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Egg morphology of *Dioctria* (Insecta: Diptera: Asilidae) species known in Turkey*

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Abstract
The egg structures of eight *Dioctria* species known in Turkey, i.e., *D. abdominalis*, *D. arcana*, *D. cornuta*, *D. flavipennis*, *D. hermonensis*, *D. linearis*, *D. sudetica*, *D. valida* were examined and described in detail, using the scanning electron microscope (SEM). The material was collected from various habitats such as watersides, forest areas and crop fields within Adana, Aksaray, Mersin, Nigde, Karaman and Konya provinces between 2006 and 2007. *Dioctria* eggs are characterized as: 1) ovoid in shape and brown in color; 2) operculum at the anterior pole of the egg; 3) one or two micropyles at the center of the operculum; 4) aeropyles scattered in the body region and operculum or only in the former. The eggs were photographed to provide useful information to the systematics of *Dioctria* genus.
Key words: egg, morphology, *Dioctria*, scanning electron microscope, Turkey.

ریخت‌شناسی تخم گونه‌های شناسایی شدهٔ ***Dioctria*** **(Insecta: Diptera: Asilidae)** در ترکیه

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چکیده
ساختار ظاهری تخم هشت گونهٔ شناسایی شده از جنس *Dioctria* در ترکیه به نام‌های *D. abdominalis*، *D. arcana*، *D. cornuta*، *D. flavipennis*، *D. hermonensis*، *D. linearis*، *D. sudetica* و *D. valida* با استفاده از میکروسکوپ الکترونی مورد بررسی قرار گرفت و با جزئیات توصیف شد. نمونه‌ها از زیستگاه‌های مختلف مانند کنار دریا، مناطق جنگلی و مزارع محصولات کشاورزی واقع در استان‌های آدانا، آکسارای، مرسین، نجده، کارامان و قونیه در سال‌های ۲۰۰۶ و ۲۰۰۷ جمع‌آوری شدند. ویژگی‌های تشخیصی تخم‌های *Dioctria* شامل: ۱- شکل تخم مرغی و رنگ قهوه‌ای، ۲- درپوش در ناحیه پیشین قطب تخم، ۳- یک یا ۲ روزنک در بخش میانی درپوش تخم و ۴- هوا روزنک‌ها در بدنه و درپوش تخم و یا فقط در بدنهٔ تخم پراکنده شده‌اند، می‌باشد. به منظور استفاده در سازگان شناسی جنس *Dioctria* تصاویر تخم‌ها ارائه شده است.
واژه‌های کلیدی: تخم، ریخت شناسی، *Dioctria*، تصویر برداری میکروسکوپ الکترونیکی، ترکیه.

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Introduction

The eggs of insects have morphological features specific to each group, which are related to their life strategies (Hinton, 1969). Ornamentation of egg exochorion is an important feature in some insect orders (Musso, 1981; Salkeld, 1983, 1984; Lavigne & Bullington, 1984; Lawson & Lavigne, 1984; Castillo *et al.,* 1994; Suludere *et al.,* 2000). Ornamentation of exochorion can serve various functions such as protection against

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desiccation and physical damage, and the facilitation of gas exchange through structural connections to inside of the egg (Hinton, 1969, 1970). Insect egg morphology has been studied using the scanning electron microscope (SEM) in the context of identifying species and tracing origins of infestations in domestic and international trade (Kučerová & Stejskal, 2002, 2010; Hasbenli *et al*., 2006, 2008; Dutra *et al*., 2013).

The eggs are diverse in size and shape among asilids. Egg surface of some species lacks any structures, that of others has irregularly disposed protuberances, or is furnished with facet-like ridges, or dotted or granular (Scarbrough, 1978; Musso, 1981; Lavigne & Bullington, 1984; Castillo *et al*., 1994; Suludere *et al*., 2000, Candan *et al*., 2004a,b).

Musso (1981) classified asilid eggs into three types: 1. pigmented eggs with a thick chorion with irregular polygonal surface pattern; 2. unpigmented eggs with a thick chorion covered with tubercles (eggs with ornamentation), or eggs with a smooth surface and thin chorion (eggs without ornamentation); 3. eggs covered with sand grains. Type 1 is found only in the subfamily Laphriinae, type 2 is found in some species of the subfamily Asilinae, and type 3 is found in *Antipalus varipes* (Meigen, 1820).

Dioctria Meigen, 1803 (Diptera: Asilidae: Dioctriinae: Dioctriini) comprises the highest number of species in the subfamily Dioctriinae as 123 species. Of them, 93 species are Palearctic, 27 species are Nearctic, one species is Neotropical, one species is from Australia, and one species is known from Afrotropical zoogeographic regions. Thirteen *Dioctria* species are known from Turkey (Engel, 1926; Lehr, 1988; Hayat & Alaoğlu, 1994; Weinberg & Hayat, 1997; Bosák & Hradský, 2001; Geller-Grimm, 2015; Bayrakdar & Hasbenli, 2009).

Body size of adult insects of genus range from 6 to 20mm. The antennae are elongate, longer than the height of the eye. The fore tibia lacks an apical claw-like spur, the hind femora without strong bristles and the pulvilli are normally developed. Wings are relatively large, the 1stradial cell, all medial cells and posterior cubital cell are open (Richter, 1988). Among Asilidae, only the Dioctriinae possess an arched postmentum (Dikow, 2009).

This study is a part of doctoral thesis of the first author. In the present study, we examine and describe in detail the egg morphology of *Dioctria* species known in Turkey, with the aim of characterizing the egg structures and discussing the systematic issues on them.

Materials and methods

Insects were collected with a sweep net from various habitats such as watersides, forest areas and crop fields within Adana, Aksaray, Mersin, Nigde, Karaman and Konya provinces between 2006 and 2007. Collected males were killed in killing jars containing ethyl acetate. Collected females, at least two, were put in the feeding containers with a wet paper-napkin bottom, which serves as oviposition bed, to obtain the eggs. Females laid eggs in feeding

containers. Features, and altitude of the locations of the collecting sites were recorded. All the materials were deposited in Zoology Museum of Gazi University, Faculty of Science.

Collected samples were identified by referring to: Séguy (1927, 1929, 1941), Engel (1926), Duda (1940), Richter (1960, 1966, 1968, 1973), Moucha ve Hradský (1963), Hradský ve Moucha (1964), Lehr (1965, 1988, 2002), Janssens (1968), Esipenko (1971), Theodor (1980), and Geller-Grimm (2003); McAlpine (1981) was referred to for terminology.

The obtained eggs were stuck to the stub with a double-sided tape, coated with gold for 120 seconds in the Polaron SC 502 Sputter Coater, and examined under a JEOL JSM 6060 Scanning Electron Microscope (SEM). At least ten eggs were examined for each species.

Results

Dioctria abdominalis Becker, 1923

Material examined: Mersin, Mut, Comelek village, Sason valley, 1045 m, 13.06.2007, 2♀.

Distribution: Turkey (Geller-Grimm, 2015), Iran (Lehr *et al*., 2007; Mohammadi *et al*., 2019)

Egg: ovoid and brown in color; width 0.35 ± 0.02 mm, length 0.40 ± 0.03 mm (Figure 1A); operculum diameter 100 µm, situated at the anterior pole of the egg, with one micropyle; operculum and the body region of the egg demarcated by an eclosion line (Figure 1A, B); marginal region of the operculum furnished with the oval rings arranged in two to four rows, remaining part smooth (Figure 1B); egg surface densely covered by oval rings of various sizes (3-9 µm in diameter) (Figure 1C, D); aeropyles found both in the operculum and body region (Figure 1D).

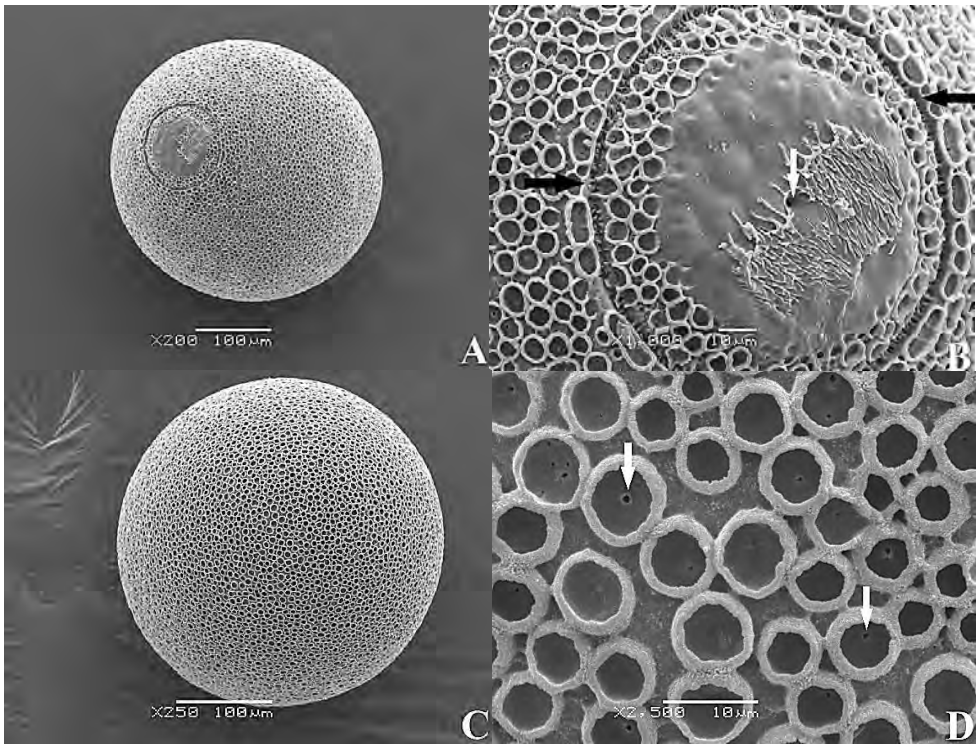

Fig. 1. *Dioctria abdominalis*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum, eclosion line (black arrows), micropyle (white arrow); **C.** General habitus, lateral view; **D.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria arcana Richter, 1966

Material examined: Mersin, Atlılar village, 1422 m, 08.06.2006, 2♀.

Distribution: Armenia (Geller-Grimm, 2015), Turkey (Bayrakdar & Hasbenli, 2009)

Egg: ovoid and brown; length slightly longer than width: width 0.33 ± 0.02 mm, length 0.44 ± 0.03 mm (Figure 2A); operculum diameter 140 µm, situated at anterior pole, with one or two micropyles at the center; having smooth surface; the eclosion line absent (Figure 2A, B, C); egg surface densely covered with oval rings of various sizes (6-14 µm in diameter) (Figure 2D, E); aeropyles present both in the operculum and body region of the egg (Figure 2E).

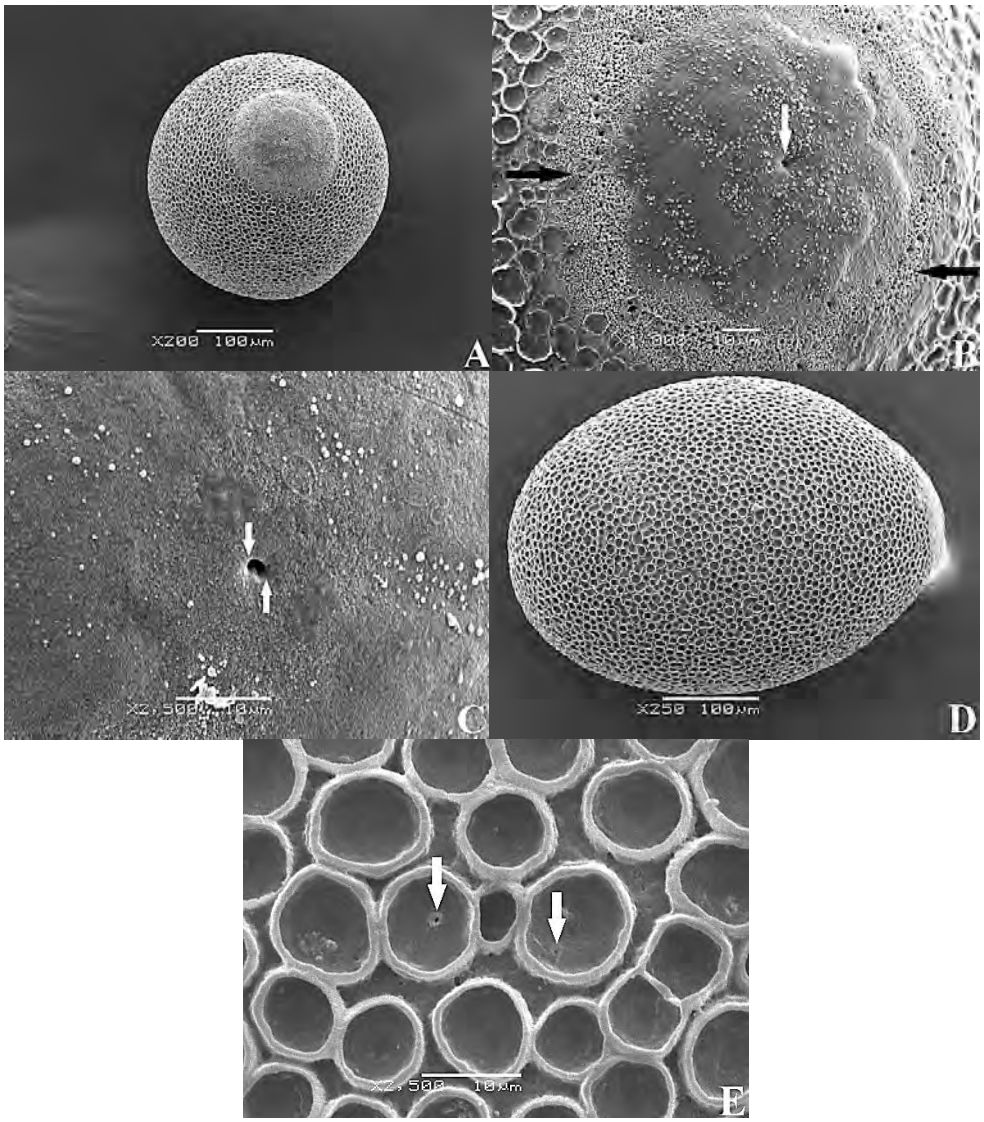

Fig. 2. *Dioctria arcana*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum, (black arrows), micropyle (white arrow); **C.** Micropyles (arrows); **D.** general habitus, lateral view; **E.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria cornuta Lehr, 2002

Material examined: Ankara, Ayas road, Atbeli, 1162 m, 08.06.2008, 2♀.

Distribution: Soviet Union (Lehr, 2002), Turkey (Bayrakdar, 2010, unpublished data)

Egg: ovoid and brown; width 0.38 ± 0.02 mm; length 0.55 ± 0.03 mm (Figure 3A); operculum diameter 130 µm, situated at the anterior pole of the egg, having smooth surface; with two micropyles at the center; the eclosion line absent (Figure 3A, B, C); egg surface densely covered by oval rings of various sizes (4-10 µm in diameter) (Figure 3D, E); aeropyles present both in the operculum and body region of the egg (Figure 3E).

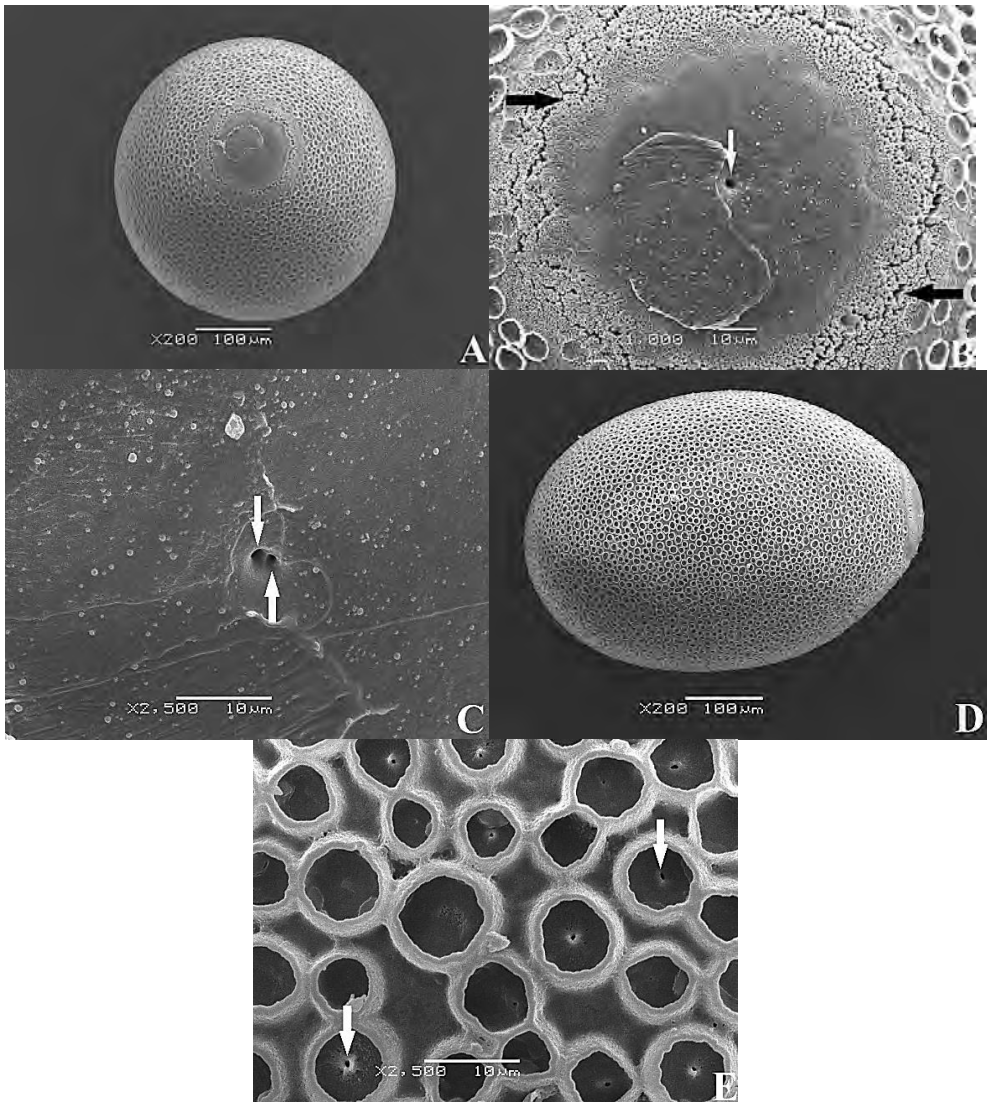

Fig. 3. *Dioctria cornuta*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum (black arrows) and micropyle (white arrow); **C.** Micropyles (arrows); **D.** General habitus, lateral view; **E.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria flavipennis Meigen, 1820

Material examined: Nigde, Ulukısla, Darbogaz village, 1721 m, 06.06.2006, 2♀.

Distribution: Austria, Bulgaria, Byelorussia, China, Czech Republic, Estonia, France, Germany, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldavia, Poland, Romania, Russia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan, West Siberia, (Geller-Grimm, 2015), Iran (Lehr *et al*., 2007; Mohammadi *et al*., 2019).

Egg: ovoid and brown; width 0.30 ± 0.02 mm and length 0.40 ± 0.03 mm (Figure 4A); operculum diameter 110 µm; situated at the anterior pole, with one or two micropyles at the center separated by eclosion line, signalized by regularly arranged oval rings; marginal region of the operculum furnished with the grouped oval rings; (Figure 4A, B, C); egg surface

covered with oval rings of varying sizes (5-9 µm in diameter) (Figure 4D, E); aeropyles present both in the operculum and body region of the egg (Figure 4E).

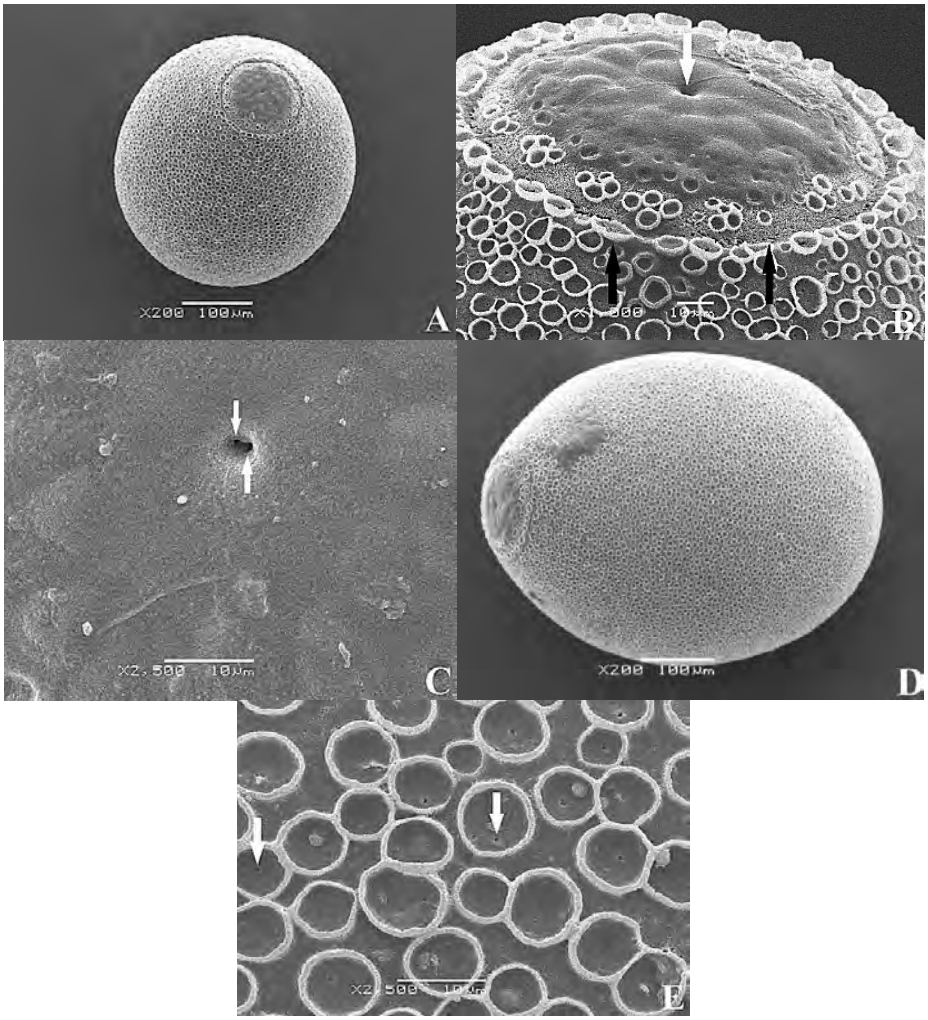

Fig. 4. *Dioctria flavipennis*, *scanning electron microscopy* of *egg*; **A.** General habitus, dorsal view; **B.** Operculum, eclosion line (black arrows), micropyle (white arrow); **C.** Micropyles (arrows); **D.** General habitus, lateral view; **E.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria hermonensis Theodor, 1980

Material examined: Mersin, Mut, Mut-Ermenek road, Gezende dam, 353 m, 21.05.2007, 2♀.

Distribution: Israel (Geller-Grimm, 2015), Turkey (Bayrakdar, 2010, unpublished data)

Egg: ovoid and brown; width 0.35 ± 0.02 mm, length 0.40 ± 0.03 mm (Figure 5A); operculum diameter 100 µm; situated at the anterior pole of the egg; with one micropyle at the center; eclosion line absent (Figure 5A, B); egg surface has polygonal pattern, most of which pentagonal (Figure 5C, D); polygons bounded by granules, smaller granules scattered inside

the polygons (Figure 5D); four to eleven aeropyles about 2 µm in diameter in each polygon (Figure 5D).

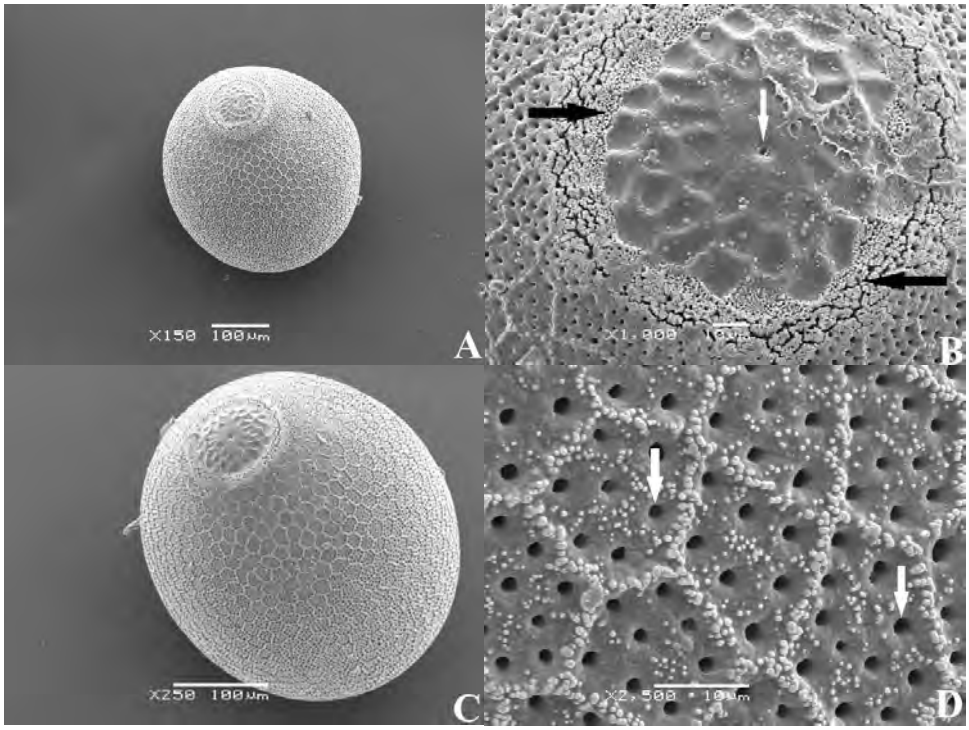

Fig. 5. *Dioctria hermonensis*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum (black arrows),micropyle (white arrow); **C.** General habitus, lateral surface; **D.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria linearis (Fabricius, 1787)

Material examined: Nigde, Ulukısla, Darbogaz-Pozantı road, 1281 m, 26.06.2007, 2♀.

Distribution: Austria, Belgium, Bulgaria, Czech Republic, Denmark, England, former Yugoslavia, France,Germany, Hungary, Italy, Luxembourg, The Netherlands, Poland, Romania, Russia, Switzerland (Geller-Grimm, 2015), Turkey (Bayrakdar, 2010, unpublished data)

Egg: ovoid and brown; width 0.30 ± 0.02 mm, length 0.40 ± 0.03 mm (Figure 6A). Operculum diameter 100 µm, situated at the anterior pole; with two micropyles at the center; marginal region furnished with grouped oval rings; eclosion line present (Figure 6A, B, C); egg surface covered by oval chorionic rings of various sizes (7-11 µm in diameter) (Figure 6C, E); aeropyles present both in the operculum and body region of the egg (Figure 6E).

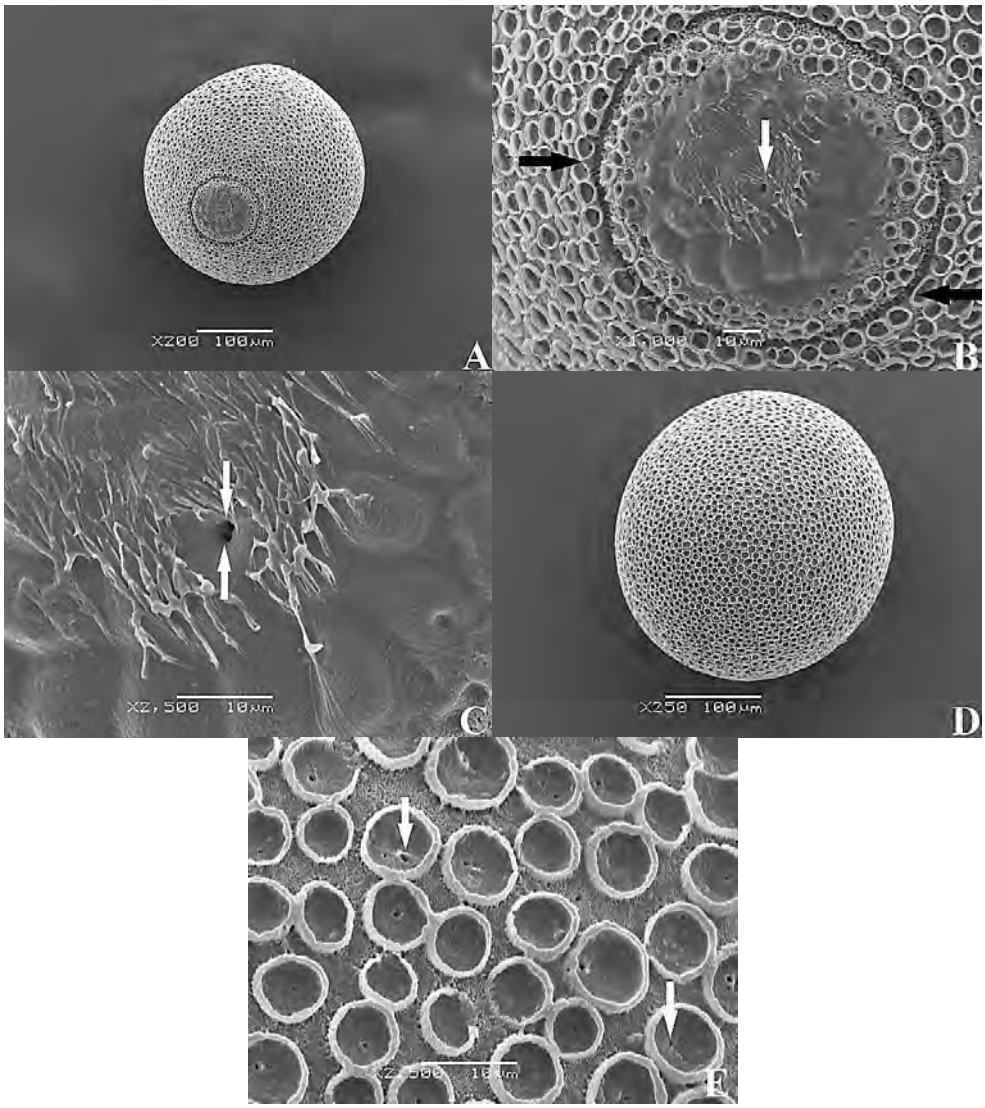

Fig. 6. A. SEM view of an egg of *Dioctria linearis*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum, eclosion line (black arrows), micropyles (white arrow); **C.** Micropyles (arrows); **D.** General habitus, lateral view, E. Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria sudetica Duda, 1940

Material examined: Kayseri, Yahyali, Burhaniye village, 1411 m, 18.05.2002, 2♀.

Distribution: Czech Republic, Slovakia, Poland, Austria, Denmark, The Netherlands, Italy (Geller-Grimm, 2015), Turkey (Bayrakdar, 2010, unpublished data)

Egg: ovoid and brown; width 0.30 ± 0.02 mm and length 0.40 ± 0.03 mm (Figure 7A); operculum diameter 115 µm, situated at the anterior pole, with smooth surface; with two micropyles at the center; eclosion line absent (Figure 7A, B, C); egg surface covered with oval rings of various sizes (5-9 µm diameter) (Figure 7D, E); aeropyles present both in the operculum and body region of the egg (Figure 7E).

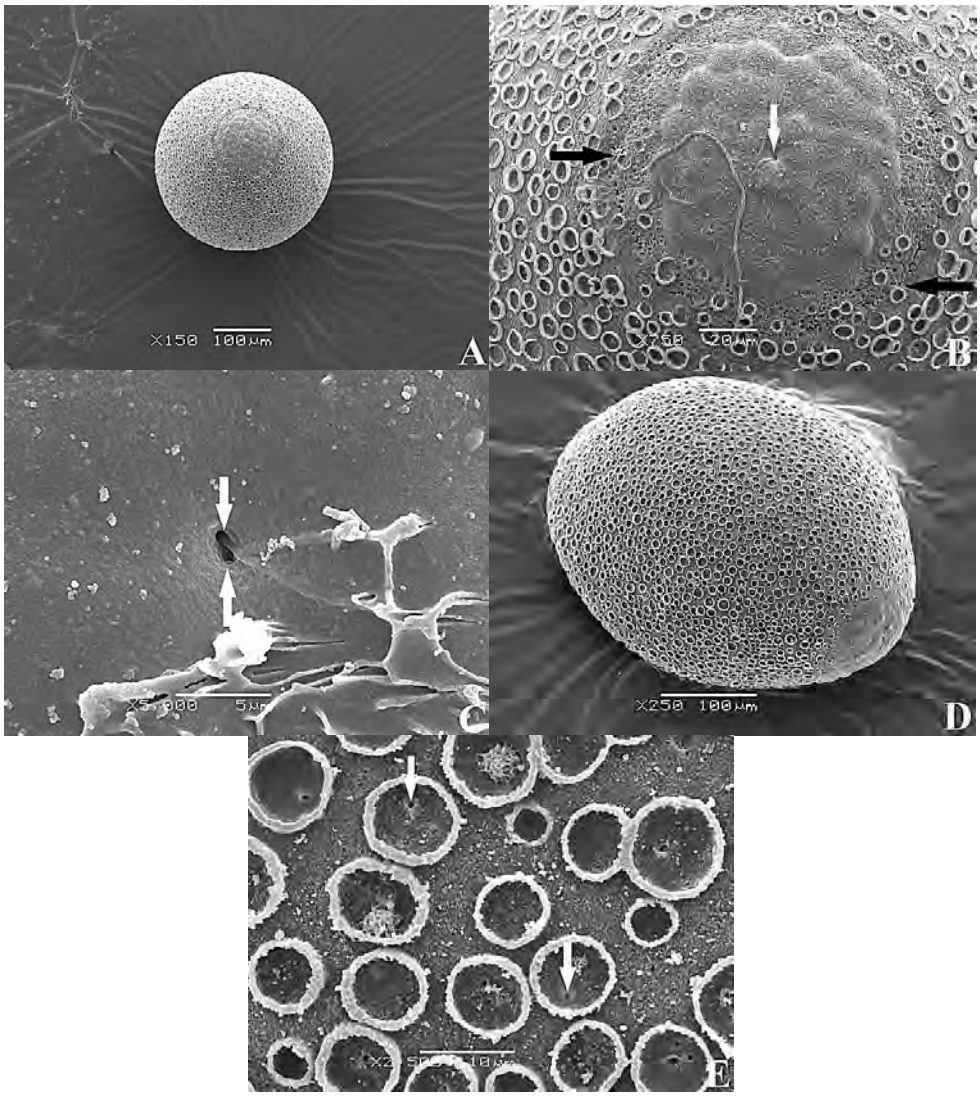

Fig.7. A. SEM view of an egg of *Dioctria sudetica*, scanning electron microscopy of egg; **A.** General habitus, dorsal view; **B.** Operculum (black arrows), micropyles (white arrow); **C.** Micropyles (arrows); **D.** General habitus, lateral view; **E.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Dioctria valida Loew, 1856

Material examined: Mersin, Silifke, Kirobasi, 1403 m, 18.05.2006, 2♀.

Distribution: Israel, Lebanon, Syria, Turkey (Geller-Grimm, 2015), Iran (Lehr *et al*., 2007; Mohammadi *et al*., 2019).

Egg: ovoid and brown; width 0.40 ± 0.02 mm, length 0.50 ± 0.03 mm (Figure 8A); operculum diameter 150 µm, situated at the anterior pole; with two micropyles are at the center; eclosion line absent (Figure 8A, B, C); egg surface is covered by numerous dimples, aeropyles (1 µm in diameter) found in the dimples (Figure 8D, E).

Egg features of the *Dioctria* species known in Turkey shown in Table 1, in brief.

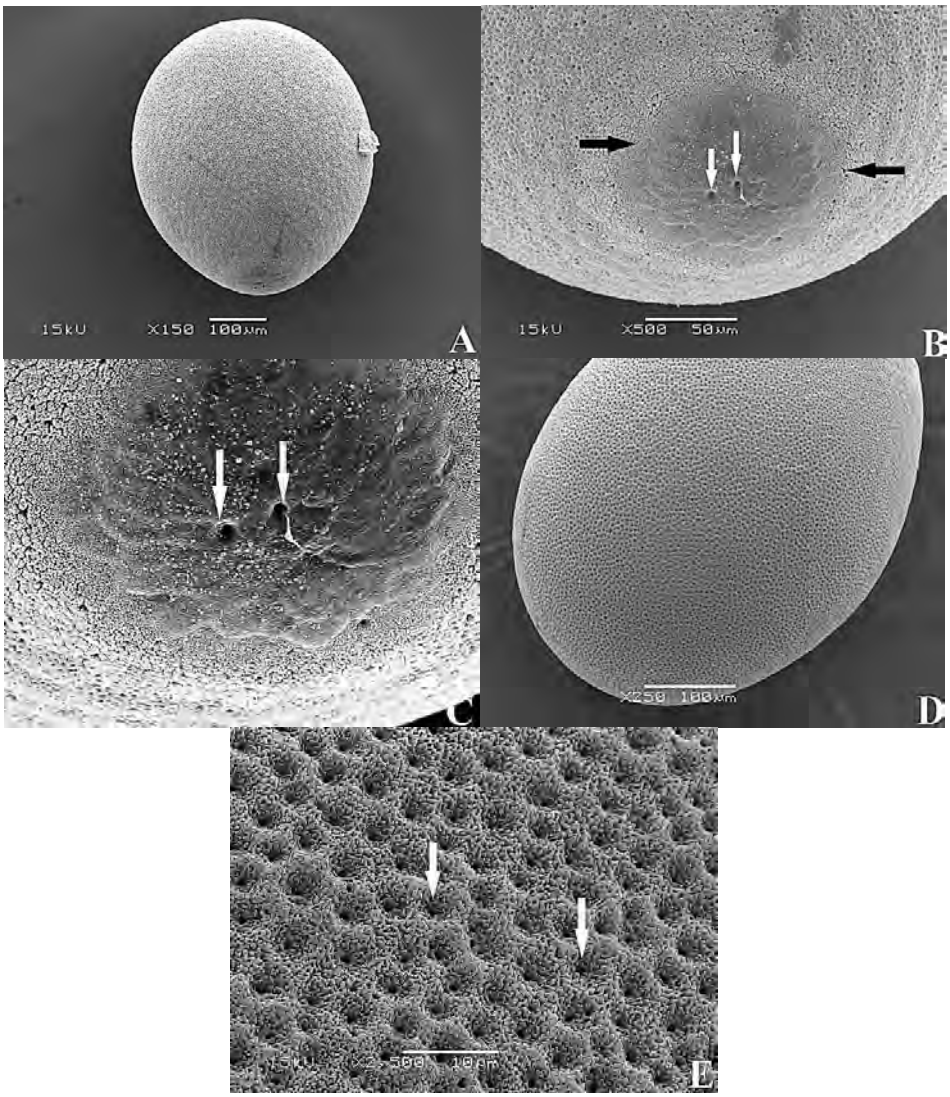

Fig. 8. *Dioctria valida*, *scanning electron microscopy* of *egg*; **A.** General habitus, dorsal view; **B.** Operculum (black arrows), micropyle (white arrow); **C.** Micropyles (arrows); **D.** General habitus, lateral view **E.** Enlargement of the body region of the egg, arrows showing the aeropyles.

Table 1. Egg features of the *Dioctria* species known in Turkey

Species	Egg shape	Egg size (width/length)	Egg surface	Number of micropyles	Eclosion line
D. abdominalis	ovoid	0.35 ± 0.02 mm -0.40 ± 0.03 mm	numerous oval rings	one	present
D. arcana	ovoid	0.33 ± 0.02 mm -0.44 ± 0.03 mm	numerous oval rings	one or two	absent
D. cornuta	ovoid	0.38 ± 0.02 mm - 0.55 ± 0.03 mm	numerous oval rings	two	absent
D. flavipennis	ovoid	0.30 ± 0.02 mm -0.40 ± 0.03 mm	numerous oval rings	one or two	present
D. hermonensis	ovoid	0.35 ± 0.02 mm - 0.40 ± 0.03 mm	polygonal pattern	one	absent
D. linearis	ovoid	0.30 ± 0.02 mm -0.40 ± 0.03 mm	numerous oval rings	two	present
D. sudetica	ovoid	0.30 ± 0.02 mm - 0.40 ± 0.03 mm	numerous oval rings	two	absent
D. valida	ovoid	0.40 ± 0.02 mm -0.50 ± 0.03 mm	numerous dimples	two, rarely one	absent

Discussion

The egg morphology of *Dioctria* species, known in Turkey, was described. The eggs of *Dioctria* are characterized as: ovoid in shape and brown in color; operculum at the anterior pole of the egg; one or two micropyles at the center of the operculum.

Egg surface of *D. abdominalis*, *D. arcana*, *D. cornuta*, *D. flavipennis*, *D. linearis*, and *D. sudetica*are densely covered with oval rings of various sizes. The operculum of *D. abdominalis*, *D. flavipennis*, and *D. linearis* is clearly defined from the body region of the egg by the eclosion line: the marginal region of the operculum is with the oval rings arranged in 2-4 rows or groups. Aeropyle openings are found both in operculum and in and between the oval rings.

Although the well-defined eclosion line is absent, the operculum is distinguishable from the body region of the egg also in *D. arcana* and *D. cornuta*, being devoid of oval rings. *D. hermonensis* eggs have a polygonal pattern, most of which are pentagonal. Polygones are bounded by the lined granules. There are 4-11 aeropyles and numerous dots in each polygon. Surface of the operculum is with reticular ridge.

Surface of *D. valida* eggs is devoid of the oval rings but with numerous dimples, at the bottom of which the aeropyle opens and the operculum is smooth.

Egg of *Dioctria* genus has thick, pigmented and ornamented chorion. There is a correlation between ovipositor type, oviposition behavior and oviposition side and egg morphology (Hinton, 1981). There are three oviposition strategies within the family Asilidae. Some genera such as *Laphria* (Laphriinae), *Leptogaster* (Leptogastrinae) and *Dioctria* (Dioctriinae) lay their eggs randomly amongst the herbs; therefore has thick chorion, some genera such as *Lasiopogon* and *Cyrptopogon* (Stichopogoninae) and Stenopogoninae bury eggs in sand or soil; and some genera such as *Dysmachus*, *Eutolmus* and *Rhadiurgus* (Asilinae) deposit their eggs on or in herbs. Stichopogoninae and Stenopogoninae deposite their eggs into the ground (Melin, 1923; Lehr, 1958, 1963; Oldroyd, 1966; Dennis & Lavigne, 1975, 1976; Hinton, 1981; Candan *et al*., 2004a). Melin (1923) reported that eggs of *Dioctria* spp. are oval and reddish brown with a chorion covered with irregular bumps. According to Candan *et al*. (2004a), *D. flavipennis* eggs are ovoid and matt brown. Egg surface covered with cup-shaped rings of various sizes, and the micropyle is at the anterior pole of the egg.

Operculum serve as hatching site. At the hatching, the operculum opens along the eclosion line, and the larvae hatch out. According to Stubbs & Drake (2001), the larvae of most asilid species emerge through an irregular split made in the eggshell, whereas those of the genera such as *Dioctria* and *Laphria* that have the eggs with the hard shell hatch out with the opening of operculum.

Oxygen and moisture intake into the eggs are significant factors for embryonic development, and the chorions have various modifications to facilitate gas exchange and to

save moisture. In some genera like *Dioctria*, aeropyles scattered on surface of thick chorion allow respiratory exchange of oxygen and carbon dioxide with relatively small loss of water, and these genera usually lay their eggs randomly. Some genera, which have a thin chorion, deposit their eggs on or in herbs to prevent moisture loss (Melin, 1923; Candan *et al*., 2004a, b).

In the present study, the egg morphology of *Dioctria* Meigen, 1803 from Turkey was examined and described in detail. The egg morphology was revealed to provide useful information to the systematics of asilids. The egg morphology of Asilidae is still little known, and further studies on it are needed.

Acknowledgments

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