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Original article

Outbreak conditions of Sunn pest, *Eurygaster maura* L., 1758 (Hemiptera: Scutelleridae): Model of Central Anatolia (Türkiye)

Süne, *Eurygaster maura* L., 1758 (Hemiptera: Scutelleridae)'nın salgın koşulları: Orta Anadolu (Türkiye) örneği

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A B S T R A C T

In this study, outbreak conditions of Sunn pest, *Eurygaster maura* L., 1758 (Hemiptera: Scutelleridae), the main agricultural pest of wheat, *Triticum aestivum* L., 1753 (Poaceae: Poales) which is the most important crop of the Central Anatolia (Türkiye) in terms of cultivation area and production was investigated. For this purpose, population density of adult sunn pests in its overwintering site and wheat cultivation area were evaluated for Central Anatolian provinces for the years between 1988 and 2021. It is observed that population density of sunn pest reached the level that requires control in 1988 for the first time. After, there were three infestation periods up to 2021 and each of them lasted for 4 years. First of them occurred between 1993 and 1996. It is observed that when average density of overwintered adult sunn pests exceeds 30 per square meter, there can be infestation in all overwintering sites of Central Anatolia. Also, there is a correlation between this density and the intensity of the infestation. Throughout the infestation periods, average temperature was determined as 20 ºC during the reproduction and development period, and it was recorded over 19 ºC during the season when temperature changes and relocations were high in overwintering site.

INTRODUCTION

The control against harmful organisms which cause yield losses, primarily against organisms that cause disease, pests and weeds, takes also an important place, in addition to the techniques used to increase agricultural production. Worldwide, 36.50% field loss occurs in all agricultural products, of which 10.2% is caused by insects (Agrios 2005).

Sunn pest is one of the major pests causing yield loss in wheat in Central Anatolia, as well as in the entire country of Türkiye (Özkan et al. 1999, Özkan and Babaroğlu 2015). Nymphs and adults of sunn pest, which gives one offspring per year, result in a large-scale loss of both germination power and bread and pasta quality of the grains, due to the suction of cereals found in various phenological periods. Without control in the area during years when the pest density is high, losses up to 100% in quantity and quality are likely to occur (Özkan and Babaroğlu 2015).

The life cycle of the sunn pest is divided into active and passive periods. Sunn pest spends a passive period of about 8-9 months in mountains called overwintering sites. This period is divided into two parts: aestivation period covering the period from July to October-November following the harvest and hibernation period covering the period from October-November to March-April of the following year. Sunn pests that passed the winter begin to migrate from overwintering sites towards the plains as spring comes and the temperature rises. With the start of migrations to the plains, the passive period ends and the active period begins. Overwintered adults that have come to the plains feed and mate for 1.5-2 months and lay eggs. At the end of this period adults die. Depending on the climatic conditions, the eggs hatch within 2-3 weeks and nymphs emerge. Undergoing 5 periods in about 1 month, nymphs become the new generation adults (NGAs). The NGAs, feeding voraciously and storing the necessary energy, are drawn to the overwintering site with the beginning of harvest season.

In Central Anatolia, sunn pest control is mainly based on pesticides, which are applied to control pest nymphs. Before deciding on chemical control by carrying out surveys, chemical control is carried out on areas of higher density with above economic damage threshold.

Overwintering site surveys are made in order to estimate the density of the adult sunn pest population in overwintering sites and, consequently, the severity of the infestation. From the overwintering site surveys done twice throughout the same life cycle, the first overwintering site survey is done in autumn, generally in November, after sunn pests are drawn to overwintering sites and the replacement on overwintering sites are completed. The second overwintering area site survey is done in spring, generally in April, after sunn pest have passed winter just before descending to the cereal fields. These surveys are carried out in the same areas of the overwintering sites which can represent the province studied each year. Counts in overwintering sites are made in the south and north directions of the lower, middle and high points in terms of height. The surveys are made to determine the density of overwintered adults in wheat fields. The studies start with the completion of the descent of the overwintered adults.

MATERIALS AND METHODS

In this study, Central Anatolian provinces such as Afyon, Ankara, Aksaray, Burdur, Eskisehir, Isparta, Karaman, Kırıkkale, Kırsehir, Kayseri, Konya, Nigde, Nevsehir and Yozgat, located in the middle of the Anatolian peninsula where wheat ranks first among the grown agricultural products, were evaluated. The spatial distiribution of average temperature taken into account for the selection of provinces.

In this study, the overwintering sites and fields surveys carried out between 1988 and 2021 for control of the sunn pest in the Central Anatolian provinces by the Ministry of Agriculture and Forest, Directorates of Provincial staffs were evaluated. Evaluations were made regarding average values based on years.

The results of the field surveys were evaluated through categorizing them into four groups:

1. Economically non-damaging density (0.1-0.4 number m^2 overwintered adults),
2. Most likely economically non-damaging density except in hot and dry years when wheat is weak and sunn pest shows strong growth (0.5-0.7 number m^2 overwintered adult),
3. Density that will cause potential damaging (0.8-1.0 number m^2 overwintered adults),
4. Density that absolutely will cause damage (1 < number m^2 overwintered adults).

Temperature data used in this study were obtained from the General Directorate of Meteorology.

Binary logistic regression analysis were used to determine the time periods (months) in which population density was affected, and regression analysis was used to determine the relationship between spring overwintering site density and overwintered adult density in wheat cultivated areas. Analyses were done using SPSS 21 statistical software (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Size and rate of infected area

Sunn pest, whose presence has been known in Central Anatolia since 1942 (Alkan 1942), became a problem for the first time in wheat cultivation areas in Ankara, Burdur and Isparta in 1988 when its population density reached levels that required control, and each year showed different levels of prevalence up to day (Table 1).

While in 1988, when the control was done for the first time, the amount of infected area was 100 thousand hectares, in 1993 it exceeded to 500 thousand hectares, and overall covered over 1 million hectares until 2000. The infected area, which increased to over 1.5 million hectares after 2000, is observed as average 2 million hectares today (Table 1). When the infected area ratios that are analyzed 3% of the

Table 1. Wheat cultivation areas in Central Anatolia between 1988 - 2020, sunn pest infected area, infected area rate (%), chemical control applied area and the loss rate (%)

Year	Cultivation area (ha)	Infected area (ha)	Infected area rate (%)	Chemical control applied area (ha)	Damage rate (%)
1988	3343116	101127	3.02	21995	
1989	3341234	243956	7.30	34526	6.25
1990	3317275	308703	9.31	1735	
1991	3415174	238530	6.98	18600	
1992	3473904	176589	5.08	19469	9.40
1993	3491215	573789	16.44	105952	14.93
1994	3468171	1425856	41.11	348069	4.89
1995	3286248	1570220	47.78	302247	3.41
1996	3145633	697191	22.16	92372	4.03
1997	2973325	1047521	35.23	72090	2.06
1998	2990267	1421156	47.53	5927	1.61
1999	3037004	828880	27.29	39099	2.33
2000	3061838	1431627	46.76	79031	2.55
2001	3057128	1642377	53.72	322155	2.33
2002	2987854	1529502	51.19	327036	2.50
2003	2940039	1772085	60.27	231851	2.00
2004	2981195	2075106	69.61	257723	1.07
2005	2945496	2588019	87.86	34812	0.89
2006	2735501	1983377	72.51	10702	1.74
2007	2711509	1864203	68.75	202563	2.70
2008	2704102	2182163	80.70	355287	2.45
2009	2582224	2201426	85.25	303301	1.91
2010	2651908	2262449	85.31	323779	1.98
2011	2728293	2249055	82.43	132833	1.13
2012	2507629	1972068	78.64	267153	1.29
2013	2651446	2050688	77.34	252793	0.86
2014	2714808	1989955	73.30	194407	0.93
2015	2699054	1970702	73.01	71128	0.64
2016	2711865	1821149	67.15	54544	0.53
2017	3048814	1896109	62.19	125118	0.74
2018	2907239	1911167	65.74	175256	1.12
2019	2711263	2052502	75.70	321278	1.75
2020	2596009	1954534	75.29	87391	0.75
2021	2071717	1814212	87.57	59173	0.53

cultivation areas were infected with this pest in 1988, while the infection rate has increased to double digits (16.44%) since 1993. The increase in the rate of infection continued and reached the highest level in 2005 with a value of 87.86%, covering a large part of the cultivation area, and today its prevalence is around 70% as seen in Table 1.

The reasons of population growth

Changes in climate, especially in temperature, together with favorable nutrient abundance and weakness of beneficial fauna in wheat ecosystem are the most important factors of sunn pest population size growth in Central Anatolia. The high susceptibility of insect populations to changes in abiotic conditions, such as the temperature that affects insect life and development, have been reported by Kansu (2005) and Schowalter (2011). Kansu (2005) states that the suitability of one or two factors in a mixed ecological habitat does not manifest itself on the population, however; it is observed that the suitability of one or two of the factors on the few populations living in a simpler ecological habitat, such as wheat fields with a large cultivation area, can have rapid effects and an extraordinary increase in population in a short time. Furthermore, it was this numerical rise that cause to the infestations.

During the overwintering sites surveys carried out in since 1955 within the framework of control carried out against wheat sting bug, *Aelia rostrata* Boh., 1852 (Hemiptera: Pentatomidae), one of the important pests of wheat in Central Anatolia, an increase of overwintering sunn pest population was observed for the first time in 1988.

Among the most important factors of the infestations of the sunn pest is the rise in average temperatures up to more than 20 ºC since the beginning of 1990s in June, which is the reproduction and development period of pests, in provinces where the study was conducted between 1955 and 2016 (Figure 1). It has been reported by different researchers that the most favorable temperature for development of the egg, nymph and NGA of the sunn pest is 20-24 ºC and the probability of an outbreak is high when temperatures during May-June are above 20 ºC for 2 consecutive years (Doronina and Makarova 1973, Fedotow and Botchowara 1955, Racz 1975, Zwölfer 1942).

As a result of global warming, an increase in temperature was observed in Türkiye as well as globally. Türkeş (2012) reports that warming tendencies are getting stronger and are manifested during summer and autumn seasons. He has also explained that the observed warming tendency has been accelerating since 1980s and a significant leap has been turned into an important hot period in the last 20 years. The transition to a period in which warmer conditions prevail over long-term averages took place in the mid-1980s in some stations and in the early 1990s in others. The studies conducted in Türkiye has revealed that the temperature change trend in all months, especially in summer, was positive, that the temperatures had been increasing particularly since the 1990s and that these temperature variations were compatible with global temperature changes (Bahadır 2011, ÇŞB 2013, Demir et al. 2008, Şensoy et al. 2007).

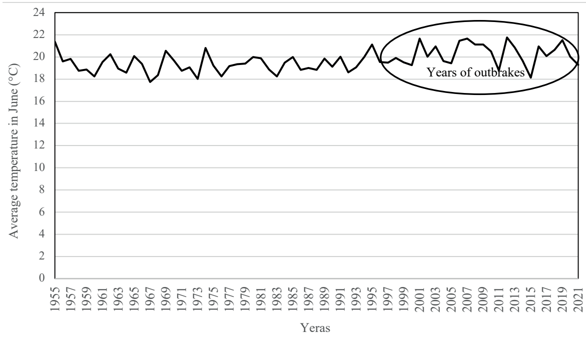

Figure 1. Average temperatures in June in Central Anatolia between years 1955-2021

Sunn pest being actually a pasture insect became harmful after pastures were converted to cereals agriculture. As in all of Türkiye, with the help of mechanization since the 1950 in Central Anatolia, expansion of cultivation areas of wheat and barley as sunn pest hosts, also application of agricultural techniques such as usage of fertilizers and irrigation for yield incensement, turning the host into a more suitable food source for the pest happens to be one of the most important causes of sunn pest infestations together with the appropriate climatic conditions. Indeed, it has been reported by many researchers that insect population growth depends on the food usability, especially the abundance of suitable food sources.

Schowalter and Lowman (1999) report that many species do not attract attention due to the fact that their population fluctuates without causing economic damaging. However, under changing environmental conditions, some of these species cause infestations, especially the changing of the natural environment by people, the expansion of sensitive dense monoculture farming areas and the procedures for rapid development of commercial agricultural products cause widespread infestations of the insects.

Kareiva (1983) reports that insect outbreaks are more frequent and intense in product systems where natural food sources are relatively unlimited, in natural monocultures or where disturbance provides suitable environments.

Boyce (1984) reports that insect with the " K " strategy like sunn pest are rarely harmful, but they become harmful with the increasement of suitable areas as a result of human activities and it is quite difficult and expensive to control such pests once they spread.

It is reported by different researchers that monoculture wheat cultivation along with suitable climatic conditions play important role in sunn pest infestations in large areas by providing unlimited suitable food for them (Doronina and Makarova 1973, Fedotow and Botchowara 1955, Lazarov et al. 1969, Nizamlıoğlu 1955, Yüksel 1968, Zwölfer 1942).

In Central Anatolia, which has unsuitable climate conditions for beneficial organisms and a wheat ecosystem, the life and activities of beneficial organisms especially egg parasitoids, which limit the population growth of the sunn pest are adversely affected due to the incorrect and / or widespread use of insecticides that are used to control sunn pest as well (Babaroğlu and Uğur 2009, 2011). In Central Anatolia particularly in local and narrow areas, only 1-2% of sunn pest population in infected areas, which vary over years, can be suppressed by egg parasitoids and these areas can be excluded from spraying due to parasitization.

Distribution of population densities

During the 34-year period of examination it has been determined that a large part of the adult density in the infected area was 0.1-0.4 overwintered adults per m^2, which is the economically non-damaging density (Table 2). Data from fields surveys, put forward that especially during the period from 2005 to today, approximately half of the total wheat cultivation areas contain overwintered sunn pest adults at this density. After 2000 the density of 0.5-0.7 adults per m2, that is most likely economically non-damaging, had exceeded to over 300 thousand hectares, except for the hot and dry years when wheat growth is weak and sunn pest growth is strong, and this amount of infection continues today. The adult density reached its peak in 2010 with an area of approximately 700 thousand hectares, which is 26.17% of the wheat cultivation area.

In this research three periods encountered in which the density of 0.8 ≤ overwintered adults per m^2, which is considered as potentially economically damaging, exceed 100 thousand hectares. The first of these periods, which is considered as outbreak period, was between 1993 and 1996 covering a 4 year period. In the second outbreak period, which also lasted for 4 years, between 2001 and 2004, the area with density of 0.8 ≤ overwintered adult per m^2 has exceeded 200 thousand hectares. The third 4 years epidemic with lower severity than the first two outbreak occurred between 2008 and 2011 (Table 2). Furthermore, the sunn pest population reached a density that is not described as an epidemic period in 2018-2019, but it did inflict economic damage. As it can be seen from these results, the population of sunn pest showed a cyclical fluctuation in Central Anatolia. The population responses to environmental conditions can be identified by synthesizing the cycles in the population fluctuation of the sunn pest, which are powerful tools that can be used to predict future outbreaks.

It has been reported by different researchers that there are fluctuations from region to region and from year to year in the population density of the sunn pest. Lazarov et al. (1969) report that *Eurygaster integriceps* Put., 1881 (Hemiptera: Scutelleridae) was first detected in Bulgaria in 1952 and the high population density seen in 1954 was seen again, 10 years later, in 1963. Doronina and Makarova (1973) reports that according to the population density of sunn pest and the severity of the damage, there are 3 types of populations; the first type population with a consistently high pest density and high loss causing rate, the second type population with periodically high density and high loss causing rate and the third type of the population with periodic high density and moderate loss causing rate. When the Central Anatolian population is evaluated according to density and loss rates (Tables 1 and 2), it appears as a population with high density and moderate loss causing rate appearing periodically. Doronina and Makarova (1973) report that there is 2-3 years decline in populations with consistently high pest density, and 5-6 years decline in populations with a high periodic density during 10-year periods.

Racz (1975) reports that sunn pest species causes periodic infestations in local areas in Hungary. According to the results of the study he conducted between 1966 and 1974, there was an increase in the population only between 1968 and 1969. The rate of damage was 10.65% and 7.41% between 1968 and 1969 respectively and it has not exceeded the acceptable limit of damage during all other years of the study. Mustatea and Lonescu (1977) reported that sunn pest population density in Romania varies from region to region and from year to year. Stamenkovic (1992) reported that they determined the highest population density of the sunn pest in the overwintering site in Yugoslavia in 1964 and between 1968 and 1970 during surveys done from 1964 to 1991 and that they applied control to the pest in the widest areas in these years. Popov et al. (1996) emphasized that the sunn pest is common in 22 regions of Romania, however, it is always present in high concentrations in the northern and eastern regions, with varying concentrations from year to year and emphasized that there are significant increases in population density in years with generally favorable climatic conditions. Radjabi (1994) and Javahery (1996) underlined that in their study where they investigate the causes of the infestation of the sunn pest between 1960 and 1992 in Iran, they concluded that the climate conditions, especially

Table 2. Overwintered adult population densities in wheat cultivation areas between 1988 and 2020 period in Central Anatolia

Year	Overwintered adult density (number m-²)									
	0.1-0.4		0.5-0.7		0.8-1.0		0.8 <		1.0 <	
	Infected		Infected		Infected		Infected		Infected	
	area (ha)	area rate (%)	area (ha)	area rate (%)	area (ha)	area rate (%)	area (ha)	area rate (%)	area (ha)	area rate (%)
1988	73522	2.20	2825	0.08	8400	0.25	24780	24.50	16380	16.20
1989	158507	4.74	39146	1.17	34657	1.04	46302	18.98	11645	4.77
1990	293014	8.83	12725	0.38	1647	0.05	2965	0.96	1318	0.43
1991	223255	6.54	12585	0.37	1708	0.05	2690	1.13	9820	0.41
1992	146375	4.21	19493	0.56	4769	0.14	10721	6.07	5952	3.37
1993	406834	11.65	62890	1.80	83306	2.39	104066	18.14	20760	3.62
1994	804016	23.18	138838	4.00	273803	7.89	483002	33.87	209199	14.67
1995	860301	26.18	209283	6.37	494685	15.05	500637	31.88	5952	0.38
1996	869317	26.18	162657	5.17	144487	4.59	165216	23.70	20729	2.97
1997	903840	30.40	96117	3.23	46614	1.57	47564	4.54	950	0.09
1998	1155952	38.66	179389	6.00	55930	1.87	85815	6.04	29885	2.10
1999	590956	19.46	184821	6.09	53103	1.75	53103	6.41	0	0.00
2000	1217336	39.76	165667	5.41	46795	1.53	48625	3.40	1830	0.13
2001	821351	26.87	379489	12.41	316110	10.34	441537	26.88	125427	7.64
2002	1095986	36.68	225149	7.54	140585	4.71	208368	13.62	67783	4.43
2003	1244183	42.32	309827	10.54	153384	5.22	218076	12.31	64692	3.65
2004	1258394	42.21	469052	15.73	264246	8.86	347659	16.75	83413	4.02
2005	2200177	74.70	324117	11.00	59075	2.01	63725	2.46	4650	0.18
2006	1731626	63.30	219158	8.01	32593	1.19	32593	1.64	0	0.00
2007	1647995	60.78	188754	6.96	26605	0.98	27455	1.47	850	0.05
2008	1722741	63.71	357385	13.22	96227	3.56	102036	4.68	5809	0.27
2009	1561919	60.49	534567	20.70	94899	3.68	104939	4.77	10040	0.46
2010	1412196	53.25	693966	26.17	130984	4.94	156286	6.91	25302	1.12
2011	1608673	58.96	544290	19.95	95929	3.52	96092	4.27	163	0.01
2012	1546683	61.68	399672	15.94	25043	1.00	25712	1.30	669	0.03
2013	1613933	60.87	410860	15.50	25895	0.98	25895	1.26	0	0.00
2014	1568488	57.78	377128	13.89	44339	1.63	44339	2.23	0	0.00
2015	1536245	56.92	412427	15.28	21390	0.79	22030	1.12	640	0.03
2016	1442125	53.18	344614	12.71	34410	1.27	34410	1.89	0	0.00
2017	1592021	51.99	296429	9.68	7660	0.25	7660	0.25	0	0.00
2018	1376897	37.46	426771	11.61	78939	2.15	107439	2.92	28560	1.49
2019	1229664	45.03	531413	19.46	239982	8.79	291426	10.67	51443	2.51
2020	1448583	55.80	448565	17.28	57386	2.21	57386	2.21	0	0.00
2021	1611806	77.80	172178	8.31	1080	0.05	1530	0.07	450	0.03

Table 3. Overwintered adult population densities in Central Anatolia provinces overwintering site between 1988 and 2021

Overwintered adult density (number m-²)		
	Spring overwintering site surveys	Autumn overwintering site surveys
1988	18.81	71.37
1989	50.27	17.73
1990	14.32	17.85
1991	16.19	26.29
1992	23.68	54.65
1993	51.65	66.31
1994	61.24	65.14
1995	60.11	62.63
1996	47.58	32.48
1997	26.47	33.52
1998	23.04	24.66
1999	21.71	46.17
2000	35.63	63.98
2001	49.60	62.15
2002	59.81	67.10
2003	52.70	61.13
2004	50.28	33.30
2005	22.88	19.64
2006	18.52	26.26
2007	25.87	38.40
2008	36.45	32.17
2009	27.94	39.13
2010	35.19	34.99
2011	28.38	24.65
2012	22.01	18.70
2013	18.31	22.84
2014	21.73	18.84
2015	17.56	14.03
2016	13.06	12.03
2017	7.96	12.22
2018	9.996	44.18
2019	41.44	34.07
2020	30.24	17.34
2021	12.61	10.95

temperature and precipitation, played the main role in the population dynamics of the sunn pest and that there was an epidemic every 6-8 years.

Relationship between overwintering site and field population densities

The control against sunn pest is based on a series of surveys aimed at determining the population density based on the life cycle of the sunn pest (Özkan and Babaroğlu 2015). When the population densities of overwintering sites are investigated for over a 32-years period, from surveys (spring) carried out from 1990 to 2021 to determine the adult sunn pest population density in the overwintering site in order to estimate the severity of the infestation; it can be seen that, although it varies in years, there is a continuous population of sunn pest in different densities in the overwintering sites (Table 3). As in the wheat cultivation areas, in the overwintering site, the population of the sunn pest shows cyclical oscillations, and the density increases approximately every 3-5 years. According to the results of the spring overwintering site surveys, it can be seen that there is an average density of 50 and above adults in m^2 during the 1st and 2nd outbreak periods and an average of 30 and adults in m^2 during the 3rd epidemic period. This intensity, which marks the beginning of the infestation cycle above, is called the outbreak threshold. Despite the importance of this threshold in outbreaks, few studies have been conducted on the effect of this threshold on pest species outbreaks. During this period, the population spreads to other suitable habitat areas with migrations.

It is observed that the severity of the infestations in cultivation areas changes according to the density of adults in overwintering sites above outbreak threshold (Figure 2). As the density of the adults in the overwintering sites increases, the sites with densities of 0.8 ≤ overwintered adults per m^2, which can be economically potentially damaging in cultivation areas, expand in parallel ($r = 0.860$; $p = 0.000$) (Table 4). Likewise, areas with 1 and above overwintered adults per m2 are expanded ($r = 0.648$; $p = 0.000$).

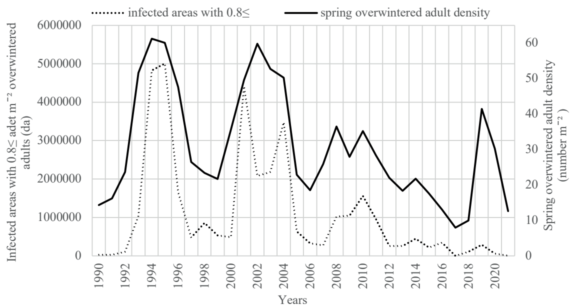

Figure 2. Wheat cultivation areas in Central Anatolia with density of 0.8 ≤ overwintered adults number m^{-2}. and spring overwintered adult density

Table 4. Relation between spring overwintering site density and wheat cultivation area in Central Anatolia

Variables		Adult density in wheat fields (number m-²)				
		1 <	0.8 ≤	0.8-1	0.5-7.0	0.5-7.0
Spring overwintering site density	Correlation coefficient	0.648*	0.860*	0.782*	-0.048	-0.275
	Significance level	0.00	0.00	0.00	0.798	0.135
	N	32	32	32	32	32

*Correlation is important at the 0.05 level

It has been reported by different researchers that there is a close relationship between population density in overwintering site and population density in wheat fields, furthermore it is cited that as the population density in the overwintering site increases, the control area expands accordingly. As a result of the work done in Bulgaria by Lazarov et al. (1969), it is reported that if 8-10 adults per m^2 are detected in the autumn surveys of overwintering site, the pest intensity is expected to be high in the consequent year.

Mustatea and Ionescu (1977) stated that, as a result of their study in Romania between 1969 and 1974, they concluded that when the density of the population in overwintering site does not exceed 3-4 overwintering adults per m^2, it is expected to be no issues in terms of control.

Jovaniç and Stamenkoviç (1978) emphasize that, in their study where they examine the population dynamics in Yugoslavia for 20 years (1958-1977) concluded that, the infestation can be expected if there are 30 or more adults per m^2 in the overwintering site and this threshold should be accepted as the tolerance limit.

Adıgüzel (1981) reported that as a result of the studies carried out in the Southeastern Anatolia Region it is proven that, an infestation can be expected if there is an average of 25-30 individuals per plant in 25 overwintering sites. Moreover, parallel to the increase in the population density in the overwintering site, the area of control will expand, and the severity of the epidemic may also increase. Şimşek et al. (1989) stated that infestations can be expected in the same region when the density of the sunn pest exceeds 20 individuals per plant in the overwintering site, and the area of control expands as the pest density increases. Karaca et al. (2009) stated that there is a 49.5% positive correlation between the adult density detected in the overwintering site of the Southeastern Anatolia region and the areas of chemical control applied in cereal cultivation areas.

As mentioned above, a part of the life cycle of the sunn pest proceeds in the overwintering site (passive period) and a part of it proceeds in the wheat fields (active period) in the plain. As a result of the analyses it was revealed that the population size in the active period varies depending on the density of the sunn pest in spring overwintering site. The density in the passive period, that is, the density of sunn pest in the overwintering site varies depending on the new generation adult density in the active period. In other words, the density of the sunn pest, which descends to the plains as the weather gets warmer in the spring, varies depending on the autumn overwintering sunn pest density that migrated from the plains to the overwintering site a year ago. As can it be seen here, the size of population of new generation adults in the field, together with the climatic conditions in the winter, affects the size of the infestations that will occur 1 year later in the same area.

Forecasting of outbreaks

When results of overwintering site surveys conducted in autumn of previous year to determine the severity of the infestation are analyzed, it is seen that the intensity was high during years of infestation. As the proportion of the wheat cultivation areas that have 0.8 ≤ overwintered adults per m^2 increases, the density of the adults in the overwintering site increases. We already mentioned that the most important reasons for this increase in the population are the suitable nutrient abundance and the favorable climatic conditions, especially the temperature. As a result of analyzes conducted to determine the relationship between the average temperatures of the 14 provinces between 1990 and 2016 and the population size in these years; it was determined that the average temperatures of especially June and September are important in the growth of the population (Table 5, Figure 3).

Presence of physiologically strong individuals within the population plays an important role in the increase of population size. In June, which is the breeding and development period of the sunn pest, if the temperature is about 20 ºC and above, favorable conditions are created for feeding and numerically significant population growth occurs. Also, this is a time period during which it is fed for the purpose of storing the nutrients it will spend during its passive period (aestivation + hibernation). During this period, it can store more nutrients, as temperatures above 20 °C will create favorable conditions for feeding. Consumption of the vast majority of the stored nutrients by the sunn pest occurs during estivation. During this period, especially in September when temperatures are highly variable, disproportionately high nutrient consumption occurs. During these two months, when high temperatures in June and high temperature variations in September prevails, breaking of the outbreak occurs.

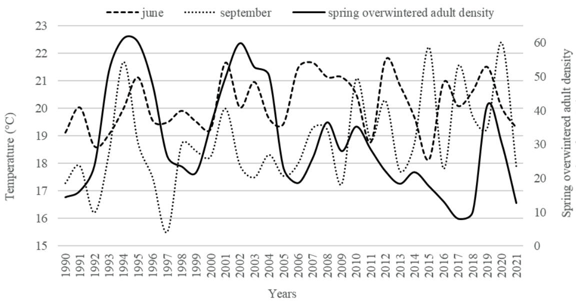

Figure 3. The periods when there was an infestation of the sunn pest in Central Anatolia and the most favorable conditions for the infestation

Zwölfer (1942) reported that the sunn pest is affected by climatic conditions and the 1st -3rd nymphal periods are very sensitive. In this period, which coincides with May-June interval, the average monthly temperature of 20-22 °C and 10-20 mm of precipitation generate the most favorable climatic conditions, and if these conditions persist for two consecutive years, sunn pest outbreaks can occur.

Fedotow and Botchowara (1955) states that during the development of eggs, nymphs and new generation adults, nutritional and climatic conditions are vital and the optimum development temperature is 20-24 °C. It is emphasized that because of the delay in the development of eggs, nymphs and new generation adults under unfavorable conditions, the compatibility between sunn pest's biology and phenology of wheat is disrupted, causing malnutrition especially in the new generation adults. Under constant humid conditions during the estivation period, high temperatures also provide a disadvantage in terms of survival.

Ouchatinkaia (1955) reported that changes in the physiological conditions of the pests occur at the beginning of diapause until temperatures reach close to the required level and after diapause until the beginning of the flight of

Table 5. The relationship between the average monthly temperatures between 1990 and 2021 and population size in Central Anatolian

Descriptive variables	B	Std. Error	Wald	df	significance level	Exp (B)
January	.124	.272	.208	1	.648	1.132
February	.140	.346	.163	1	.687	1.150
March	.084	.542	.024	1	.876	1.088
April	-.685	.449	2.323	1	.127	.504
May	-.834	.729	1.310	1	.252	.434
June	2.056	.975	4.444	1	.035	7.816
July	-1.716	.982	3.056	1	.080	.180
August	-.545	.530	1.056	1	.304	.580
September	1.435	.641	5.008	1	.025	4.200
October	-.849	.571	2.211	1	.137	.428
November	-.232	.385	.365	1	.546	.793
December	.488	.348	1.966	1	.161	1.629
Constant	15.743	19.991	.620	1	.431	6873338.736
Number of observations	32					
Log-Likelihood value	23.197					
Cox & Snell R^2	0.465					
Nagelkerke R^2	0.628					
Correct classification percentage						
Outbreak will happen	76.9					
Outbreak will not happen	94.7					
Overall Percentage	87.50					
Hosmer and Lemeshow Test	X^2=11.156; df=8; P=0.193					

*P < 0.10 significance level

the overwintered adults to the fields. During these periods, unfavorable climatic conditions cause the activity of changes in the pest body to increase and the food to decrease rapidly. However, it is stated that during the hibernation period as the pest remains immobile during diapause it keeps the exchange rate of stored nutrients at low levels and to ensure that it remains resistant to unfavorable conditions.

As a result of his studies in Southeastern Anatolia, Yüksel (1968) reports that if the average temperatures in May are 17.5 °C or above, and the total monthly precipitation is 30-35 mm or less, and if these conditions persist for two consecutive years, the sunn pest outbreak can happen.

Doronina and Makarova (1973) state that they achieved similar results with Ouchatinkaia (1955) as they report that the pest is not only dependent on the amount of nutrients accumulated during the feeding, but also on the usage of them during other periods of life cycle, and that temperature is the factor affecting the accumulation of nutrients intensively during the feeding period of the new generation adults. It is reported that the pest intensity drops significantly if the temperature is below or around 20 °C during nymph development. It is pointed out that in such years, nymphs develop slowly and erratically, and some of the sunn pest nymphs could not mature until the harvest and individuals who are retreated to overwintering sites are weak in terms of survival. Again, it is stated that also the temperatures during estivation period affect the population size. However, the relationship between the temperature during the hibernation period and the population size is insignificant.

Gospodinov (1973) indicated that in Russia, when the temperatures are 14-15 °C in May, 18 °C in June and 20 °C in July, an increase in outbreak level in *E. integriceps* densities is observed.

Racz (1975) reported that as a result of his study in Hungary shows, if the average temperatures are above 21 °C for 2 consecutive years in May and June, the probability of *E. integriceps* outbreak is high. The researcher states that low temperatures and high precipitation in June create unfavorable conditions for an *E. integriceps* infestation.

CONCLUSIONS

Changes in density, which is one of the basic elements of population dynamics, are the most important data in explaining the characteristics of the population. In this respect, revealing the insect density and the factors affecting it helps to explain the population dynamics. In the evaluation made in this study, the relation of the growth of the population size of the sunn pest with respect to the temperatures and the overwintered adult density was determined. Apart from these, it is a known fact that food and the effect of natural enemies play a role in the related issue. It is presumed that in the case of temperatures being around 20 °C in June, approximately over 19°C in September, and low temperature variations in September, and overwintered adult density of 30 ≤ pests per m^2 in the overwintering sites of 14 provinces of Central Anatolia, the probability of an outbreak is high.

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Author's Contributions
Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest
The authors have declared no conflict of interest.

ÖZET

Bu çalışmada Orta Anadolu'da (Türkiye) yetiştiriciliği yapılan tarım ürünleri içerisinde ekim alanı ve üretim bakımından ilk sırada yer alan buğday, *Triticum aestivum* L., 1753 (Poaceae: Poales)'ın ana zararlısı Süne, *Eurygaster maura* L., 1758 (Hemiptera: Scutelleridae)'nin salgın koşulları incelenmiştir. Bu amaçla, Orta Anadolu'ya ait illerin 1988-2021 yıllarını kapsayan periyottaki kışlak ve buğday ekim alanlarındaki ergin süne popülasyon yoğunlukları değerlendirilmiştir. Orta Anadolu'da mücadeleyi gerektiren popülasyon yoğunluğu ile ilk kez 1988 yılında dikkati çeken Süne, 2021 yılına kadar, birincisi 1993-1996 yıllarında olmak üzere 4'er yıl süren 3 salgın dönemi gerçekleştirmiştir. Orta Anadolu'ya ait tüm kışlaklarda ortalama kışlamış ergin yoğunluğunun m2'de 30 adedin üzerine çıkması durumunda buğday ekim alanlarında salgının oluşabileceği ve kışlak ergin yoğunluğuna bağlı olarak salgının şiddetinin de değişebileceği belirlenmiştir. Salgınların oluştuğu dönemlerde kışlaktaki ergin yoğunluğu ile birlikte üreme ve gelişme periyodunda ortalama sıcaklığın 20 °C, kışlakta sıcaklık değişimlerinin ve yer değiştirmelerin yüksek olduğu dönemde ise 19 °C'nin üzerinde seyrettiği belirlenmiştir.

Anahtar kelimeler: iklim değişikliği, tahmin, sıcaklık, buğday

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