fat ratio (%) of male and female individuals collected from Ekecik (Aksaray province) and TV tower (Kırşehir province) overwintering sites during aestivation, hibernation and active life periods in 2013-2019

| Overwintering site | Critical Period | Gender | Fat ratio (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| Ekecik (Aksaray province) | Beginning of aestivation | ♀ | 39.57 | 40.36 | 39.00 | 37.21 | 40.18 | 39.00 |
| | | ♂ | 35.29 | 36.42 | 35.50 | 34.09 | 39.33 | 33.18 |
| | Beginning of hibernation | ♀ | 28.60 | 29.98 | 27.75 | 26.86 | 34.98 | 30.54 |
| | | ♂ | 27.68 | 26.36 | 27.48 | 24.47 | 28.74 | 25.43 |
| | Active life periods | ♀ | 26.66 | 23.57 | 24.75 | 24.67 | 32.72 | 29.02 |
| | | ♂ | 24.30 | 21.35 | 23.63 | 22.91 | 25.77 | 23.17 |
| TV Tower (Kırşehir province) | Beginning of aestivation | ♀ | 38.94 | 38.92 | 37.18 | 38.26 | 42.83 | 39.07 |
| | | ♂ | 34.37 | 36.08 | 33.09 | 32.88 | 37.98 | 33.32 |
| | Beginning of hibernation | ♀ | 27.96 | 31.02 | 31.42 | 28.52 | 33.58 | 32.61 |
| | | ♂ | 25.49 | 29.46 | 24.23 | 25.03 | 26.67 | 25.30 |
| | Active life periods | ♀ | 23.47 | 27.87 | 26.18 | 26.11 | 28.31 | 28.84 |
| | | ♂ | 21.19 | 22.24 | 19.92 | 22.00 | 21.53 | 23.97 |

When examined according to the critical periods, it was determined that the sunn pest had the highest fat content at the beginning of summer (Table 2). During the aestivation, there was a decrease in the amount of fat, and the lowest amount of fat was detected in individuals that have just come out of hibernation (F= 334.59; df= 2; P= 0,000).

**Table 2.** Fat ratios (%) of individuals collected from Ekecik and TV tower overwintering sites in 2013-2018 at the beginning of aestivation, hibernation and active life periods

| Fat ratios (%) mean ± standard error of mean | | |
|---|---|---|
| Beginning of aestivation | Beginning of hibernation | Active life periods |
| 37.17±0.56 a[1] | 28.34±0.59 b | 24.76±0.62 c |

[1]Values with different minuscule in the same row are statistically different from each other.

According to Tauber et al. (1986), Danks (1987), insects entering diapause decrease their stored reserves during this time and contain fewer reserves after diapause. It has also been demonstrated by other studies that the new generation adults because of wings maximize their fat reserves by feeding in the wheat fields until to the overwintering site for aestivation and have the lowest fat rate at the beginning of the active period (Bel'kevich 1957, Choumakow et al. 1954, Karaca et al. 2007, Kılınçer et al. 1987, Lazarov et al. 1969, Strogaia1950, 1955).

A difference has been noted in fat ratios depending on the life cycle of sunn pest (F= 10.449; df= 5; P= 0.000). The highest fat ratio was determined in the 5th life cycle, followed by the 2nd and 6th life cycles, and the 4th life cycle was found to have the lowest fat ratio (Table 3). The situation in question arises from the inconsistency between the wheat phenology and the biology of the pheasant, and the fact that the pest cannot be fed well and cannot accumulate enough fat reserves due to the adverse development of the climatic conditions during feeding. On the contrary, the phenology of the wheat and the climatic conditions are suitable for sunn pests, which is due to the accumulation of sufficient fat reserves.

Strogaia (1955) stated that the body fat ratio of the sunn pest (*E. integriceps*) varied over the years and emphasized that this was due to climatic conditions that affect feeding time and performance. Doronina and Makarova (1973) reported that the body fat ratio varied according to years, and the fat ratio at the beginning of hibernation was 30% in stout individuals and 25% in weak individuals. Paulian et al. (1973) emphasized that when both the phenology of wheat and the climatic conditions were suitable for nutrition, they can accumulate high fat reserves. Areshnikov et al. (1977) reported that the fat content of sunn pests varied according to years and overwintering sites. Similarly, the fat ratios of female individuals differed according to their life cycles depending on the feeding and hibernation conditions (Popov 1977).

One of the most important reasons for the differences in fat rates between cycles was the nutritional performance of the new generation adults. The new generation adult fat ratios in overwintering (Table 4) showed a parallel course to the cycle average fat ratios ($r = 91.80$; $r^2 = 84.27$).

**Table 3.** Fat rates (%) of individuals collected from Ekecik and TV tower overwintering sites in 2013-2019

| Fat ratios (%) mean ± standard error of mean | | | | | |
|---|---|---|---|---|---|
| Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| 29.46±1.76 bc | 30.30±1.87 b | 29.17±1.73 bc | 28.58±1.62 c | 32.72±1.91 a | 30.29±1.55 b |

[a]Values with different minuscule in the same row are statistically different from each other.

**Table 4.** Fat rates (%) of individuals collected from Ekecik and TV tower beginning of aestivation in 2013-2019

| Fat ratios (%) mean ± standard error of mean | | | | | |
|---|---|---|---|---|---|
| Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| 37.04±1.29 | 37.94±1.02 | 36.19±1.26 | 35.61±1.27 | 40.80±1.27 | 36.14±1.67 |

Differences in fat ratios in their life cycles at the beginning of aestivation, it changed depending on the climatic conditions during the period from the new generation adults to its exit to the overwintering site for aestivation. Temperature (average; min.; max.), proportional humidity, and wind speed in the process leading up to the migration of new generation adult individuals to the overwintering sites affect the feeding performance of the pest (Table 5). As shown in Table 5, high increases in fat rates occurred in parallel with temperature increases, but the increase in fat rates was low because pests cannot feed at high proportional humidity, and wind speed.

Changes in body fat rates during diapause were given in Table 6. As seen in the table, 35% of the body fat amount was used during the passive period. The important part of body fat; approximately 25% was consumed during aestivation and 13% during hibernation. They did not feed during the aestivation period, which was an important part of the sunn pest's passive period. At the same time, the average temperatures in this period were both high and showed irregular changes. As a result, we believe that fat consumption was also high, as there was no slowdown in metabolic activities. Similarly, the fat consumption rates of insects during their diapause depend on both the average and the variability of the temperature (Sinclair 2015). Williams et al. (2012) stated that the variable temperatures in fall and spring caused disproportionately high-fat consumption in these seasons (Jensen inequality).

**Table 5.** Relationship between fat ratios (%) and some climate data

| Variables | | | Statistical data | | |
|---|---|---|---|---|---|
| | | | r | $r^2$ | Sign. |
| Fat ratios (%) | Temperature (°C) | Mean | 0.812 | 0.659 | 0.000* |
| | | Minimum | 0.729 | 0.531 | 0.000* |
| | | Maximum | 0.833 | 0.694 | 0.000* |
| | Average humidity (%) | | -0.686 | 0.471 | 0.000* |
| | Average wind speed (km/h) | | -0.517 | 0.267 | 0.008* |

*The correlation is significant at the 0.01 level.

**Table 6.** Fat change rates (%) of male and female individuals collected from Ekecik and TV tower overwintering sites in aestivation, hibernation and active life periods beginning in 2013-2019

| Life cycle | Gender | Fat change rates (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Beginning of aestivation-Beginning of hibernation | | Beginning of hibernation-Beginning of active life periods | | Beginning of aestivation–Beginning of active life periods | |
| | | Ekecik | TV tower | Ekecik | TV tower | Ekecik | TV tower |
| Life cycle 1 2013-2014 | ♀ | 27.72 | 28.20 | 6.78 | 16.06 | 32.62 | 39.73 |
| | ♂ | 21.56 | 25.84 | 12.21 | 16.87 | 31.14 | 38.35 |
| Life cycle 2 2014-2015 | ♀ | 25.72 | 20.30 | 21.38 | 10.15 | 41.60 | 28.39 |
| | ♂ | 27.62 | 18.35 | 19.01 | 24.51 | 41.38 | 38.36 |
| Life cycle 3 2015-2016 | ♀ | 28.85 | 15.49 | 10.81 | 16.68 | 36.54 | 29.59 |
| | ♂ | 22.59 | 26.78 | 14.01 | 17.79 | 33.44 | 39.80 |
| Life cycle 4 2016-2017 | ♀ | 27.82 | 25.46 | 8.15 | 8.45 | 33.70 | 31.76 |
| | ♂ | 28.22 | 23.87 | 6.38 | 12.11 | 32.80 | 33.09 |
| Life cycle 5 2017-2018 | ♀ | 12.94 | 21.60 | 6.46 | 15.69 | 18.57 | 33.90 |
| | ♂ | 26.93 | 29.78 | 10.33 | 19.27 | 34.48 | 43.31 |
| Life cycle 6 2018-2019 | ♀ | 21.69 | 16.53 | 4.98 | 11.56 | 25.59 | 26.81 |
| | ♂ | 23.36 | 24.07 | 8.89 | 5.26 | 30.17 | 28.06 |
| Average | ♀ | 24.06 | 21.30 | 9.69 | 13.14 | 31.42 | 31.64 |
| | ♂ | 25.09 | 24.81 | 11.88 | 16.22 | 33.99 | 37.01 |
| | ♂+♀ | 24.55 | 22,95 | 10.73 | 14.55 | 32.67 | 34.16 |

Fats play an important role in the life cycle of sunn pests. The development of sunn pests consists of two periods as fat accumulation and fat consumption. Approximately 1/3 of the accumulated fat is used in the passive period, and 2/3 is used in the active period. Fat consumption is high in metabolic activities and has no nutrition aestivation. It was also reported by different researchers that it was consumed in low amounts in the active life period, which was a period of growth and development, and in the hibernation period, when the metabolism was very slow. It has been reported by different researchers that similar results were observed from other studies (Choumakow et al. 1954, Fedotow 1945, Fedotow et al. 1955, Karaca et al. 2007, Karel 1958, Lazarov et al. 1969, Ouchatinskaya 1953, 1955; Popov 1979, 2002; Strogaia 1950, 1955).

Although there was no statistically significant difference in the fat consumption of female and male individuals (t= 0.582; df= 70; p= 0.234), it was observed that fat consumption was generally higher in male individuals (Table 6). While the amount of fat consumed during aestivation period did not differ according to generations (F= 0.648; df= 5; P= 0.667), the amount of fat consumed during hibernation varied according to generations (F= 3.375; df= 5; P= 0.025) (Table 7). Karel (1958) and Popov (1979, 2002) report that fat consumption differs both genders and generations, with fat consumption higher in male individuals.

Another criterion is also examined in the study is the bodyweight of sunn pest. The average initial body mass was determined as 109.09 mg as a result of the weighing of the adults collected from two overwintering sites at the beginning of aestivation, hibernation, and active life during 6 life cycles in 2013-2019. Initial mass for females and males were 110.59 mg and 107.42 mg, respectively. Sunn pest population had a very heterogeneous structure in terms of mass (Table 8). As a result of the variance analysis, it was determined that initial body mass varied depending on the life cycle, critical period, gender, and location (F= 3.459; df= 10; P= 0.001).

Although the male and female individuals collected from Ekecik and TV tower overwintering sites varied based on their life cycle, the highest body mass was detected at the beginning of estivation. Between the beginning of hibernation and the beginning of the active period, in the male individuals in the first life cycle in the Ekecik overwintering site and differences in the mass of the male and female individuals in the second and sixth life cycles in both overwintering sites were determined (Table 8). In other life cycles, both by gender and by overwintering sites differences in mass were not determined. Individuals at the beginning of aestivation were heavier than individuals in other critical periods. This is because the new generation adults are fed enough for aestivation, hibernation, and one year later for survival and reproduction before migrating to the overwintering area, and they stored maximum levels of fat, protein, and carbohydrates in their bodies.

Our results are similar to other studies. Karel (1958) and Paulian and Popov (1980) report that new generation adult of sunn pest (E. integriceps) feed intensively before migrating to the overwintering site, storing large amounts of fat and increasing their body mass.

By different researchers that the sunn pest having finished feeding that migrated to the overwintering site for aestivation had the highest body mass, during the period from aestivation site to hibernation site migration, there was a large decrease in average body mass, and a similar situation was detected in the period from hibernation to the time of migration to the plain is the emphasized (İslamoğlu et al. 2013, Kılınçer et al. 1987, Lazarov et al. 1969, Memişoğlu 1985, Radjabi 1995, Yüksel 1968).

When we consider in terms of life cycles, although it varied according to the critical period and gender, the highest values were found in the second and fifth life cycles. Although there was no difference at the beginning of hibernation except for one period, the differences were generally detected at the onset of aestivation and active period (Table 8). Body mass also differed according to years due to changes in nutritional performance depending on the climatic conditions and feeding time in the period up to the exit of the sunn pest to the overwintering site for aestivation after nymph become to the new generation adult. Many studies have also demonstrated that the body mass of the new generation adult vary by years (Areshnikov et al. 1977, Doronina and Makarova 1973, Karaca et al. 2003, Lazarov et al. 1969, Popov 1977, Strogaia 1955, Taranukha et al. 1967, Yüksel 1968).

**Table 7.** Fat consumption rates (%) of different generations during aestivation and hibernation

| Critical periods | Fat consumption rates (%) mean ± standard error of mean | | | | | |
|---|---|---|---|---|---|---|
| | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| Aestivation | 25.83±1.51 a[1] | 22.99±2.19 a | 23.43±2.95 a | 26.34±1.02 a | 22.81±3.70 a | 21.41±1.70 a |
| Hibernation | 12.98±2.30 ab | 18.76±3.08 a | 14.82±1.55 ab | 8.77±1.20 b | 12.93±2.83 ab | 7.67±1.57 b |

[1]Values with different minuscule in the same row are statistically different from each other.

**Table 8.** Mass of male and female individuals beginning of aestivation, hibernation and active life periods collected from Ekecik and TV tower overwintering sites in 2013-2019

| Overwintering site | Gender | Critical period | Body weight (mg) mean ± standard error of mean (min. – max.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| Ekecik (Aksaray province) | ♀[1] | Beginning of aestivation | 113.42±1.30) b (87.3-154.6) A | 116.79±0.83 ab (88.0-152.3) A | 115.11±1.65 b (87.9-151.6) A | 114.67±1.41 b (85.7-158.2) A | 119.63±1.09 a (77.6-159.8) A | 112.60±0.08 b (83.7-149.3) A |
| | | Beginning of hibernation | 104.46±1.39 a (87.1-120.1)B | 108.42±0.78 a (82.8-139.5) B | 104.78±1.54 a (67.5-152.5 B | 107.55±1.49 a (70.7-150.8) B | 107.87±1.37 a (74.0-154.1) B | 106.39±1.29 a (64.6-166.0) B |
| | | Beginning of active life periods | 105.79±1.23 b (75.6-128.8) B | 98.83±1.70 c 61.7-125.9) C | * | 106.29±1.27 b (70.3-145.0) B | 111.99±1.68 a (64.0-142.0) B | 103.96±0.68 b (63.1-142.8) C |
| | ♂ | Beginning of aestivation | 114.71±1.38 ab (88.0-154.8) A | 114.60±0.99 ab (84.7-153.9) A | 111.45±1.50 b (87.8-156.8) A | 114.08±1.32 ab (87.5-151.4) A | 117.65±1.78 a (82.8-163.7) A | 109.80±0.80 b (82.6-143.5) A |
| | | Beginning of hibernation | 106.21±1.31 a (81.5-133.8) B | 107.00±0.89 a (68.9-143.1) B | 103.15±1.27 a (66.7-124.0) B | 103.13±1.45 a (78.6-142.1) B | 105.40±1.57 (67.2-139.7) B | 103.14±1.38 a (51.0-152.3) B |
| | | Beginning of active life periods | 102.07±1.16 a (75.6-131.2) C | 102.15±1.56 a (68.1-143.2) C | * | 102.22±1.35 a (61.9-155.8) B | 103.79±1.92 a (61.7-128.0) B | 97.63±0.72 b (64.5-129.4) C |
| TV tower (Kırşehir province) | ♀ | Beginning of aestivation | 112.90±1.53 bc (72.7-136.8) A | 117.69±0.87 a (91.8-141.4) A | 115.25±1.57ab (67.3-148.7) A | 110.93±1.22 c (63.4-137.7) A | 117.72±1.12 a (85.2-153.0) A | 106.60±1.40 c (104.0-140.9)A |
| | | Beginning of hibernation | 107.17±1.20 a (70.6-135.8) B | 107.06±1.16 a (71.8-139.0) B | 106.28±1.58 a (68.4-135.8) B | 106.57±1.40 a (77.3-142.7) B | 108.69±1.01 a (64.2-129.4) B | 103.39±1.25 a (62.7-134.0) B |
| | | Beginning of active life periods | 105.54±1.20 b (78.1-139.2) B | 101.22±1.44 b (74.9-130.8) C | * | 104.31±1.19 b (61.2-139.4) B | 109.44±1.89 a (69.0-134.0) B | 100.15±0.94 b (60.2-147.6) C |
| | ♂ | Beginning of aestivation | 112.34±0.96 b (79.2-134.3)A | 116.23±0.90 a (82.3-149.3) A | 104.85±1.54 c (71.1-138.7) A | 109.68±1.50 b (63.6-139.7) A | 116.30±0.98 a (89.4-139.6) A | 105.30±0.80 c (72.1-133.1) A |
| | | Beginning of hibernation | 103.97±1.26 b (67.8-133.9)B | 102.21±1.23 b (67.2-132.3) B | 102.60±1.40 b (70.5-131.6) A | 99.34±1.67 b (76.5-125.4) B | 107.77±0.94 a (80.4-139.8) B | 100.56±1.09 b (62.4-132.2) B |
| | | Beginning of active life periods | 101.67±1.16 a (73.5-149.6)B | 95.11±1.65 b (53.2-121.8) C | * | 98.55±1.16 b (69.6-131.1) B | 104.46±2.05 a (72.0-134.2) B | 96.16±1.03 b (51.8-132.1) C |

[1]Each gender has been evaluated within itself.
[a]Values with different minuscule in the same row are statistically different from each other.
[A]Values with different majuscule in the same column are statistically different from each other.
*Individuals were taken for fat analysis without weighing.

The differences in the mass in the life cycles at the beginning of aestivation have also been stated above, depending on the climatic conditions from the age of the new generation to the exit to overwintering for aestivation. Temperature (mean; min.; max.), relative humidity, and wind speed in the period until the exit of new generation adults to the overwintering site affect the nutritional performance of the pest (Table 9). As shown in Table 9, the increase in mass was high in parallel with the temperature, whereas the increase in mass was also low as high relative humidity and wind speed reduce the nutritional performance of the pest.

**Table 9.** Relationship between body fat mass and some climatic data

| Variables | | | Statistical data | | |
|---|---|---|---|---|---|
| | | | r | $r^2$ | Sign. |
| Body weight (mg) | Temperature (°C) | Mean | 0.748 | 0.560 | 0.000** |
| | | Minimum | 0.707 | 0.499 | 0.000** |
| | | Maximum | 0.753 | 0.567 | 0.000** |
| | Relative humidity (%) | | -0.682 | 0.465 | 0.000** |
| | Average wind speed (km/h) | | -0.459 | 0.211 | 0.021* |

*The correlation is significant at the 0.05 level.
**The correlation is significant at the 0.01 level.

At the beginning of hibernation, only the weights obtained from male individuals in the TV tower overwintering site differed according to cycles. These differences were parallel to the difference at the beginning of aestivation (Table 8). As a result of the correlation analysis, it is revealed that a significant part of the difference at the beginning of hibernation was due to the mass at the beginning of aestivation ($r = 0.612$; $r^2 = 0.374$; $P= 0.004$). At the beginning of the active period, we believe that the differences in mass of males and females in both overwintering sites according to their life cycle change depending on the nutritional performance of the new generation adult and the conditions during aestivation and hibernation periods.

When evaluated fresh body mass according to gender; although it varies according to overwintering site, critical period and life cycle, there was a in favor of the female individual in the differences detected (Table 10). Similarly, Strogaia (1955), Vinogradova (1969), Taranukha et al. (1967), Yüksel (1968), Lazarov et al. (1969), Gospodinov (1973), Özkan and Kansu (1987), Javahery (1993), Popov (1977 2002), Karaca et al. (2003) and Amiri et al. (2010) report that females were generally heavier than males.

Although there was usually no difference in body mass of adult according to overwintering site in which they were collected, it has been revealed that individuals collected from Ekecik overwintering site have higher body mass according to gender, critical period, and life cycle (Table 11). Lazarov et al. (1969) reported, as a result of their work in Bulgaria in 1964-1967, adults of E. integriceps in the 150-200 meters deep from the edge of the forest heavier than individuals at 50 meters deep from the edge of the forest. Likewise, Areshnikov et al. (1977) stated that the body mass of individuals collected from overwintering site in different regions in Ukraine varied according to the regions.

**Table 10.** Male and female body mass (mg) collected from Ekecik and TV tower overwintering sites in the beginning of aestivation, hibernation and active life periods in 2013-2018

| Overwintering site | Critical period | Gender | Body weight (mg) mean ± standard error of mean (min. – max.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| Ekecik (Aksaray province) | Beginning of aestivation[1] | ♀ | 113.42±1.30 a (87.3-154.6) | 116.79±0.83 a (88.0-152.3) | 115.11±1.65 a (87.9-151.6) | 114.67±1.41 a (85.7-158.2) | 119.63±1.09 a (77.6-159.8) | 112.60±0.08 a (83.7-149.3) |
| | | ♂ | 114.71±1.38 a (88.0-154.8) | 114.60±0.99 a (84.7-153.9) | 111.45±1.50 a (87.8-156.8) | 114.08±1.32 a (87.5-151.4) | 117.65±1.78 a (82.8-163.7) | 109.80±0.80 a (82.6-143.5) |
| | Beginning of hibernation | ♀ | 104.46±1.39 a (87.1-120.1) | 108.42±0.78 a (82.8-139.5) | 104.78±1.54 a (67.5-152.5) | 107.55±1.49 a (70.7-150.8) | 107.87±1.37 a (74.0-154.1) | 106.39±1.29 a (64.6-166.0) |
| | | ♂ | 106.21±1.31 a (81.5-133.8) | 107.00±0.89 a (68.9-143.1) | 103.15±1.27 a (66.7-124.0) | 103.13±1.45 b (78.6-142.1) | 105.40±1.57 a (67.2-139.7) | 103.14±1.38 a (51.0-152.3) |
| | Beginning of active period | ♀ | 105.79±1.23 a (75.6-128.8) | 98.83±1.70 a (61.7-125.9) | * | 106.29±1.27 a (70.3-145.0) | 111.99±1.68 a (64.0-142.0) | 103.96±0.68 a (63.1-142.8) |
| | | ♂ | 102.07±1.16 b (75.6-131.2) | 102.15±1.56 a (68.1-143.2) | * | 102.22±1.35 b (61.9-155.8) | 103.77±1.92 b (61.7-128.0) | 97.63±0.72 b (64.5-129.4) |
| TV tower (Kırşehir province) | Beginning of aestivation | ♀ | 112.90±1.53 a (72.7-136.8) | 117.69±0.87 a (91.8-141.4) | 115.25±1.57 a (67.3-148.7) | 110.93±1.22 a (63.4-137.7) | 117.72±1.12 a (85.2-153.0) | 106.60±1.40 a (104.0-140.9) |
| | | ♂ | 112.34±0.96 a (79.2-134.3) | 116.23±0.90 a (82.3-149.3) | 104.85±1.54 b (71.1-138.7) | 109.68±1.50 a (63.6-139.7) | 116.30±0.98 a (89.4-139.6) | 105.30±0.80 a (72.1-133.1) |
| | Beginning of hibernation | ♀ | 107.17±1.20 a (70.6-135.8) | 107.06±1.16 a (71.8-139.0) | 106.28±1.58 a (68.4-135.8) | 106.57±1.40 a (77.3-142.7) | 108.69±1.01 a (64.2-129.4) | 103.39±1.25 a (62.7-134.0) |
| | | ♂ | 103.97±1.26 b (67.8-133.9) | 102.21±1.23 b (67.2-132.3) | 102.60±1.40 b (70.5-131.6) | 99.34±1.67 b (76.5-125.4) | 107.77±0.94 a (80.4-139.8 | 100.56±1.09 a (62.4-132.2) |
| | Beginning of active period | ♀ | 105.54±1.20 a (78.1-139.2) | 101.22±1.44 a (74.9-130.8) | * | 104.31±1.19 a (61.2-139.4) | 109.44±1.89a (69.0-13.4) | 100.15±0.94 a (60.2-147.6) |
| | | ♂ | 101.67±1.16 b (73.5-149.6) | 95.11±1.65 b (53.2-121.8) | * | 98.55±1.16 b (69.6-131.1) | 104.46±2.05 b (72.0-134.2) | 96.16±1.03 b (51.8-132.1) |

[a]Values with different minuscule in the same column are statistically different from each other.
[1]Each critical period has been evaluated within itself.
[*]Individuals were taken for fat analysis without weighing.

**Table 11.** Body weight (mg) of male and female individuals collected from Ekecik and TV tower overwintering sites in the beginning of aestivation, hibernation and active life periods in 2013-2019

| Gender | Critical period | Overwintering site | Body weight (mg) mean ± standard error of mean (min. – max.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016 2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 |
| ♀ | Beginning of aestivation[1] | Ekecik | 113.42±1.30 a (87.3-154.6) | 116.79±0.83 a (88.0-152.3) | 115.11±1.65 a (87.9-151.6) | 114.67±1.41 a (85.7-158.2) | 119.63±1.09 a (77.6-159.8) | 112.60±0.08 a (83.7-149.3) |
| | | TV tower | 112.90±1.53 a (72.7-136.8) | 117.69±0.87 a (91.8-141.4) | 115.25±1.57 a (67.3-148.7) | 110.93±1.22 b (63.4-137.7) | 117.72±1.12 a (85.2-153.0) | 106.60±1.40 b (104.0-140.9) |
| | Beginning of hibernation | Ekecik | 104.46±1.39 a (87.1-120.1) | 108.42±0.78 a (82.8-139.5) | 104.78±1.54 a (67.5-152.5) | 107.55±1.49 a (70.7-150.8) | 107.87±1.37 a (74.0-154.1) | 106.39±1.29 a (64.6-166.0) |
| | | TV tower | 107.17±1.20 a (70.6-135.8) | 107.06±1.16 a (71.8-139.0) | 106.28±1.58 a (68.4-135.8) | 106.57±1.40 a (77.3-142.7) | 108.69±1.01 a (64.2-129.4) | 103.39±1.25 a (62.7-134.0) |
| | Beginning of active period | Ekecik | 105.79±1.23 a (75.6-128.8) | 98.83±1.70 a (61.7-125.9) | * | 106.29±1.27 a (70.3-145.0) | 111.99±1.68 a (64.0-142.0) | 103.96±0.68 a (63.1-142.8) |
| | | TV tower | 105.54±1.20 a (78.1-139.2) | 101.22±1.44 a (74.9-130.8) | * | 104.31±1.19 a (61.2-139.4) | 109.44±1.89 a (69.0-134.0) | 100.15±0.94 a (60.2-147.6) |
| ♂ | Beginning of aestivation[1] | Ekecik | 114.71±1.38 a (88.0-154.8) | 114.60±0.99 a (84.7-153.9) | 111.45±1.50 a (87.8-156.8) | 114.08±1.32 a (87.5-151.4) | 117.65±1.78 a (82.8-163.7) | 109.80±0.80 a (82.6-143.5) |
| | | TV tower | 112.34±0.96 a (79.2-134.3) | 116.23±0.90 a (82.3-149.3) | 104.85±1.54 b (71.1-138.7) | 109.68±1.50 b (63.6-139.7) | 116.30±0.98 a (89.4-139.6) | 105.30±0.80 a (72.1-133.1) |
| | Beginning of hibernation | Ekecik | 106.21±1.31 a (81.5-133.8) | 107.00±0.89 a (68.9-143.1) | 103.15±1.27 a (66.7-124.0) | 103.13±1.45 a (78.6-142.1) | 105.40±1.57 a (67.2-139.7) | 103.14±1.38 a (51.0-152.3) |
| | | TV tower | 103.97±1.26 a (67.8-133.9) | 102.21±1.23 b (67.2-132.3) | 102.60±1.40 a (70.5-131.6) | 99.34±1.67 a (76.5-125.4) | 107.77±0.94 a (80.4-139.8) | 100.56±1.09 a (62.4-132.2) |
| | Beginning of active period | Ekecik | 102.07±1.16 a (75.6-131.2) | 102.15±1.56 a (68.1-143.2) | * | 102.22±1.35 a (61.9-155.8) | 103.79±1.92 a (61.7-128.0) | 97.63±0.72 a (64.5-129.4) |
| | | TV tower | 101.67±1.16 a (73.5-149.6) | 95.11±1.65 b (53.2-121.8) | * | 98.55±1.16 b (69.6-131.1) | 104.46±2.05 a (72.0-134.2) | 96.16±1.03 a (51.8-132.1) |

[1]Each critical period was evaluated within itself.
[a]Values with different minuscule in the same column are statistically different from each other.
*Individuals were taken for fat analysis without weighing.

*Relationship body mass and fat ratios*

It was determined that there was a significant positive correlation between body mass and fat ratios, increase in fat ratio in direct proportion to the increase in weight (r= 0.862; $r^2$= 0.744; P=0.000). The similar results were obtained when have evaluated according to gender (in female individuals, r= 0.823; $r^2$= 0.678; P= 0.000; in male individuals, r= 0.883; $r^2$= 0.779; P= 0.000).

It is also stated by different researchers that there was a positive relationship between body mass and nutrient reserves and that individuals with large bodies generally have more fat reserves than small ones (Sinclair and Marshall 2018, Williams et. al. 2015). Popov (1977, 2002) reported that there was positive linear relationship (r= 0,885) between the body mass and fat ratio of the sunn pest, and that as the mass increases in both genders, there was a similar increase in the fat ratio. Areshnikov et al. (1977) stated that, there was a positive relationship between body mass and fat ratios of adults in the overwintering site.

High fat ratio increases the survival rate during diapause as well as increases reproductive. High fat reserves, along with favorable climatic conditions, affect the size of the adult population in the overwintering site. As a result of our studies (Table 12), especially individuals of females have a fat content of over 27% at the beginning of the active life period, high temperature, low rainfall, and wind speed conditions during the active life period increase the reproductive power of the pest. Consequently, there was an increase in the overwintering population at the beginning of aestivation. If the situation in question continues for two years in a row, sunn pest outbreaks begin.

Similarly, Zwölfer (1942), Yüksel (1968), Racz (1975) reported that the sunn pest may cause an outbreak if suitable climatic conditions occur for two consecutive years with the presence of physiologically strong individuals in the population. Forecast and warning systems are decision support systems, by anticipating pest outbreaks that help to optimizing pest control, reduce costs, and ultimately

**Table 12.** Hibernation period of densities (adult m$^{-2}$), female fat ratio (%)

| Overwintering site | Critical periods | Gender | Lifecycle (Years) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Life cycle 1 2013-2014 | Life cycle 2 2014-2015 | Life cycle 3 2015-2016 | Life cycle 4 2016-2017 | Life cycle 5 2017-2018 | Life cycle 6 2018-2019 | Life cycle 6 2019-2020 |
| Ekecik (Aksaray province) | Beginning of aestivation | Adult density | 12,00* | 53.50 | 56.00 | 41.50 | 61.00 | **298.00** | **324.50** |
| | | Fat ratio (%) | 39.57 | 40.36 | 39.00 | 37.21 | 40.18 | 39.00 | 37.16 |
| | Beginning of hibernation | Adult density | 11.00* | 48.00 | 38.50 | 29.14 | 49.00 | 282.00 | 147.00 |
| | | Fat ratio (%) | 28.60 | 29.98 | 27.75 | 26.86 | 32.08 | 30.54 | 26.57 |
| | Beginning of active period | Adult density | 10.00* | 45.50 | 22.54 | 21.67 | 39.00 | 231.00 | |
| | | Fat ratio (%) | 26.66 | 23.57 | 24.75 | 24.67 | 27.50 | 29.02 | |
| TV tower (Kırşehir province) | Beginning of aestivation | Adult density | 50.00 | 51.33 | 50.00 | 51.00 | 78.00 | **273.00** | **266.50** |
| | | Fat ratio (%) | 38.94 | 38.92 | 37.18 | 38.26 | 39.93 | 39.07 | 37.43 |
| | Beginning of hibernation | Adult density | 46.00 | 53.33 | 32.44 | 27.00 | 47.00 | 293.00 | 174.00 |
| | | Fat ratio (%) | 27.96 | 31.02 | 31.42 | 28.52 | 30.68 | 32.61 | 28.19 |
| | Beginning of active period | Adult density | 42.00 | 39.00 | 21.37 | 24.96 | 38.00 | 250.00 | |
| | | Fat ratio (%) | 23.47 | 26.87 | 26.18 | 26.11 | **27.19** | **28.84** | |

* Survey area has been changed. In the following years, compared to the new survey area, approximately 30 more adults per square meter were recorded.

minimize product loss, by predicting pest outbreaks and providing time to manage outbreaks to occur.

One of the important indicators that we can use in the forecast of the sunn pest outbreak is that the pest is physiologically strong, together with suitable climatic conditions and nutrient abundance. Especially fat is (fats are) of vital importance in pests such as sunn pest that spend a large part of their life cycle in diapause. High fat ratio not only increases the survival rate during diapause but also affects the spread of the pest to wider areas by increasing the migration performance from overwintering site after diapause, also increases the reproductive potency. There is a positive relationship between body mass and fat ratios. Since individuals with large bodies generally have a higher percentage of fat reserves, they show higher performance than small ones in the period after diapause and during diapause.

As a result of our studies (Table 12), especially individuals of females have a fat content of over 27% at the beginning of the active life period, high temperature, low rainfall, and wind speed conditions during active life period increase the reproductive power of the pest. Consequently, there is an increase in the overwintering population at the beginning of aestivation. If the situation in question continues for two years in a row, sunn pest outbreaks begin.

Another important result obtained as a result of the study was that the population of sunn pest has a very heterogeneous structure in overwintering sites. The population varies in terms of both body mass and fat ratio depending on individuals, gender, years, and critical periods. It has been demonstrated that the results that have been obtained are important indicators to be used in conjunction with climate and nutrient in the forecast and warning system to be created to forecast sunn pest outbreaks.

**ÖZET**

Süne (*Eurygaster maura* L. (Hem: Scutelleridae)) salgınlarının tahmin edilmesini amaçlayan bu çalışma; iki kışlakta 2013-2019 yıllarında 6 yaşam döngüsü süresince yürütülmüştür. Çalışma süresince her yaşam döngüsünde 3 kritik periyod; yazlama, kışlama ve aktif yaşam dönemleri başlangıçlarında kışlak yoğunlukları ile sünenin yağ oranları ve ağırlıkları belirlenmiş, aralarındaki ilişkiler saptanmıştır. Süne kışlak popülasyonu hem ağırlık, hem de yağ oranları açısından cinsiyetlere, yaşam döngülerine, kritik dönemlere bağlı olarak farklılıklar gösterdiği, vücut kitlesi ile yağ oranları arasında pozitif bir ilişkinin bulunduğu belirlenmiştir. Yağ oranının uygun iklim koşulları ve besin bolluğu ile birlikte süne salgın tahminlerinde kullanabileceğimiz önemli göstergelerden olduğu, hibernasyon sonrası yağ oranının yüksek; özellikle dişi bireylerde %27 ve üzerinde, aktif yaşam süresince iklim koşullarının uygun; yüksek sıcaklık, düşük orantılı nem, rüzgar hız ve yağış ile uygun besin bolluğunun olduğu koşulların üst üste iki yıl süreyle gerçekleşmesi durumunda popülasyon büyüklüğünde önemli ölçüde artışların olduğu ve zararlının salgın oluşturabildiği ortaya konulmuştur.

Anahtar kelimeler: besin, fizyolojik durum, iklim, tahmin ve uyarı

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