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Chemical Analysis of the Metathoracic Scent Gland of *Eurygaster maura* (L.) (Heteroptera: Scutelleridae)

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ABSTRACT

Eurygaster maura **(L.) (Heteroptera: Scutelleridae) is one of the most devastating pests of wheat in Turkey. The metathoracic scent gland secretions of male and female *E. maura* were analyzed separately by gas chromatography-mass spectrometry. Twelve chemical compounds, namely, Octane, n-Undecane, n-Dodecane, n-Tridecane, (E)-2-Hexenal , (E)-2-Hexen-1-ol, acetate, Cyclopropane, 1-ethyl-2-heptyl, Hexadecane, (E)-3-Octen-1-ol, acetate, (E)-5-Decen-1-ol, acetate, 2-Hexenoic acid, Butyric acid, and Tridecyl ester were detected in both males and females. These compounds, however, differed quantitatively between the sexes. In both females and males, n-Tridecane and (E)-2-Hexanal were the most abundant compounds and constituted approximately 90% of the total content. Minimal amounts of Octane were detected in males and Hexadecane in females.**

Keywords: (E)-2-Hexenal, GC-MS, Metathoracic scent gland, n-Tridecane, Wheat.

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INTRODUCTION

Eurygaster species (Heteroptera: Scutelleridae) are the most devastating pests of wheat in an extensive area of the Near and Middle East, Western and Central Asia, Eastern and South Central Europe, and Northern Africa (Critchley, 1998; Vaccino *et al*., 2006; Ravan *et al*., 2009). In Turkey, *Eurygaster maura* (L.), *Eurygaster integriceps* (Put.) and *Eurygaster austriaca* (Schrk.) are the most common species of the genus (Critchley, 1998). The species distributions vary by region. While *E. maura* is the dominant species in the Central Anatolia region, *E. integriceps* dominates in the Southeastern Anatolia, Aegean and Thrace regions (Koçak and Babaroğlu, 2005). Adults and nymphs of *E. maura* cause damage by feeding on the leaves, stems and grain kernels of the wheat plants (Lodos, 1986; Özkan and Babaroğlu, 2015), and can lead to economic losses as high as 100% in the absence of control measures (Lodos, 1986; Özbek and Hayat, 2003).

In the order Heteroptera, nearly all species have scent glands and many of these are colloquially referred to as “stink bugs” (Aldrich, 1988). Both nymphs and adults have scent glands in Heteroptera species (Abad and Atalay, 1994; Abad, 2000). The scent glands were first described in adult Heteroptera by Dufour in 1833, and in the nymphs by Künkel (1866) (Davidova-Vilimova, 2006). The name of the scent gland is based on the parts of the body where they are located (metathorax, abdomen) (Abad *et al*., 1994; Hassani *et al*., 2010; Kment and Vilimova, 2010; Kheyri *et al*., 2014). The “dorsoabdominal scent glands” and the “metathoracic scent glands” are of the greatest importance, with both often playing vital roles in defense. The dorsoabdominal scent glands, however, are developed in the nymphs, while the metathoracic scent glands are exclusively found in adults (Abad, 2000; Raska, 2009;

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Kheyri *et al*., 2014; Parveen *et al*., 2014; Noge, 2015; Krajicek *et al*., 2016; Rohanová *et al*., 2016; Barao *et al*., 2017).

Insects have developed a multitude of defense mechanisms to protect themselves from their enemies. In *Heteroptera* species, the MetaThoracic scent Gland (MTG) is one of the most effective defense mechanism against predation (Chapman, 1972; Aldrich, 1988). When the bugs are disturbed or molested, they produce large quantities of strong-smelling and irritating defensive chemicals, which are then released from the MTG (Aldrich, 1988; Durak and Kalender, 2007a; Raska, 2009; Abad *et al*., 2012; Parveen *et al*., 2014; Noge, 2015). Several researchers have reported that diverse substances may be secreted from the MTGs to serve different purposes or roles such as defense against predation, alarm, mating and aggregation (Aldrich, 1988; Ho and Millar, 2001; Marques *et al*., 2007; Hassani *et al*., 2010; Abad *et al*., 2012; Gonzaga-Segura *et al*., 2012; Krajicek *et al*., 2016; Weiler *et al*., 2017).

The main objective of this study was to determine the compounds produced in the MTGs of adult male and female *E. maura*. The MTG secretion of *E. maura* has previously been analyzed by Durak and Kalender (Durak and Kalender, 2007a), and the closely related species, *E. integriceps*, was analyzed by Durak (2006) and Hassani *et al*. (2010). In this study, our results are compared with the previous studies and the probable causes of the differences are discussed.

MATERIALS AND METHODS

Insect Material

Adult male and female *E. maura* were collected from wheat fields in Selçuklu, Konya, Turkey, from June through July 2012. Insects were kept in transparent plastic jars and reared and maintained in a climate chamber set at 26±1°C, 65±5%RH and a 16:8 light-dark photoperiodic regime (Gözüaçık *et al*., 2011). Bugs were maintained on fresh wheat plants until dissection.

Extraction

Adult *E. maura* males and females were killed individually by freezing to prevent premature discharge of the gland contents (Marquez *et al*., 2007; Hassani *et al*., 2010). The insects were dissected in sodium phosphate buffer (pH 7.2) (Durak, 2006). An adult *E. maura* was pinned in a petri dish with the dorsal side up. The dissection process consisted of cutting the dorsal abdominal edges of the insect cuticle up to the metathoracic region and then under the scutellum. The dorsal abdominal cuticle was pulled back and the viscera removed. The scent gland complex, located in the ventral abdominal metathoracic region, could then be accessed and removed with the aid of a small surgical scissors (Figure 1) (Zarbin *et al*., 2000). Twenty male and twenty female gland reservoirs were removed and immersed in 1 ml analytical grade hexane distilled from CaH_2 (Zarbin *et al*., 2000; Durak and Kalender, 2007a; Hassani *et al*., 2010).

Chemical Analysis

The MTG secretions were analyzed separately for both sexes of *E. maura*. Extracts were analyzed by Gas Chromatography-Mass Spectrometry (GC-MS) with an Agilent 7890A series fitted with an HP Innovax column (60 m×0.25 mm ID×0.25 μm film) and interfaced to an Agilent 5975C mass selective detector (electron impact ionization, 70 eV). Helium carrier gas was programmed for constant flow (1.2 mL min^{-1}). The GC was programmed from 60°C/10 minutes initially, then 4°C min^{-1} to 220 °C. After remaining at this temperature for 10 minutes, the temperature was raised 1°C min^{-1} to 240°C and kept at this temperature for 30 minutes.

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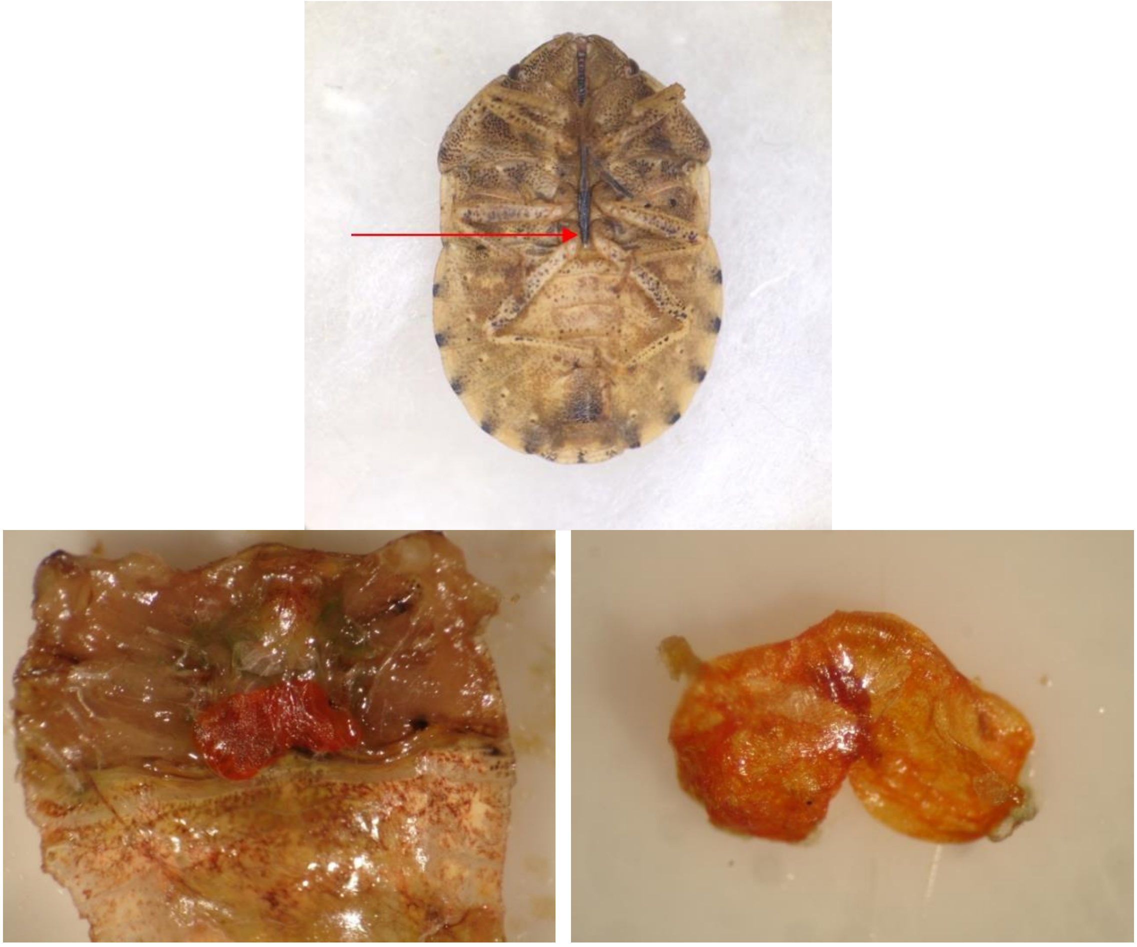

Figure 1. The dissection of *Eurygaster maura* metathoracic scent gland.

Thus, the total duration of the analysis was determined as 110 minutes. The temperature of the injector was 240°C. Compounds were tentatively identified by GC-MS, and identifications were confirmed by comparison of the retention times and mass spectra of reference samples. The relative amount of each compound was determined as the area under its respective GC peak. Wiley and Nist libraries were used to identify the compounds (Durak and Kalender, 2007a; Hassani *et al*., 2010).

RESULTS

The chemical contents of the MTG of both sexes of *E. maura* were qualitatively the same with a total of 12 chemical compounds being identified (Table 1), however, most of the compounds differed quantitatively between the sexes (Figures 2 and 3). Major components are shown in bold.

Analysis of the MTG of *E. maura* yielded 6 types of alkanes (Octane, n-Undecane, n-Dodecane, n-Tridecane, Hexadecane, Cyclopropane, 1-ethyl-2-heptyl), 1 type of aldehyde ((E)-2-Hexenal), 3 types of acetates ((E)-2-Hexen-1-ol, acetate, (E)-3-Octen-1-ol, acetate, (E)-5-Decen-1-ol, acetate) and 2 types of acids (2-Hexenoic acid, Butyric acid, tridecyl ester) in both males and females. The alkane, "n-Tridecane", was found to be the predominant compound in the MTGs of both sexes of *E. maura* (60.22 and 56.78% in females and males, respectively). Another alkane, "Octane" (0.07%), was the least

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Table 1. Compounds in the metathoracic scent gland secretions of male and female *E. maura.* [a]

Groups	Chemical compounds	Female (%)	Male (%)
Alkanes	Octane	0.07	0.13
	n-Undecane	0.48	0.55
	n-Dodecane	1.32	1.20
	n-Tridecane	**60.22**	**56.78**
	Hexadecane	0.16	0.08
	Cyclopropane, 1-ethyl-2-heptyl	0.33	0.27
Aldehyde	(E)-2-Hexenal	**33.42**	**30.78**
Acetates	(E)-2-Hexen-1-ol, acetate	**1.78**	**8.62**
	(E)-3-Octen-1-ol, acetate	0.20	0.21
	(E)-5-Decen-1-ol, acetate	1.25	0.99
Acids	2-Hexenoic acid	0.35	0.15
	Butyric acid, tridecyl ester	0.42	0.24

[a] Major components are shown in bold.

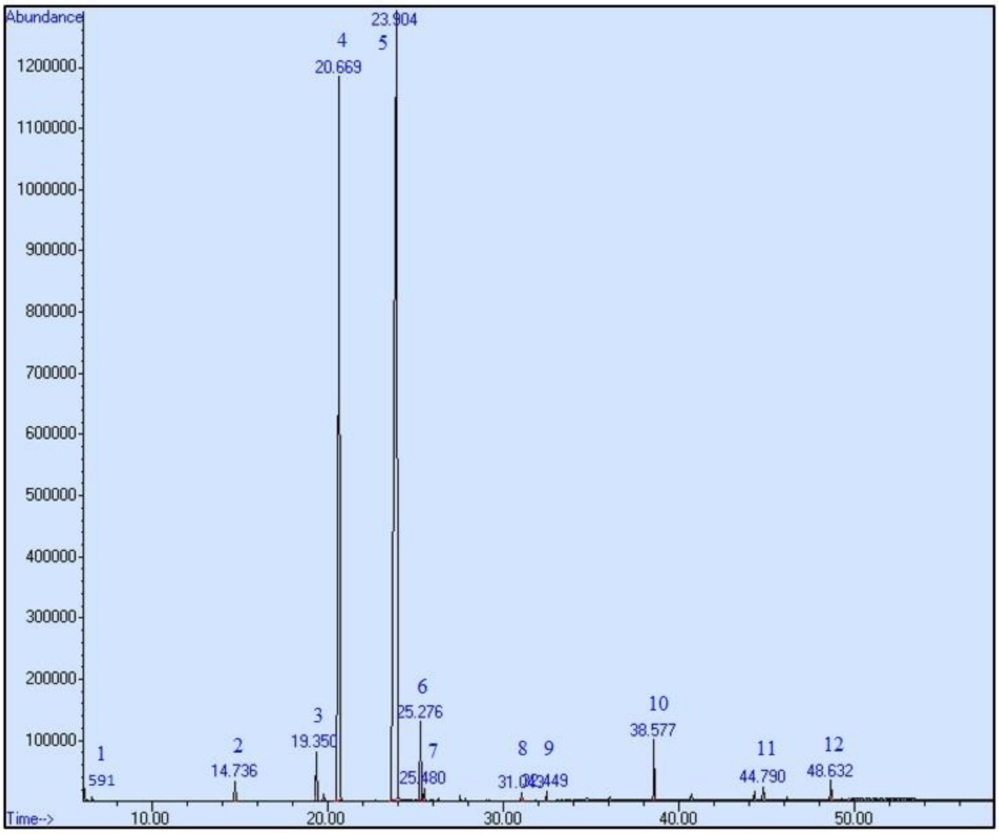

Figure 2. Gas chromatogram of an extract of the MTG secretion of *E. maura* females: (1) Octane, (2) n-Undecane, (3) n-Dodecane, (4) (E)-2-Hexenal, (5) n-Tridecane, (6) (E)-2-Hexen-1-ol, acetate, (7) Cyclopropane, 1-ethyl-2-heptyl, (8) Hexadecane, (9) (E)-3-Octen-1-ol, acetate, (10) (E)-5-Decen-1-ol, acetate, (11) 2-Hexenoic acid, (12) Butyric acid, tridecyl ester.

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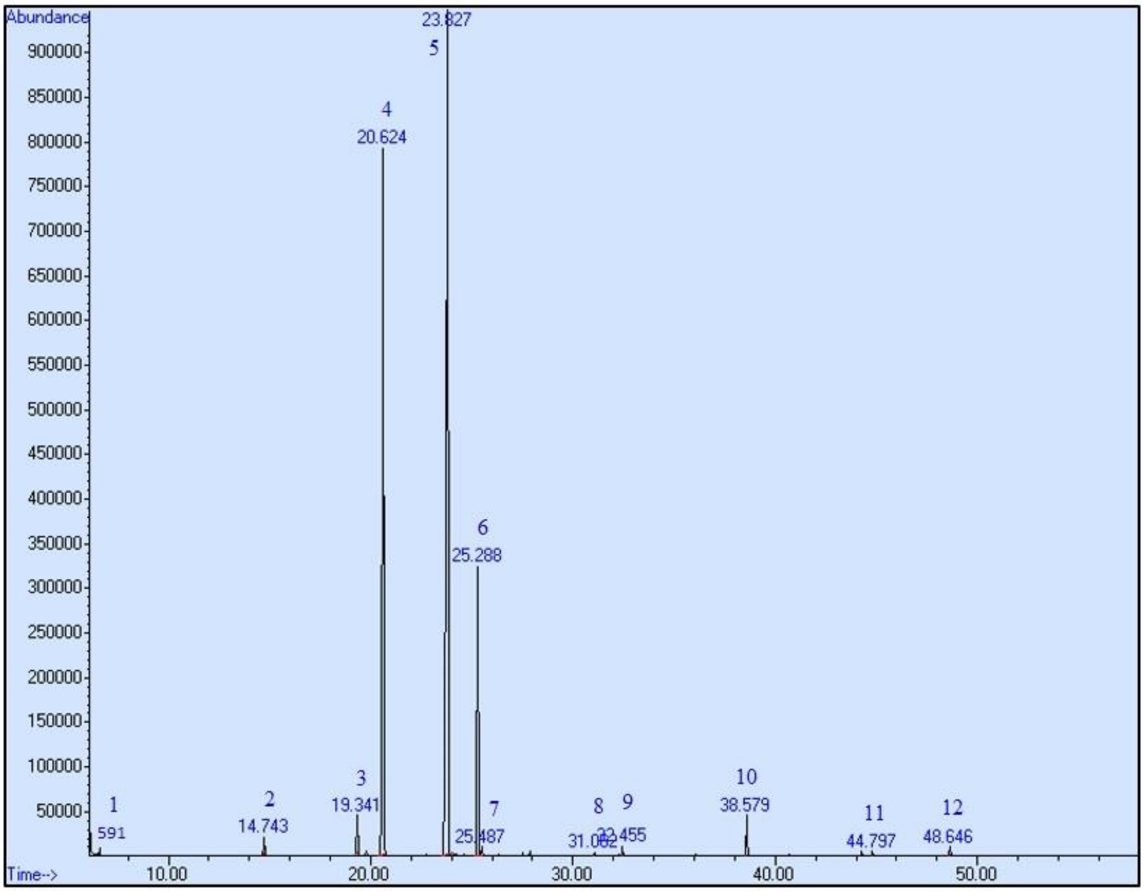

Figure 3. Gas chromatogram of an extract of the MTG secretion of *E. maura* males, 1, 2…12 as defined under Figure 2.

common of the 12 components present in the female glands, while in males, another alkane, “Hexadecane” (0.08%), was the least common of the glandular compounds.

The second most abundant compound found in both sexes was “(E)-2-Hexenal” (33.42% and 30.78% for female and male, respectively). The two compounds, n-Tridecane and (E)-2-Hexenal, comprised 93.64% of the total chemical compound in females and 87.56% in males.

DISCUSSION

The scent substances of Heteroptera are, for the most part, short to medium unbranched carbon-chain aliphatic substances, acids, aldehydes, ketoaldehydes, ketones, alcohols, and esters (Staddon, 1979; Aldrich, 1988; Krall *et al*., 1999; Noge, 2015). In Heteroptera, the secretion of MTGs is generally characterized as a defensive function. However, the secretion is often involved in various other, mostly pheromonal, functions as well. Alkanes and aldehydes, the compounds that are most commonly found in the MTGs of Heteroptera, are effective in defense against predators as well as functioning as alarm pheromones (Raska, 2009; Zhang *et al*., 2014).

The most common chemicals found in the MTG secretion are alkanes, aldehydes, esters, alcohols and terpenoids. Lactones, ketones, alcenes and miscellaneous other compounds are less commonly encountered chemicals (Farine *et al*., 1993). Aldehydes and other hydrocarbons found in the MTG in several *Heteroptera* species have a dual

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function. In this study, one aldehyde and 6 hydrocarbons were detected in the MTG of both males and females of *E. maura*. The function varies according to their concentration or the manner in which they are emitted (Farine *et al*., 1992).

(E)-2-Hexenal, n-Undecane, n-Dodecane and n-Tridecane are known as toxins, irritants or repellents (Krall *et al*., 1999; Zarbin *et al*., 2000; Šanda *et al*., 2012). These compounds are secreted by the bugs when they are disturbed or molested, indicating that these compounds are involved in defensive behavior. In our study, the aldehydes and alkanes, (E)-2-Hexenal, n-Undecane, n-Dodecane and n-Tridecane, were identified in the analyses of the MTG of both sexes of *E. maura* and thought to be the primary materials responsible for chemical defense.

In the present study, n-Tridecane was determined to be the most abundant compound in the MTG in both sexes of *E. maura*. Previously, it has been identified by other researchers as the most abundant compound in the MTG of many Pentatomoidea species, including *Chlorochroa sayi* Stål, *C. uhleri* (Stål) and *C. ligata* (Say), *Graphosoma semipunctatum* (Fabricius), *Dichelops melacanthus* (Dallas), *Dolycoris baccarum* (L.), *Carpocoris fuscispinus* (Boheman) (Pentatomidae), and *Tessaratoma papillosa* (Drury) (Tessaratomidae) (Ho and Millar, 2001; Durak and Kalender, 2007b; Marques *et al*., 2007; Durak, 2008; Laumann *et al*., 2009; Durak and Kalender, 2012; Zhao *et al*., 2012). This compound has also been detected in many other species of Heteroptera (Aldrich, 1988; Borges *et al*., 2001; Zarbin *et al*., 2000). The ratio of this particular alkane in the MTG of female and male *E. maura* was 60.22% and 56.78%, respectively, of the total compounds found. In other insect species, such as *D. baccarum* and *C. fuscispinus* (Heteroptera: Pentatomidae), n-Tridecane was found to be approximately 50% of the total in the MTG of both adult females and males (Durak, 2008; Durak and Kalender, 2012).

According to previous studies, two special functions have been claimed for n-Tridecane; 1) to promote the penetration of the toxic scent carbonyls through the cuticle of arthropod predators and 2) to act as a fixative, delaying evaporation of the scent carbonyls from the surface of the body of the scent emitter. It also has to be considered that n-Tridecane may possibly have a defensive function in its own right (Staddon, 1979; Šanda *et al*., 2012; Gregorovicova and Cernicova, 2016).

(E)-2-Hexenal, the second most abundant compound in both sexes of *E. maura* in this study, has been identified in many species of Lygaeidae (Staddon and Olagbemiro, 1984), Pentatomidae (Aldrich, 1988; Ho and Millar, 2001; Zarbin *et al*., 2000; Durak, 2006; Durak and Kalender, 2007b; Marques *et al*., 2007; Durak and Kalender, 2012; Noge *et al*., 2012), Rhopalidae (Aldrich, 1988), Coreidae (Steinbauer and Davier, 1995; Noge *et al*., 2012), Miridae (Drijfhout *et al*., 2002), Alydidae (Yasuda *et al*., 2007; Noge *et al*., 2012) and Scutelleridae (Durak, 2006; Durak and Kalender, 2007a; Abad *et al*., 2012). As in our findings with *E. maura*, *Eurydema rugosa* Motschulsky and *E. pulchra* (Westwood) contain considerable amounts of (E)-2-Hexenal and n-Tridecane together (Ishiwatari 1974).

It appears that E-2-Hexenal may play a primary role in all three functions, including pheromonal, allomonal, and kairomonal (Lockwood and Story, 1987). When sprayed suddenly, (E)-2-Hexenal is an alarm pheromone, but acts as an aggregation pheromone when exuded gradually and in small amounts. A similar situation, i.e. dispersal at high concentrations and aggregation at low concentrations, was observed for n-Tridecane in the first instar of *Nezara viridula* (L.) (Lockwood and Story, 1985; 1987; Farine *et al*., 1992; 1993). It was reported that (E)-2-Hexenal worked synergistically with n-Tridecane and was more effective as repellents to insects when combined than when tested individually (Krall *et al*., 1999). Accordingly, n-Undecane, n-Dodecane and n-Tridecane

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show synergistic effects on toxicity and repellency when combined with aldehydes and acetates (Gunawardena and Herath, 1991).

In addition to the defensive and pheromonal effects of compounds found in the MTG of many heteropterans, they may also play a kairomonal role in some of these insects. Lauman *et al*. (2009) tested the effect of crude extracts of the MTGs from five different host species on the host-searching behavior of the scelionid egg parasitoids, *Telenomus podisi* Ashmead and *Trissolcus basalis* (Wollaston). The females of both species were attracted to crude MTG extracts of the preferred hosts *Euschistus heros* (Fabricius) and *N. viridula*. Additionally, the parasitoids responded to synthetic standards of individual compounds identified in these stinkbug glands. *Trissolcus basalis* responded positively to 4-oxo-(E)-2-Hexenal and (E)-2-Decenal, while *T. podisi* responded positively to 4-oxo-(E)-2-hexenal. This parasitoid was also shown to respond positively to (E)-2-Hexenal and n-Tridecane, both of which are defensive compounds released from the MTGs by several stinkbugs.

The behavioral responses of the scelionid egg parasitoid, *Trissolcus semistriatus* (Nees von Esenbeck), to hexane extracts of the MTG secretion of *E. maura* were investigated using a Y tube olfactometer. Low concentrations of MTG secretions from both sexes attracted the parasitoids, but attraction was reduced with increased concentrations, where parasitoids tended to prefer clean air. Low concentrations of MTG secretion in both sexes increased the parasitisation rates by *T. semistriatus.* Conversely, increased concentrations resulted in decreased parasitisation rates. Use of the Y tube olfactometer demonstrated that the MTG secretion of *E. maura*, especially in males, plays active roles in intraspecific aggregation and dispersal depending on the concentration (Ögür, 2016).

(E)-2-Hexen-1-ol, acetate found in the MTG of *E. maura* during this study was also detected in the MTG secretion of *D. baccarum* (Durak, 2008) and *T. papillosa* (Zhang *et al*., 2009). They stated that (E)-2-Hexen-1-ol, acetate released by irritated *T. papillosa* individuals may serve as a warning compound to their congeners, resulting in an alarming effect. Another alkane found in the *E. maura* MTG, Hexadecane, was also identified by Durak and Kalender (2007a) in *E. maura* and Zhang *et al*. (2014) in the MTG of *Adelphocoris suturalis* (Hemiptera: Miridae). The alkanes are reported to function as short-range attractants and defense pheromones (Lockwood and Story, 1985, Krall *et al*., 1999; Zhang *et al*., 2014).

Previous studies on the chemical analysis of the MTG of *E. maura* and *E. integriceps* have shown differences in their chemical compounds (Table 2). Durak and Kalender (2007a) analyzed the MTG secretion from females and males of *E. maura* using GC-MS and found 16 and 20 different chemical substances, respectively. In studies on *E. integriceps*, Durak, (2006) found 16 and 23 different chemical substances in the female and male, respectively, while Hassani *et al*. (2010) found a total of 7 and 7. In the first two studies above, quantitative as well as qualitative differences were found in the compositions of these substances when comparing males and females, but only quantitative differences were found in the third study.

In the Durak and Kalender (2007a) and Durak (2006) studies, the chemical compounds from the MTGs of *E. maura* and *E. integriceps* were found to be very similar. Three major compounds found for both species were Tetracosane, n-Tridecane, and Octadecanoic acid. Hassani *et al*. (2010) found a total of 7 compounds in the MTG of adult *E. integriceps* when using *in vitro* and *in vivo* methods. Similar to our study on *E. maura*, they determined that (E)-2-Hexenal and n-Tridecane comprised nearly 95% of the total secretion in both females and males of *E. integriceps*. In the present study, we found that n-Tridecane and (E)-2-Hexenal comprised approximately 90% of the total

Table 2. Compounds in the metathoracic scent gland secretions of male and female *Eurygaster* spp. [a]

	Chemical compounds	This study (*E. maura*)		Durak and Kalender (2007a) (*E. maura*)		Durak (2006) (*E. integriceps*)		Hassani *et al*. (2010) (*E. integriceps*)	
		Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)
Alkanes	Octane	0.07	0.13	nd	nd	nd	nd	nd	nd
	n-Undecane	0.48	0.55	nd	0.11	nd	nd	nd	nd
	n-Dodecane	1.32	1.20	0.3	0.34	0.30	0.17	nd	nd
	Pentadecane	nd	nd	nd	0.46	nd	2.19	nd	nd
	n-Tridecane	**60.22**	**56.78**	**22.94**	**34**	**23.2**	**11.95**	**18.11**	**20.98**
	Hexadecane	0.16	0.08	0.33	0.28	0.30	0.90	nd	nd
	Nonadecane	nd	nd	1.12	3.82	3.02	0.41	0.5	0.36
	Octadecane	nd	nd	1.68	0.43	1.54	2.12	nd	nd
	Tricosane	nd	nd	1.72	0.36	1.70	5.16	nd	nd
	Heptadecane	nd	nd	nd	nd	nd	2.02	nd	nd
	Tetracosane	nd	nd	**41.51**	**3.82**	**42.53**	**4.24**	nd	nd
	Hexacosane	nd	nd	2.25	2.91	6.75	1.26	nd	nd
	Octacosane	nd	nd	5.52	26.58	2.24	5.52	nd	nd
	Cyclopropane, 1-ethyl-2-heptyl	0.33	0.27	nd	nd	nd	nd	nd	nd
Alcenes	1-Nonadecene	nd	nd	0.45	1.43	0.42	nd	nd	nd
	Cyclodecene	nd	nd	1.29	nd	0.82	nd	nd	nd
	5-Decyne	nd	nd	nd	nd	nd	nd	0.32	0.44
Aldehyde	(E)-2-Hexenal	**33.42**	**30.78**	0.27	2.63	0.25	3.90	**78.1**	**74.7**
Acetates	(E)-2-Hexen-1-ol, acetate	**1.78**	**8.62**	nd	nd	nd	nd	**2.59**	**3.14**
	(E)-3-Octen-1-ol, acetate	0.20	0.21	nd	nd	nd	nd	nd	nd
	(E)-5-Decen-1-ol, acetate	1.25	0.99	nd	nd	nd	nd	nd	nd
	(E)-2-Hexenyl acetate	nd	nd	0.39	0.19	0.40	0.24	nd	nd
	Diisooctyl acetate	nd	nd	nd	1.00	nd	nd	nd	nd
	L-Histidinemethylesterdihydrochloride	nd	nd	nd	nd	nd	2.27	nd	nd
	Dodecylester	nd	nd	nd	nd	nd	2.63	nd	nd
	Methyl acetate	nd	nd	nd	nd	nd	0.40	nd	nd
Acids	2-Hexenoic acid	0.35	0.15	nd	nd	nd	nd	nd	nd
	Butyric acid, tridecyl ester	0.42	0.24	nd	nd	nd	nd	nd	nd
	n-Hexanoic acid	nd	nd	4.92	1.29	5.12	nd	nd	nd
	n-Hexadecanoic acid	nd	nd	1.89	1.51	1.50	nd	nd	nd
	Octadecanoic acid	nd	nd	**8.96**	**4.21**	**7.33**	**35.65**	nd	nd
	5-methyl-trimethylsilyl oxy-benzoic acid	nd	nd	nd	nd	nd	0.31	nd	nd
	1-Phenanthrene carboxylic acid	nd	nd	nd	nd	nd	11.19	nd	nd
Alcohol	3,7,11-(3-metyl-trideuterio)-trimetyl-(4,4,5,5-tetradeuterio)dodeca-1,6,10-trien-3-ol	nd	nd	nd	3.76	nd	nd	nd	nd
	1-Octadecanethiol	nd	nd	nd	nd	nd	0.90	nd	nd
Ether	Dimethyl ether	nd	nd	nd	nd	nd	1.38	nd	nd
Steroid	14-BETA-H-Pregna	nd	nd	nd	1.32	nd	2.19	nd	nd
Lactone	2(5H)-Furanone	nd	nd	nd	nd	nd	0.27	nd	nd
	2(5H)-Furanone, 5-Ethyle	nd	nd	nd	nd	nd	nd	0.1	0.11
Cycloalcen	Limonene	nd	nd	nd	nd	nd	nd	0.28	0.27

[a] nd : Not detected; Major components are shown in bold.

secretion both in females (93.64%) and males (87.56%) of *E. maura.*

We speculate that the differences noted in the chemical compounds may be due to several factors, including the GC-MS device used, the libraries used for identifying the compounds, as well as possible differences in the collection time of the adult insects, and the diversity of the habitats and populations. Noge *et al*. (2015) discovered that secretory components differed during adult aging in the coreid, *Hygia lativentris* (Motschulsky).

Another possibility is that *E. maura* and *E. integriceps* may have been misidentified in one or more of studies. *Eurygaster maura* is extremely similar to *E. integriceps* in external morphology and notoriously difficult to separate even by taxonomists. The most reliable distinguishing character is the structure of the genitalia of *Eurygaster* species: the penis of *E. maura* has 2 hooks and 4 in *E. integriceps* (Kerzhner and Yachevskii, 1967). Another character is the internal spines of *E. maura* that are convoluted and are almost straight in *E. integriceps* (Kerzhner and Yachevskii, 1967; Lodos, 1986). Due to our concerns regarding the differences in chemical composition of the MTGs in these two closely related species, we usually reared *E. maura* male and females and then examined the male aedeagus and female genitalic structures in copulated couples according to the key provided by Kerzhner and Yachevskii (1967) to verify our identifications.

In conclusion, this study was an analysis of the chemical composition of MTGs in *E. maura*. Results showed that n-Tridecane and (E)-2-Hexenal were the major compounds and constituted approximately 90% of the total MTG content in both female and male *E. maura*. In most studies in Heteroptera, these two compounds have been identified as being primarily defensive in nature. Further studies are necessary to investigate the precise biological function of this alkane–aldehyde combination and chemical communication in *E. maura*. This will provide advantage to us in the management of the pest. In summary, this study has provided useful information on the MTG compounds of *E. maura*, and will contribute to further studies on the MTG compounds in this and other species of Pentatomidae.

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REFERENCES

1. Abad, R. F. P. and Atalay, R. 1994. *Eurydema ventrale* Klt. (Heteroptera, Pentatomidae)’nin Pis Koku Bezlerinin Morfolojik Özellikleri Üzerinde Araştırmalar. *Turk. Entomol. Derg.*, 18**(2)**: 77–82.
2. Abad, R. F .P., Karsavuran, Y. and Atalay, R. 1994. *Ancyrosoma leucogrammes* (Gmel.) (Heteroptera: Pentatomidae)’in Erginlerinde Pis Koku Bezlerinin Morfolojik Özellikleri Üzerinde Araştırmalar. *Turk. Entomol. Derg.*, 18**(1):** 15–20.
3. Abad, R. F. P. 2000. *Eurygaster integriceps* Put. (Heteroptera: Scutelleridae)'in Pis Koku Bezlerinin Morfolojik Özellikleri Üzerinde Araştırmalar. *Türkiye 4. Entomoloji Kongresi*, Adana, PP. 257–265.
4. Abad, R. F. P., Azhari, S., Djozan, D. and Hejazi, M. J. 2012. Compounds in Abdominal and Metathoracic Scent Glands of Nymphs and Adults of *Graphosoma lineatum* (Linnaeus, 1758) (Het., Scutelleridae) Under Laboratory Conditions. *Mun. Ent. Zool.*, 7**(2):** 870–880.
5. Aldrich, J.R. 1988. Chemical Ecology of the Heteroptera. *Ann. Rev. Entomol*., 33**:** 211–238.
6. Barão, K. R., Ferrari, A., Adami, C. V. and Grazia, J. 2017. Diversity of the External Thoracic Scent Efferent System of Carpocorini (Heteroptera: Pentatomidae) with Character Selection for Phylogenetic Inference. *Zool. Anz., 268:* 102–111.
7. Borges, M., Zhang, A., Camp, M. J. and Aldrich, J. R. 2001. Adult Diapause Morph of the Brown Stink Bug, *Euschistus servus* (Say) (Heteroptera: Pentatomidae). *Neotrop. Entomol.,* 30**(1):** 179–182.

8. Chapman, R. F. 1972. *The Insects*. The English Universities Press Ltd., New York, 819 PP.
9. Critchley, B. R. 1998. Literature Review of Sunn Pest *Eurygaster integriceps* Put. (Hemiptera, Scutelleridae). *Crop Prot.,* 17**(4):** 271–287.
10. Davidová-Vilímová, J. 2006. Dorsal Abdominal Glands in *Aradus betulae* (Heteroptera, Aradidae). *Denisia 19, zugleich Kataloge der OÖ. Landesmuseen Neue Serie*., 50**:** 137–148.
11. Drijfhout, F. P., Groot, A.T., Posthumus, M.A., Beek, T. A. and Groot, A. 2002. Coupled Gas Chromatographic-Electroantennographic Responses of *Lygocoris pabulinus* (L.) to Female and Male Produced Volatiles. *J. Chem. Ecol.,* 12: 113–118.
12. Durak, D. 2006. Heteropterlerin Bazı Türlerinde Koku Bezlerinin Yapısı. Doktora Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara, PP. 2–122.
13. Durak, D. and Kalender, Y. 2007a. Fine Structure and Chemical Analysis of the Metathoracic Scent Gland of *Eurygaster maura* (Linnaeus, 1758) (Heteroptera: Scutelleridae). *Folia Biol. (Kraków),* 55(3-4): 133–141.
14. Durak, D. and Kalender, Y. 2007b. Fine Structure and Chemical Analysis of the Metathoracic Scent Gland of *Graphosoma semipunctatum* (Fabricius, 1775) (Heteroptera: Pentatomidae). *J. Appl. Biol. Sci.*, *1*(***1***)**:** 43–50.
15. Durak D. 2008. Morphology and Chemical Composition of Metathoracic Scent Glands in *Dolycoris baccarum* (Linnaeus, 1758) (Heteroptera: Pentatomidae). *Acta Zool., 89***(3):** 193–199.
16. Durak, D. and Kalender, Y. 2012. Structure and Chemical Analysis of the Metathoracic Scent Glands of *Carpocoris fuscispinus* (Boheman, 1851) (Heteroptera: Pentatomidae) from Turkey. *Turk. J. Zool*., 36**(4):** 526–533.
17. Farine, J.P., Bonnard, O., Brossut, R. and Le Quere J.L. 1992. Chemistry of Pheromonal and Defensive Secretions in the Nymphs and the Adults of *Dysdercus cingulatus* Fabr. (Heteroptera, Pyrrhocoridae). *J. Chem. Ecol.*, 18**(1):** 65–76.
18. Farine, J. P., Everaerts, C., Brossut, R. and Quere le J. 1993. Defensive Secretions of Nymphs and Adults of Five Species of Pyrrhocoridae (Insecta: Heteroptera). *Biochem. Syst. Ecol*., 21**(3):** 363–371.
19. Gonzaga-Segura, J., Valdez-Carrasco, J. and Castrejón-Gómez, V.R. 2012. The Metathoracic Scent Gland of the Leaf-Footed Bug, *Leptoglossus zonatus*. *J. Insect Sci.,* **13:** 1–10.
20. Gözüaçık, C., Karaca, V., Duman, M. and Mutlu, Ç. 2011. Güneydoğu Anadolu Bölgesinde Süne (*Eurygaster integriceps* Put.) (Hem.: Scutelleridae) Yumurta Parazitoiti *Trissolcus semistriatus* Nees. (Hym.: Scelionidae)'un Üretim ve Salımı Üzerinde Araştırmalar. *GAP VI. Tarım Kongresi*, Şanlıurfa, PP. 51–56.
21. Gregorovičová, M. and Černíková, A. 2016. Reactions of Leopard Geckos (*Eublepharis macularius*) to Defensive Secretion of *Graphosoma lineatum* (Heteroptera: Pentatomidae): An Experimental Approach. *Ethol. Ecol. Evol., 28***(4):** 367–384.
22. Gunawardena, N. E. and Herath, H. M. W. K. B. 1991. Significance of Medium Chainn-Alkanes as Accompanying Compounds in Hemipteran Defensive Secretions: An Investigation Based on the Defensive Secretion of *Coridius janus*. *J. Chem. Ecol., 17***(12):** 2449–2458.
23. Hassani, S., Abad, R. F. P., Djozan, D. and Fazel, M. M. 2010. Compounds in Metathoracic Glands of Adults of the Sunn Pest, *Eurygaster integriceps* (Puton) (Heteroptera: Scutelleridae). *Mun. Ent. Zool.*, 5**(1):** 232–239.
24. Ho, H. Y. and Millar, J. G. 2001. Compounds in Metathoracic Glands of Adults and Dorsal Abdominal Glands of Nymphs of Stink Bugs, *Chlorochroa uhleri, C. sayi* and *C. ligata* (Hemiptera: Pentatomidae). *Zool. Stud.,* 40**(3):** 193–198.
25. Ishiwatari, T. 1974. Studies on the Scent of Stink Bugs (Hemiptera: Pentatomidae). I. Alarm Pheromone Activity. *Appl. Entomol. Zool*., 9: 153-158.
26. Kerzhner, I. M. and Yachevskii, T. L. 1967. Order Hemiptera (Heteroptera). In: "*Keys to the Insects of the European USSR*", (Ed.): Bei-Bienko, G. Ya. Israel Program for Scientific Translations, Jerusalem, PP. 851–1118.
27. Kheyri, H., Cribb, B. W. and Merritt, D. J. 2014. The Comparative Morphology of Epidermal Glands in Pentatomoidea (Heteroptera). *Arthropod Struct. Dev.,* 43**(3):** 211–219.
28. Kment, P. and Vilimova, J. 2010. Thoracic Scent Efferent System of Pentatomoidea. *Zootaxa*, 2706**:** 1–77.
29. Koçak, E. and Babaroğlu, N. 2005. Orta Anadolu Bölgesi Kışlaklarındaki *Eurygaster*

(Heteroptera: Scutelleridae) Türleri. *Turk. Entomol. Derg.*, 29**(4):** 301–307.
30. Krajicek, J., Havlikova, M., Bursova, M., Ston, M., Cabala, R., Exnerova, A., Stys, P. and Bosakova, Z. 2016. Comparative Analysis of Volatile Defensive Secretions of Three Species of Pyrrhocoridae (Insecta: Heteroptera) by Gas Chromatography-Mass Spectrometric Method. *PloS One*, *11***(12):** e0168827.
31. Krall, B. S., Bartelet, R. J., Lewis, C. J. and Whitman, D. W. 1999. Chemical Defense in the Stink Bug *Cosmopepla bimaculata*. *J. Chem. Ecol.*, 25**:** 2477–2494.
32. Laumann, R. A., Aquino, M. F. S., Moraes, M. C. B., Pareja, M. and Borges, M. 2009. Response of the Egg Parasitoids *Trissolcus basalis* and *Telenomus podisi* to Compounds from Defensive Secreations of Sting Bugs. *J. Chem. Ecol.*, 35**:** 8–19.
33. Lockwood, J. A. and Story, R. N. 1985. Bifunctional Pheromone in the First Instar of the Southern Green Stink Bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae): Its Characterization and Interaction with Other Stimuli. *Ann. Entomol. Soc. Am.*, 78: 474–479.
34. Lockwood, J. A. and Story, R. N. 1987. Defensive Secretion of the Southern Green Stink Bug (Hemiptera: Pentatomidae) as an Alarm Pheromone. *Ann. Entomol. Soc. Am.*, 80: 686–691.
35. Lodos, N. 1986. *Türkiye Entomolojisi II: Genel, Uygulamalı ve Faunistik*, Cilt II. Ege Üniversitesi Ziraat Fakültesi Yayınları No: 429, İzmir- Bornova, PP. 406–423.
36. Marques, F. A., Wendler, E. P., Maia, B. H. L., Ventura, M. U. and Arruda-Gatti, I. C. 2007. Identification of Defensive Compounds in Metathoracic Glands of Adults of the Stink Bug *Dichelops melacanthus* (Hemiptera: Pentatomidae). *J. Braz. Chem. Soc.*, *18***(6):** *1242–1246*.
37. Noge, K., Prudic, K. L. and Becerra, J. X. 2012. Defensive Roles of (E)-2-alkenals and Related Compounds in Heteroptera. *J. Chem. Ecol.*, *38***(8):** 1050–1056.
38. Noge, K. 2015. Studies on Chemical Ecology of the Heteropteran Scent Gland Components. *J. Pestic. Sci.*, *40***(3):** 143–145.
39. Noge, K., Kakuda, T., Abe, M. and Tamogami, S. 2015. Identification of the Alarm Pheromone of *Hygia lativentris* and Changes in Composition during Development. *J. Chem Ecol.*, 41**(8):** 757–765.
40. Ögür, E. 2016. *Eurygaster maura* (L.) (Heteroptera: Scutelleridae)'nın Metatorasik Koku Bezi Salgısı, Yumurta Kalitesi ve Buğday Tarlalarındaki Bazı Yabancı Otların Ekstraktlarının Yumurta Parazitoiti *Trissolcus semistriatus* (Nees) (Hymenoptera: Scelionidae)'a Etkileri. Doktora Tezi, *Selçuk Üniversitesi Fen Bilimleri Enstitüsü*, Konya, 139 PP.
41. Özbek, H. and Hayat, R. 2003. *Tahıl, Sebze, Yem ve Endüstri Bitki Zararlıları*. Atatürk Üniversitesi Yayınları, Erzurum, PP. 66–82.
42. Özkan, M. and Babaroğlu, N. E. 2015. *Süne*. T. C. Gıda Tarım ve Hayvancılık Bakanlığı Gıda ve Kontrol Genel Müdürlüğü, Ankara, PP. 17–37.
43. Parveen, S., Usmani, K., Khokhar, S., Ramamurthy, V. V. and Vilímová, J. 2014. External Thoracic Scent Efferent System of Scutelleridae (Hemiptera: Heteroptera). *Zool. Anz.*, 253: 236-258.
44. Raska, J. 2009. Function of Metathoracic Scent Glands in Terrestrial Heteroptera. Undergraduate thesis, *Univerzita Karlova v Praze Přírodovědecká Fakulta Katedra Zoologie*, Praha, PP. 1–28.
45. Ravan, S., Mehrabadi, M. and Bandani, A. 2009. Biochemical Characterization of Digestive Amylase of Wheat Bug, *Eurygaster maura* (Hemiptera: Scutelleridae). *Afr. J. Biotechnol.*, *8***(15):** 3640–3648
46. Rohanová, M., Schaefer, C. W., Křížková, P. and Vilímová, J. 2016. Scent Efferent System of Dorsal Abdominal Scent Glands in Nymphs of Rhopalidae (Hemiptera: Heteroptera: Pentatomomorpha) and Its Comparison with Other Pentatomomorpha. *Zool. Anz.*, *260:* 1–10.
47. Šanda, M., Žáček, P., Streinz, L., Dračínský, M. and Koutek, B. 2012. Profiling and Characterization of Volatile Secretions from the European Stink Bug *Graphosoma lineatum* (Heteroptera: Pentatomidae) by Two-Dimensional Gas Chromatography/Time-of-Flight Mass Spectrometry. *J. Chromatogr. B*, *881***:** 69–75.
48. Staddon, B. W. 1979. The Scent Glands of Heteroptera. *Adv. Insect Physiol.*, **14:** 351–418.
49. Staddon, B. O. and Olagbemiro, T. O. 1984. Composition and Novel Pattern of Emission of Defensive Scent Oils in the Larva of Cotton Seed Bug *Oxycarenus hyalinipennis* (Costa) (Heteroptera: Lygaeidae). *Cell. Mol. Life Sci.*, 40**(1):** 114–116.
50. Steinbauer, M. J. and Davier, N. W. 1995. Defensive Secretions of *Amorbus*

obscuricornis (Westwood), *A. rubiginosus* (Guerin-Meneville) and *Gelonus tasmanicus* (Le Guillou) (Hemiptera: Coreidae). *Aust. J. Entomol.*, 34**:** 75–78.

51. Vaccino, P., Corbellini, M., Reffo, G., Zoccatelli, G., Migliardi, M. and Tavella, L. 2006. Impact of *Eurygaster maura* (Heteroptera: Scutelleridae) Feeding on Quality of Bread Wheat in Relation to Attack Period. *J. Econ. Entomol.*, *99***(3):** 757–763.
52. Weiler, L., Barão, K. R., Cassis, G. and Grazia, J. 2017. Morphology of the External Scent Efferent System of Neotropical Shield Bugs (Hemiptera: Scutelleridae: Pachycorinae). *Zoomorphology*, *136***(1):** 29–44.
53. Yasuda, T., Mizutani, N., Endo, N., Fukuda, T., Matsuyama, T., Ito, K., Moriya, S. and Sasaki, R. 2007. A New Component of Attractive Aggregation Pheromone in the Bean Bug, *Riptortus clavatus* (Thunberg) (Heteroptera: Alydidae). *Appl. Entomol. Zool.*, 42**(1):** 1–7.
54. Zarbin, P. H. G., Borges, M., dos Santos, A.A., Oliveira, A.R.M., Simonelli, F. and Marques, A. 2000. Alarm Pheromone System of Stink Bug *Piezodorus guildinii* (Heteroptera: Pentatomidae). *J. Braz. Chem. Soc.*, 11**(4):** 424–428.
55. Zhang, Z.M., Wu, W.W. and Li, G.K. 2009. Study of the Alarming Volatile Characteristics of *Tessaratoma papillosa* Using SPME–GC–MS. *J. Chromatogr. Sci.*, *47***(4):** 291–296.
56. Zhang, Z., Luo, J., Wang, Y., Chen, L., Chen, L. and Lei, C. 2014. Morphology and Chemical Analysis of the Metathoracic Scent Glands System in *Adelphocoris suturalis* (Hemiptera: Miridae). *J. Insect Sci.*, *14***(1):** 293.
57. Zhao, D., Gao, J., Wang, Y., Jiang, J. and Li, R. 2012. Morphology and Volatile Compounds of Metathoracic Scent Gland in *Tessaratoma papillosa* (Drury) (Hemiptera: Tessaratomidae). *Neotrop. Entomol.*, 41**:** 278–282.

تجزیه شیمیایی غده بو دهنده پس سینه ای *Eurygaster maura* (L.) (Heteroptera: Scutelleridae)

ا. اوگور، و ز. تونکر

چکیده

Eurygaster maura (L.) (Heteroptera: Scutelleridae) یکی از نابود کننده ترین آفت های گندم در ترکیه است.در این پژوهش، غده بو دهنده پس سینه ای جنس نر و ماده *E. maura* به طور جداگانه با استفاده از کروماتوگرافی-طیف سنجی جرمی تجزیه شد. دوازده ماده شیمیایی به نام های Octane، n-Undecane، n-Dodecane، n-Tridecane، (E)-2-Hexenal، (E)-2-Hexen-1-ol، Cyclopropane, 1-ethyl-2-heptyl، acetate, Hexadecane، (E)-3-Octen-1-ol، acetate، (E)-5-Decen-1-ol، acetate، 2-Hexenoic acid، Butyric acid، و Tridecyl ester در حشره نر و ماده تشخیص داده شد. اما، از نظر کمیت، این مواد در بین این دو جنسیت تفاوت داشتند. در هر دو جنسیت نر و ماده، مواد n-Tridecane و (E)-2-Hexenal بیشترین فراوانی را داشتند و مجموعا ۹۰٪ کل مواد را تشکیل می دادند. مقدارکمینه Octane در جنس نر و کمینه Hexadecane در جنس ماده مشاهده شد.