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CONTENTS / İÇİNDEKİLER

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RESEARCH ARTICLE

Comparative Seed Morphology of Eight *Allium* L. Species from Sections *Codonoprasum* and *Scorodon*

Özge Vatandaşlar[1], Mine Koçyiğit[2]

Abstract

Objective: The *Allium* L. genus is one of the largest species of sectoral importance due to its consumption as food and its medical importance. For this reason, different characters are used to solve taxonomic problems and clearly identify species. One of these characteristics is the micromorphological characteristics of the seed.

Materials and Methods: Light microscopy was used to examine the size and maturity of the seeds, and their micromorphology was studied using an FEI Quanta 450 FEG-EDS scanning electron microscope (SEM) at Istanbul University, Faculty of Science Department of Physics Nano- and Optoelectronics Research Laboratories. Twelve characteristics were determined on the seed surfaces of the examined eight *Allium* species. Cluster analysis was performed on these characteristics using Jaccard similarity analysis with PAST 1.81.

Results: Seed surfaces of eight *Allium* species (4 species from the sect. *Codonoprasum* and 4 species from the sect. *Scorodon* were examined. *Allium phrygium* Boiss., *A. balansae* Boiss., *A. sivasicum* N. Özhatay & Kollmann, *A. djilgense* Boiss. ex Regel, and *A. tauricola* Boiss. are endemics for Türkiye. The epidermal cells of the testa were either regularly or irregularly polygonal. The arrangement of the cells was generally compact, primarily consisting of cellular reticulate tissue. The anticlinal walls of the testa epidermal cells were either straight or curved, while the periclinal walls varied from flat or concave to various extents. Additionally, the epidermal cells exhibited verrucae and granulose features. The micromorphological characteristics of the seeds are summarized in a list. According to seed characteristics, two main branches formed in the similarity tree. In particular, the species in the Sect. *Scorodon* are grouped together.

Conclusion: Micromorphological traits, such as surface texture, cell shape, and seed testa patterns, can provide valuable information for identifying species and understanding taxonomic and evolutionary relationships. In the context of *Allium*, these traits can be particularly useful because they often exhibit significant variation among species and are stable and characteristic enough to serve as reliable taxonomic markers. By analyzing these micromorphological features, it is possible to gain insight into the evolutionary history and relationships of different taxa within the species.

Keywords: *Allium*, endemic, Cluster analysis, SEM, testa

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Introduction

One of the important plants known and cultivated since ancient times is *Allium* L. In particular, epidemic diseases such as cholera and plague in the Middle Ages, II. During World War II, garlic was used for the treatment of wounded people (Baytop, 1999). In addition to being used as a vegetable and spice, garlic is used for medicinal purposes in Türkiye and around the world (Ekşi *et al.,* 2020). In Türkiye, the leaves and bulbs of *Allium* species, both naturally grown and cultivated, are used by the public for various purposes. *Allium* species are used in the treatment of hemorrhoids around Ankara, Bartın and Gönen (Gürhan & Ezer, 2004; Tuzlacı & Aymaz, 2001), in the treatment of hemorrhoids, earache, and poisoning in Kırklareli (Kültür, 2007), and as an expectorant, cough suppressant, and blood pressure reducer in Çankırı (Ezer & Avcı, 2004), in the Middle and Western Black Sea region, for boil ripening, diabetes, and rheumatism pain, around Kırşehir, as an expectorant, blood pressure reducer, for reducing intoxication after alcohol consumption, around Trabzon, for wound treatment, earache, hair loss (Yazıcıoğlu & Alpınar, 1993), and wounds and boils. They are used to treat worms around Muğla, as food around Bodrum, for inflamed wounds around Malatya (Yeşil & Akalın, 2009), and for inflamed wounds and stomach ache around Kayseri (Özkan Gençler & Koyuncu, 2005). It is used for the treatment of boils in Portugal (Novais *et al.,* 2004), in veterinary medicine, insect bites, and as a diuretic in Italy (Guarrera *et al.*, 2005), and in Morocco for the treatment of diabetes, heart diseases, hypertension, skin diseases, scorpion, and snake bites (Jouad *et al.,* 2001).

The taxonomically difficult *Allium* is the largest genus of petaloid monocots, comprising approximately 1200 taxa (Govaerts *et al.*, 2024). In Türkiye, the genus is represented by 225 taxa in 15 sections. In recent years, seed characteristics have also been frequently used to solve taxonomic problems.

In studies based on the morphological characteristics of *Allium* seeds, differences in size and shape were determined in the epidermal cells of the testa. In particular, testa characteristics have been revealed in 17 sections of the *Allium* genus (Friesen *et al*., 2006; Kruse, 1994). Additionally, the seed surface of 20 *Allium* taxa from Iran have been studied (Neshati & Fritsch, 2009). In a study conducted in Canada, the genus was revised according to seed characteristics (Choi & Cota-Sanchez, 2010). Seed surface of 24 *Allium* species in Korea and northeastern China were examined, and it was concluded that there were differences (Choi & Oh, 2011). In Poland, the seeds of eight *Allium* species were examined and different species were identified (Bednorz *et al*., 2011). Studies have shown that seed morphology contributes to *Allium* taxonomy in Central Asia (Baasanmunkh *et al.,* 2020; Shukherdorj *et al.,* 2021).

In Turkey, 62 *Allium* seeds were examined (Celep *et al*., 2012). Seed surface examinations have also been included in studies describing new species in recent years. It is stated in all studies that the identification of micromorphological seed characters is useful for evaluating the taxonomic relationships among *Allium* taxa.

In this study, the seed surfaces of eight *Allium* species belonging to two very similar sections, *Codonoprasum* and *Scorodon*, were examined. Five of the species examined were endemic. We evaluated whether there was any similarity between the sections in terms of seed surfaces.

Materials and Methods

Allium samples in the Herbarium of the Faculty of Pharmacy, Istanbul University (ISTE) were examined. The seeds of each species were examined under a stereomicroscope to ensure that only normal-sized and mature seeds were used. Herbarium numbers and locality information are given in Table 1. Light microscopy was used to examine the

Table 1. Localities and herbarium numbers of the examined *Allium* samples.

ISTE no	Scientific name (Endemism)	Localities	Altitudes (m)	Collected Date
87671	*A. phrygium* Boiss. **(E)**	Isparta, Barla Village	967	20.07.2008
87585	*A. pseudoflavum* Vved.	Kars, Ani Ruins	1260	6.07.2007
92251	*A. flavum* L.	Kırklareli, Demirköy, Yıldız Mountains, and Mahya Hill	1031	4.07.2009
87725	*A. staticiforme* Sm.	Balıkesir, Between Bandırma and Biga, the Denizkent dunes	0	20.06.2009
97291	*A. balansae* Boiss. **(E)**	Nevşehir, Avanos Kayseri road	992	7.07.2012
40183	*A. sivasicum* N. Özhatay & Kollmann **(E)**	Sivas, 20 km from Sivas to Hafik		15.06.1978
87807	*A. djimilense* Boiss. ex Regel **(E)**	Trabzon, From Soğanlı Pass to Uzungöl	2245	19.08.2009
87674	*A. tauricola* Boiss. **(E)**	Kars, Boğatepe Province	2300	20.07.2008

size and maturity of the seeds, and their micromorphology was studied using an FEI Quanta 450 FEG-EDS scanning electron microscope (SEM) at Istanbul University. All measurements were performed using the image analysis systems KAMERAM and the Canon A 640 camera. Twelve characteristics were determined based on the seed surfaces of the examined *Allium* species (Table 2), and the codas used to evaluate the 12 identified characteristics are listed in Table 3. Cluster analysis was performed on these characteristics using Jaccard similarity analysis with PAST 1.81 (Hammer *et al*., 2001).

Results and Discussion

The seed surfaces of eight *Allium* species, four species from the Sect. *Codonoprasum* and four species from Sect. *Scorodon* were examined (Figs. 1, 2). The micromorphological characteristics of the seeds are summarized in Table 4. The testa epidermal cells were regular or irregular polygonal. The cellular arrangement was tight with cellular reticulate tissue. The anticline walls of seed testa epidermal cells were straight or straight to arched, the periclinal walls ranged from flat or concave to

Table 2. Data Matrix of *Allium* Seed Characteristics, Characteristics -states and their codings.

Cs	Characteristics	Characteristics-states and their codings	
C1	Seed shape	semicircle = 0	drop-shaped-semicircle = 1
C2	Epidermal cell shape	≤4 = 0	≥ 4 = 1
C3	Relief of intercellular space (cell boundary)	Reticulate tissue = 0	Not reticulate tissue = 1
C4	Periclinal wall (PW)	Flat = 0	Concave = 1
C5	Fine relief of the PW	Many small domes with dispersed verrucae = 0	Others = 1
C6	Diameter of verrucae on PW	Small to large = 0	Others = 1
C7	Number of verruca on PW	≥ 15 = 0	Others = 1
C8	Epidermal cell area (µm2)	≥ 750 µm2 = 0	≤ 750 µm2 = 1
C9	Intercellular space length (µm)	≥ 6 µm = 0	≤ 6 µm = 1
C10	Seed length (mm)	≥ 3 µm = 0	≤ 3 µm = 1
C11	Seed width (mm)	≥ 1.50 µm = 0	≤ 1.50 µm = 1
C12	Seed area (µm2)	≥ 5 µm = 0	≤ 5 µm = 1

Table 3. Seed Macro-Micromorphological data matrix for *Allium* based on scoring of Characteristics, Characteristics -states from Table 2.

Cs	*A. phrygium*	*A. pseudoflavum*	*A. flavum*	*A. staticiforme*	*A. balansae*	*A. sivasicum*	*A. djimilense*	*A. tauricola*
C1	0	0	0	0	1	1	1	1
C2	1	1	1	1	1	1	0	0
C3	1	0	0	0	1	1	1	1
C4	0	0	1	1	0	0	0	1
C5	0	0	1	1	0	1	1	0
C6	1	0	0	1	0	0	0	1
C7	0	0	1	1	1	1	1	0
C8	1	1	1	1	0	0	0	0
C9	0	1	1	0	1	1	0	1
C10	1	0	0	1	1	0	1	1
C11	1	0	0	0	1	0	1	1
C12	1	0	0	0	1	1	1	1

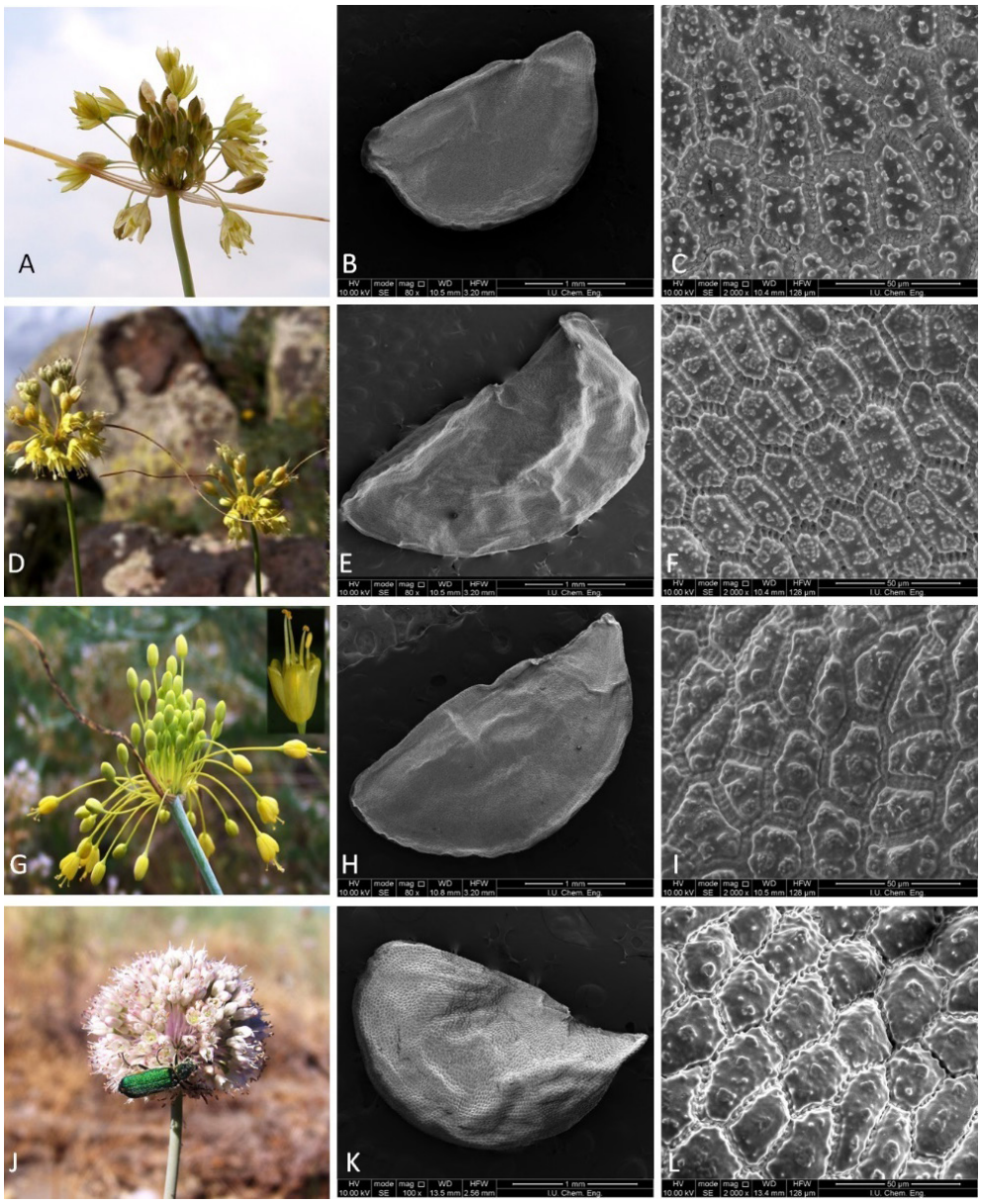

Figure 1. The examined *Allium* species from sect. *Codonoprasum: A. phrygium* (A, B, C), *A. pseudoflavum* (D, E, F), *A. flavum* (G, H, I), *A. staticiforme* (J, K, L).

various degrees, and there were verrucae and granulose on the epidermal cells. In *A. balansae*, no granules were observed in the periclinal walls. *Allium sivasicum* rarely exhibits an indistinct granular structure. The seed shapes of *Allium* species from the Sect. *Codonoprasum* were semicircular, the species from the Sect. *Scorodon* had slightly narrowed in the area where the seed attached to the placenta, and therefore, it was observed as a drop. While *A. sivasicum* has the longest seed length (3.85 mm), *A. phrygium* has the shortest seed length (2.53 mm). The widest seed was *A. staticiforme* (1.80 mm), while the narrowest seed was *A. tauricola* (1.25 mm).

In the Jaccard similarity analysis based on these data, the phenetic correlation value was calculated as 0.839. According to seed characteristics, two main branches formed in the similarity tree. In particular, the species in the Sect. *Scorodon* are grouped together. Although *A. phrygium* is described in Section *Codonoprasum* remains outside the main branch and is essentially located within its own section (Fig. 3).

Macro- and micro-morphological features have proven valuable for defining taxa (Choi & Oh, 2011; Lin & Tan, 2015; Namin *et al.,* 2009). In *Allium*, the micromorphological characteristics of the seed testa are particularly important for describing new taxa (Koçyiğit *et al.,* 2024). Our findings indicate that stable and distinct seed

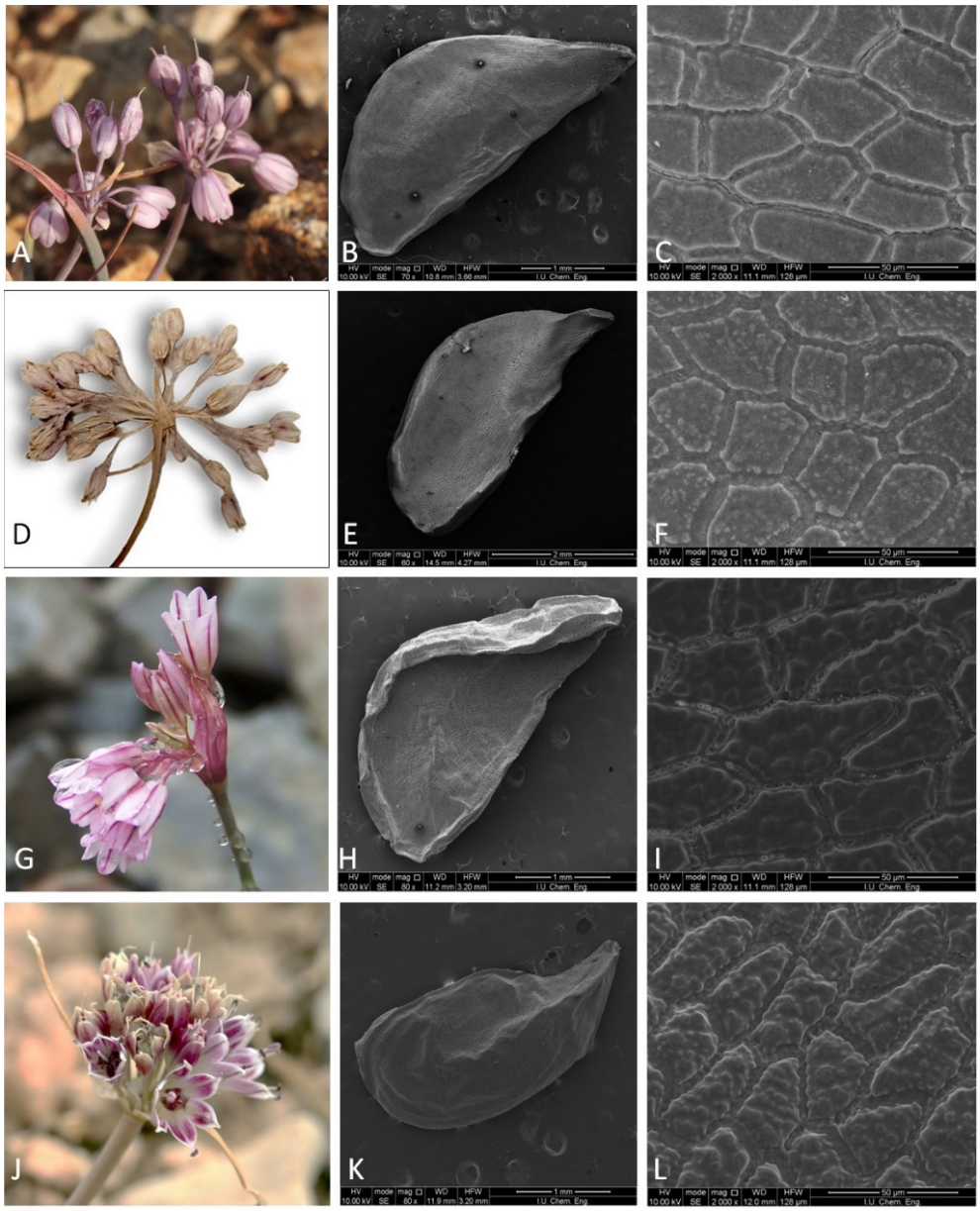

Figure 2. The examined *Allium* species from sect. *Scorodon: A. balansae* (A, B, C), *A. sivasicum* (D, E, F), *A. djimilense* (G, H, I), *A. tauricola* (J, K, L).

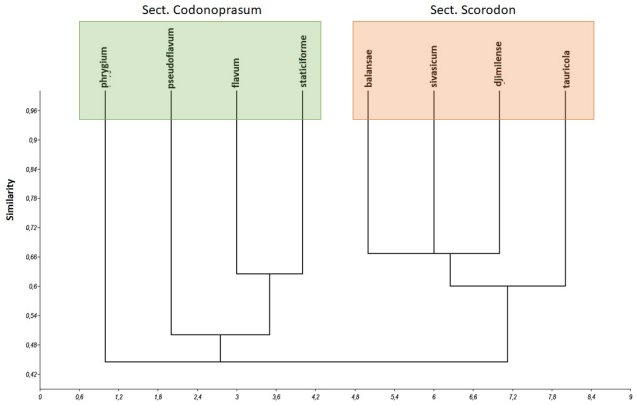

Figure 3. Cluster analysis of the considered *Allium* species, based on the Seed Macro-Micromorphological data matrix presented in Table 3.

micromorphological traits can effectively identify species and reflect taxonomic relationships and evolutionary stages. Thus, features such as testa curvature, anticlinal wall relief, and the microsculpture of outer periclinal walls are important for taxonomy in *Allium*. We propose that the cellular arrangement, presence, and nature of reticulated tissue, periclinal wall outline, and degree of verrucation are important for distinguishing between *Allium* subdivisions. Additionally, the characteristics of anticlinal walls, along with their size and density, are important for understanding species relationships. Therefore, seed coat micromorphological traits can be instrumental in species identification and taxonomy within *Allium*.

Table 4. Micromorphological characteristics of seed testa of eight species of *Allium* from Sections *Codonoprasum* and *Scorodon*.

	A. phrygium	*A. pseudoflavum*	*A. flavum*	*A. staticiforme*	*A. balansae*	*A. sivasicum*	*A. djimilense*	*A. tauricola*
Seed shape	Semicircle	Semicircle	Semicircle	Semicircle	Drop-shaped-semicircle	Drop-shaped-semicircle	Drop-shaped-semicircle	Drop-shaped-semicircle
Epidermal cell shape	Variably polygonal (4-5)	Variably polygonal (5-6)	Variably polygonal (4-5)	Variably polygonal (4-5)	Variably polygonal (4-5)	Variably polygonal (4-5)	Variably polygonal (3-5)	Variably polygonal (3-5)
Epidermal cell arrangement	Side-by-side	Side-by-side	Side-by-side	Side-by-side	Side-by-side	Side-by-side	Side-by-side	Side-by-side
Anticlinal wall	Straight to arched	Straight to arched	Straight to arched	Straight to arched	Straight to arched	Straight to arched	Straight to arched	Straight to arched
Relief of intercellular space (cell boundary)	Scabrate	Reticulate tissue with a broad mesh of connecting threads	Reticulate tissue with a broad mesh of connecting threads	Reticulate tissue with a broad mesh of connecting threads	Slightly scabrate	Slightly scabrate	Scabrate	Scabrate
Periclinal wall (PW)	Flat	Flat	Concave	Concave	Flat	Flat	Flat	Concave
Fine relief of the PW	Many small domes with dispersed verrucae	Many small domes with dispersed verrucae	One large central dome with central and marginal verrucae	One large central dome with central and marginal verrucae	Rare small dispersed verrucae	Many small dispersed verrucae	Dispersed same size verrucae without domes	Many small domes with dispersed verrucae
Diameter of verrucae on PW	Small to medium	Small to large	Small to large	Small to medium	Almost absent	Very small	Small	Small to large
Number of verrucae on PW	≥ 15	≥ 15	≤15	≤15	0	≤15	≤15	≥ 15
Epidermal cell area (μm^2)	66.63±13.4	741.22±11.2	724.68±17.3	659.82±10.62	893.79±15.8	1088.99±17.04	1392.90±14.3	765.03±11.41
Intercellular space length (μm)	8.27±3.4	5.33±6.7	6.26±6.5	5.12±4.7	6.35±5.4	7.4±3.8	5.12±5.1	6.18±2.4
Seed length (mm)	2.53±3.12	3.11±4.11	3.22±3.17	2.91±5.13	2.98±4.13	3.85±3.72	2.94±4.22	2.62±3.16
Seed width (mm)	1.47±2.52	1.72±3.32	1.69±4.72	1.80±4.62	1.39±3.86	1.67±4.22	1.41±3.42	1.25±4.72
Seed area (μm^2)	4.43±3.18	6.40±3.31	5.87±3.62	5.92±3.72	4.15±3.21	4.83±2.32	4.20±2.83	3.66±3.11

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Conflict of Interest: The authors have no conflict of interest to declare.

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

Iğdır İlinde Depolanmış Gıdalardaki Akar (Acari) Türleri Üzerine Araştırmalar

Seren Doğar [1], Neslihan Gültekin[1]

Öz

Amaç: Bu çalışma, Iğdır ilinde depolanmış gıdalarda bulunan akar türlerini tespit etmek, beslendiği gıda çeşitleri, morfolojik tanımları ve sistematik analizlerinin yapılması ve türlerin dijital fotoğraflarının hazırlanması amacıyla ele alınmıştır.

Materyal ve Yöntem: Depolanmış hububat, kuru baklagil, kurutulmuş meyve ve peynir numuneleri Berlese hunisine konulmuştur. Daha sonra stereomikroskop altında akarlar ayıklanmıştır. Genel akar vücutlarının makro teknikle fotoğraflanması için Atatürk Üniversitesi Biyoçeşitlilik Uygulama ve Araştırma Merkezi'nde bulunan upright mikroskoba (Zeiss Axio Imager A2) takılı yüksek çözünürlüklü dijital kamera (Canon 6D Mark 2 DSLR) ve yazılım programı (EOS Utility) kullanılmıştır. Çoklu çekim yapılan dijital fotoğraflar Adobe Photoshop CS 6.0 yazılımı kullanılarak birleştirilip PSD ve JPG formatında kaydedilmiştir.

Bulgular: Iğdır il merkezi dâhil Tuzluca, Karakoyunlu ve Aralık ilçelerinde depolanmış 29 çeşit gıda maddesinden, 10 familyaya ait ve 13 cinse bağlı *Acarus siro* Linnaeus, 1758, *Tyrophagus putrescentiae* (Schrank, 1781), *Tyrophagus perniciosus* Zachvatkin, 1941, *Tyroborus lini* Oudemans, 1924, *Lepidoglyphus destructor* (Schrank, 1781), *Carpoglyphus lactis* (Linnaeus, 1758), *Cheyletus eruditus* (Schrank, 1781), *Cheyletus malaccensis* Oudemans, 1903, *Tydeus interruptus* Thor, 1932, *Acarophenax tribolii* Newstead ve Duvall, 1918, *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997), *Pediculaster* sp., *Balaustium* aff. *xerothermicum* Gabrys, 2000 *Balaustium* aff. *unidentatum* (Tragardh, 1904), *Dermanyssus gallinae* (De Geer, 1778), *Proctolaelaps pomorum* (Oudemans, 1929), *Blattisocius dentriticus* (Berlese, 1918) ve *Blattisocius mali* (Oudemans, 1929), olmak üzere 18 tür tespit edilmiştir. Bunlardan *Tyrophagus putrescentiae*, %27,12 oranıyla en fazla saptanan tür olmuştur. Bunu %24,24 oranı ile *A. siro* ve %18,47 ile de *C. lactis* takip etmiştir. Diğer türler ise daha düşük oranda tespit edilmiştir.

Sonuç: 133 gıda örneğinden toplam 1386 birey akar ayıklanmıştır. Bu gıda maddelerinin akarla bulaşıklık oranı belirlenmiştir. Akarların tanıtımı ve teşhisinde önem arz eden morfolojik karakterleri yazılmış ve dijital fotoğraflar hazırlanmıştır. Ayrıca bu türlerin dünya ve Türkiye'deki yayılışları ve gıda maddelerinin çeşitliliği de verilmiştir.

Anahtar Kelimeler: Akar, depolanmış gıda, morfoloji, sistematik, Iğdır

Research on Mite (Acari) Species in Stored Foods in Iğdır Province

Abstract

Objective: The aim of this study was to identify the mite species found in stored foods in Iğdır province, the types of food they feed on, their morphological descriptions and systematic analysis, and to prepare digital photographs of the species.

Materials and Methods: Samples of stored grains, legumes, dried fruits and cheese were placed in the Berlese funnel. Then, mites were sorted under a stereomicroscope. A high-resolution digital camera (Canon 6D Mark 2 DSLR) and software program (EOS Utility) attached to an upright microscope (Zeiss Axio Imager A2) at Atatürk University Biodiversity Application and Research Center were used to photograph general mite bodies with macro technique. Multiple digital photos were combined using Adobe Photoshop CS 6.0 software and saved in PSD and JPG formats.

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Results: Eighteen mite species belonging to 10 families and 13 genera were identified from 29 kinds of foodstuffs stored in Iğdır city center and its districts; Tuzluca, Karakoyunlu and Aralık. The detected species are: *Acarus siro* Linnaeus, 1758, *Tyrophagus putrescentiae* (Schrank, 1781), *T. perniciosus* Zachvatkin, 1941, *Tyroborus lini* Oudemans, 1924, *Lepidoglyphus destructor* (Schrank, 1781), *Carpoglyphus lactis* (Linnaeus, 1758), *Cheyletus eruditus* (Schrank, 1781), *C. malaccensis* Oudemans, 1903, *Tydeus interruptus* Thor, 1932, *Acarophenax tribolii* Newstead & Duvall, 1918, *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997), *Pediculaster* sp., *Balaustium* aff. *xerothermicum* Gabrys, 2000, *Balaustium* aff. *unidentatum* (Tragardh, 1904), *Dermanyssus gallinae* (De Geer, 1778), *Proctolaelaps pomorum* (Oudemans, 1929), *Blattisocius dentriticus* (Berlese, 1918) and *B. mali* (Oudemans, 1929). *Tyrophagus putrescentiae* was the most frequently detected species with a rate of 27.12%. This was followed by *A. siro* with a rate of 24.24% and *C. lactis* with a rate of 18.47%, while other species were detected at a lesser rate.
Conclusion: A total of 1386 individual mites were extracted from 133 food samples. The rate of mite contamination of these foodstuffs has been determined. Morphological characters that are important for the identification and diagnosis of mites were written and digital photographs were prepared. In addition, the distribution of these species in the world, their distribution in Turkey and the diversity of foodstuffs are also given.
Keywords: Igdır, mite, morphology, stored food, systematics

Giriş

Depolanmış gıdaların tüketim aşamasına gelene kadar zararlı organizmalardan kaynaklanan ürün ve kalite kayıpları en az düzeyde olmalıdır. Genellikle depolanmış ürünlerde hayvansal kökenli organizmaların neden olduğu kayıplar yıllık ortalama %10 olarak bilinmektedir (Prewet, 1975). Zararlının bulaşma durumuna göre bu oran artabilir. Depolanmış gıdalara bulaşan zararlılar, bu gıdalarla beslenerek doğrudan veya dolaylı yollarla zarar verirler. Beslenme sonucu, ürünlerde ağırlık kaybı, tohumluk özelliğinin düşmesi, kalite ve besin değerlerinde olumsuz farklılıklar ürünün ticari değerini düşürür. Aynı zamanda, zararlıların salgılamış oldukları ağ ve benzeri maddeler, vücut kalıntıları ve dışkıları gıdanın kalite özelliklerini düşürür. Ayrıca zararlıların bulaşma oranı yoğun ise gıdada kızışma, kokuşma ve küflenme de görülebilir. Ülkemiz iklim özellikleriyle bu zararlıların gelişmesine olanak vermektedir. (Ferizli & Emekci, 2010).

Gıdalar üzerinde bahsedilen zararlara neden olan canlı gruplarından biri akarlardır. Akarlar genellikle gözle görülemeyecek kadar küçük olup, ancak mikroskop altında görülebilen canlılardır. Bu canlılar genellilkle 20-30°C sıcaklıkta ve %60-80 nemli ortamlarda yaşarlar. Ortamın ıslak ve nemli olmasını daha çok tercih ederler. Gıda akarları, yağ ve protein oranı yüksek olan gıdalara bulaşan akarlar olarak bilinmektedir. Hijyenik olmayan çevre koşulları ve uygun olmayan depolama yöntemleri ile depolanan gıdalarda akar bulaşması ve gelişmesi kaçınılmazdır. Çok küçük oldukları için akarların varlığını fark etmek zordur. Bu nedenle bazı ürünlerdeki zararları gözden kaçabilir. Depolanmış gıdalarda akarlarla bulaşıklık oranı belli bir düzeye geldiğinde, gıda tamamen elden çıkar veya pazar değerini kaybeder. Yeterince bilgisi olmayan esnaflarımız, bu bozuk gıdaları satışa sunarlar. Bu bulaşık gıdaların tüketilmesi ise insan sağlığı üzerinde bazı olumsuzluklara neden olur. Bunlar; astım, dermatit, idrar yolları rahatsızlıkları, sindirim sistemi hastalıkları, konjonktivit, sistemik anafilaksi ve çeşitli alerji reaksiyonlarıdır (Cevizci *vd*., 2010; Dizlek & Çakmak, 2017; Valbuza *vd*., 2020).

Türkiye'de yapılan ilk çalışmada arpalarda yaşayan akarların, kaşıntılara sebep olması ile insanlarda arpa uyuzu denilen cilt rahatsızlıklarını meydana getirdiği kaydedilmektedir (Özek & Behçet, 1924). Daha sonra bazı araştımacılar depolanmış gıdalarda akar varlığını tespit etmek için çeşitli araştırmalar yürürtmüştürler (Aygün *vd*., 2007; Cevizci *vd*., 2010; Çobanoğlu, 1996; Dizlek & Çakmak, 2017; Gültekin & Özkan, 1999; Kalay, 2016; Karadere & Karatepe, 2019; Karatepe *vd*., 2017; Özer *vd*., 1989). Yapılan bu çalışmaların incelenmesi ile ülkemizde toplam 47 gıda akar türünün mevcut olduğu ve en yoğun türün ise *Acarus siro* Linnaeus, 1758 olduğu tespit edilmiştir (Gültekin, 2022). Bu tür beslenme durumuna göre kozmopolittir (Hughes, 1976).

Iğdır ili için depolanmış gıdalardaki zararlılar ile ilgili çok az çalışma bulunmaktadır. Bunlardan biri Gültekin *vd*. (2019)'nın yapmış oldukları bir çalışmada, Iğdır il merkezinde kiler depolarında 11 böcek türünün beslendiğini tespit etmişlerdir. Fakat depolanmış gıdalarda akar ile ilgili herhangi bir çalışmaya rastlanmamıştır. Bu nedenle bu çalışma; Iğdır ilinde depolanmış gıdalarda bulunan akar türlerini tespit etmek, beslendiği gıda çeşitleri, morfolojik tanımları ve sistematik analizlerinin yapılması ayrıca türlerin dijital fotoğraflarının hazırlanması amacıyla ele alınmıştır.

Materyal ve Yöntem

Iğdır il merkezi, Tuzluca, Karakoyunlu ve Aralık ilçelerini temsil edecek şekilde evlerin kiler kısımlarından, marketlerin ambarından, değirmen ve fırınlardan depolanmış hububat, kuru baklagil, kurutulmuş meyve ve peynir numuneleri 200 g olacak şekilde polietilen torbalarla ayda bir olmak üzere 2020 yılının Mayıs-Kasım ayları arasında toplanmış ve örneklerin alındığı yerlere ait etiket bilgileri numune torbalarına eklenmiştir.

Iğdır Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü Entomoloji Laboratuvarına getirilen gıda numuneleri 25 cm çapındaki eleklere konulmuştur. Berlese hunisine yerleştirilen gıda numuneleri 72 saat süre ile 10 watt floresan lamba takılı ışık kaynağının altında bekletilmiştir. Işığın etkisi ve ısınmaya bağlı olarak nem oranının azalması ile ortamdan uzaklaşan akarlar, elekten geçip, hunilerin alt kısmına yerleştirilen ve içinde %70'lik etil alkol bulunan şişelerde toplanmıştır. Daha sonra şişeler petri kaplarına boşaltılarak, stereomikroskop altında damlalık ve iğneler yardımıyla içindeki akar ve böcekler ayıklanmıştır. Ayıklanan akar örnekleri gliserin damlatılan ve wax (mum) ile hazırlanmış lam üzerine alınmıştır. Lam ve lamel arasına alınan örnek elektrikli ocak üstünde ısıtılarak sabitleme yapılmıştır.

Genel akar vücutlarının makro teknikle fotoğraflanması için Atatürk Üniversitesi Biyoçeşitlilik Uygulama ve Araştırma Merkezi'nde bulunan upright mikroskoba (Zeiss Axio Imager A2) takılı yüksek çözünürlüklü DSLR dijital kamera (Canon 6D Mark 2) ve yazılım programı (EOS Utility) kullanılmıştır. Çoklu çekim yapılan dijital fotoğraflar Adobe Photoshop CS 6.0 yazılımı kullanılarak birleştirilip PSD ve JPG formatında kaydedilmiştir.

Fotoğrafların tamamı, çalışma materyalinden olup yazarlar tarafından çekilmiştir.

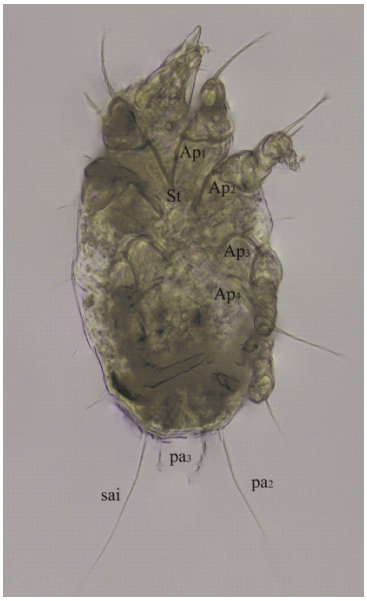
Atatürk Üniversitesi Biyoçeşitlilik Uygulama ve Araştırma Merkezi'nde yürütülen mikroskop çalışmasında morfolojik karakterler belirlenerek idiozoma ölçümleri yapılmıştır. Taksonomik tür teşhislerinde Gabrys (2000), Gabrys (2016), Hughes (1976) ve Ramaraju & Madanlar (1997) kaynaklarından yararlanılmıştır. Bu çalışmada kullanılan terminoloji ise Ayyıldız & Taşdemir (2019) tercih edilmiştir. Akarların teşhisleri literatüre dayalı olarak ikinci yazar tarafından yapılmıştır.

Kısaltmalar: Ap1-Ap4: Apodem, BC: Bursa copulatrix, Ch: Kelisera, E: Empodium, g: Genital, GF, Genital folder, GS: Genital duyu organları, Ps: Subracoxal seta, RS: Receptaculum seminis, St: Sternum

Bulgular ve Tartışma

Acari Altsınıfının Sistematikteki Yeri (Evans, 1992)

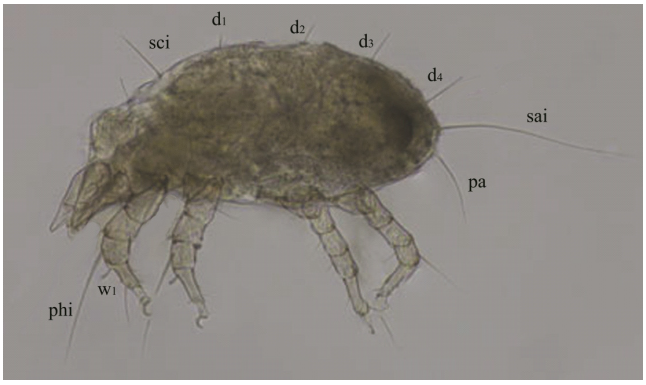
Alem: Animalia
Şube: Arthropoda
Altşube: Chelicerata
Sınıf: Arachnida
Altsınıf: Acari Leach, 1817
Üsttakım: Actinotrichida (Acariformes)
Üsttakım: Anactinotrichida (Parasitiformes)
Takım: Astigmata
Familya: Acaridae
Cins: *Acarus* Linnaeus, 1758
Tür: *Acarus siro* Linnaeus, 1758



Şekil 1. *Acarus siro* Linnaeus, 1758'da ergin erkek bireyin ventralden görünümü (×20)

Sinonim: *Acarus siro* var. *farinae* L., 1758; *Aleurobius farinae* var. *africana* Oudemans, 1906.

Erkek (Şek. 1): İncelenen örneklerin idiozoma uzunluğu 100 - 150 µm.



Şekil 2. *Acarus siro* Linnaeus, 1758'da ergin dişi bireyin lateralden görünümü (×20)

Şekil 3. *Acarus siro* Linnaeus, 1758'da ergin dişi bireyin dorsalden görünümü (×40)

Vücut renksiz ve posterior kenar düzgün bir şekilde yuvarlaktır. Keliser belirgin bir şekilde dişlidir; sabit parçanın tabanında mandibular bir diken ve bunun arkasında konik mahmuz benzeri bir çıkıntı bulunur.

Dorsal propodozomal plaka, *sc* (scapular) setalara kadar uzanan geniş bir plakadır. Seta *vi* (internal vertical) keliserin uçlarına kadar uzanır, *ve* (external vertical) setası ise oldukça kısa ve propodozomal plakanın yan

köşelerine yakın bölgede bulunur. Supracoxal seta tabanda geniş ve kalın taraksı yapıdadır. İdiozomada bulunan *sc* setaları enine bir sıra halinde dizilmiş olup; *sce* (external scapular), *sci* (internal scapular) setasından biraz daha kısadır. İdiozomal setalar ince ve bazıları seyrek taraksıdır, özellikle *vi* ve *sc* setaları uç kısımdan yarısına kadar taraksı görünür. Vücudun posterior kenarında iki çift, kısa ve uzun seta bulunur; bunlardan *sae* (external sacral) ve *pa3* setaları kısa, *sai* (internal sacral) ve *pa2* setaları ise uzun ve kavislidir (Şek. 1).

Ap_1 orta çizgide birleşerek kısa bir sternum oluştururken, Ap_2, Ap_3 ve Ap_4 serbesttir (Şek. 1). Genital açıklık, IV. coxa arasında olup aedeagus skleritleri posteriora doğru ayrılır ve aedeagus küt uçlu yay şeklinde bir boruya benzer. Anüsün posterior ucunun her iki yanında çiftleşme esnasında dişi bireyi tutma görevi gören bir çift modifiye seta bulunur.

Tüm bacaklar iyi gelişmiş bir pretarsus ve saplı tırnağa sahiptir. I. bacak tarsus segmentinin ucunda, *u* ve *v* dikenleri birleşerek büyük bir diken oluşturur. II., III. ve IV. bacak tarsusunda bulunan *s* dikeni ise büyüktür. I. ve II. bacak tarsusunda bulunan solenidiyon *w1* yaklaşık 45°C'lik açı ile eğik durur. Solenidiyon *w1* tabanda geniş olup, ortaya doğru tedricen daralıp, uca doğru hafif genişleyen şekildedir. Famulus kambur şeklindedir ve solenidiyon *w1*'in anteriordaki küçük bir çukurdan çıkar. Erkek bireylerde IV. bacak tarsus segmentindeki tutucu yapılar birbirlerinden çapları kadar uzak mesafede ve tibiaya olan mesafesi pretarsustan daha yakındır. I. bacaktaki genu ve femur belirgin şekilde genişlemiştir. Genu segmentinde bulunan, solenidiyon *σ1*, *σ2*' nin üç katından daha uzundur. Femurun ventral yüzeyindeki çıkıntıdan uzanan *vf* setasına sahip bir mahmuz bulunur.

Şekil 4. *Acarus siro* Linnaeus, 1758'da ergin dişi bireyin ventralden görünümü (×40)

Dişi (Şek. 2-4): İncelenen örneklerin idiozoma uzunluğu 150-225 µm.

Vücut erkek bireye göre daha oval ve posterior kenar terminalde bulunan bursa copulatrixe doğru hafifçe girintilidir. İdiozoma dorsal setalarının dizilimi erkek bireyle aynı, ancak setalar daha seyrek taraksı şeklindedir (Şek. 2).

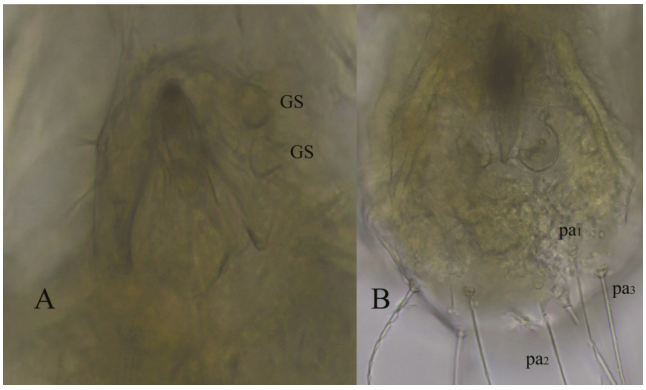
Genital açıklık, III. ve IV. coxa arasında bulunur. Anal açıklık beş çift anal seta ile çevrilidir. Bunlardan *a2* setası; *a1, a4* ve *a5*'in iki katı, *a3* ise neredeyse dört katı uzunluğundadır; *pa1* ve *pa2* (post anal setalar) vücudun posterior kenarının ilerisine doğru uzanır. Bursa copulatrix, çan şeklindeki bir yapıyı birleştiren dar, bir tüpe açılır.

I. bacak çifti diğer bacak çiftlerinden daha dar ve femur segmentinde mahmuz bulunmaz. I. bacak tarsus segmentinin, diken dizilimi *u* ve *v* dikenlerinin *s*'den küçük ve dar olması dışında, erkek bireyle aynıdır. Tüm bacaklarda *s* dikeni geriye doğru bir eğri şeklindedir.

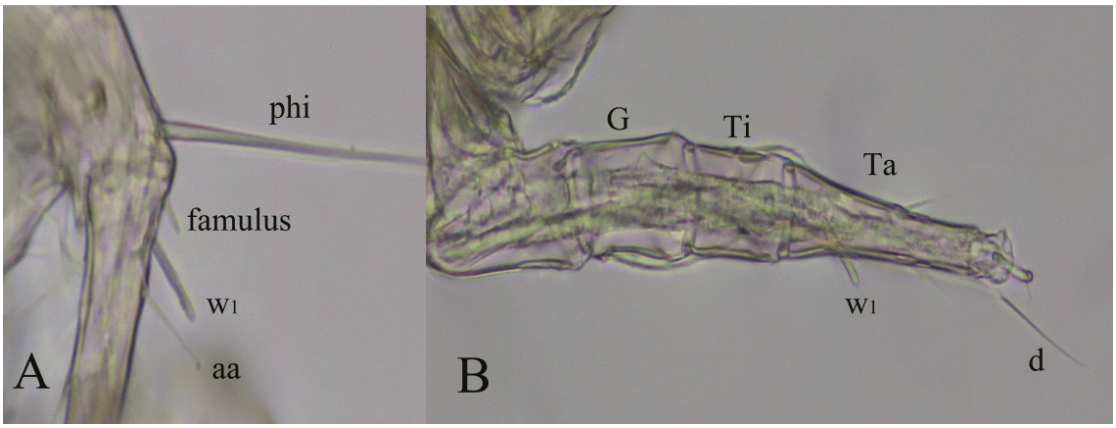
İncelenen Materyal: Mısır: Merkez, 12.11.2020, 2 ♀. Pirinç: Merkez, 27.05.2020, 3 ♀, 2 ♂. Mercimek: Merkez, 19.05.2020, 180 birey. İncir: Tuzluca, 05.07.2020, 1 ♀. Peynir: Karakoyunlu, 28.08.2020, 1 ♀. Un: Karakoyunlu, 26.05.2020, 12 ♀; Aralık, 22.10.2020, 80 birey. Nohut: Aralık, 14.11.2020, 5 ♀. Fasulye: Aralık, 17.05.2020, 50 birey.

Dünyadaki yayılışı: Kozmopolittir (Hughes, 1976).

Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999), Edirne (Çobanoğlu, 1996), Ankara (Tiğin & Özer, 1971), İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017), Niğde (Karatepe *vd*., 2017), Samsun (Kalay & Sullivan, 2013), Diyarbakır ve Şanlıurfa (Emekçi, 2001).

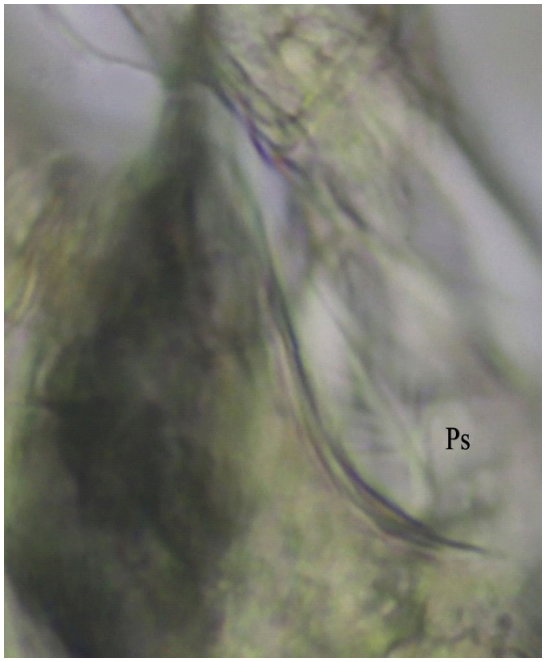


Şekil 5. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin erkek birey (×40); genital bölgesi ve aedeagus (A) ve anal bölgesi (B)



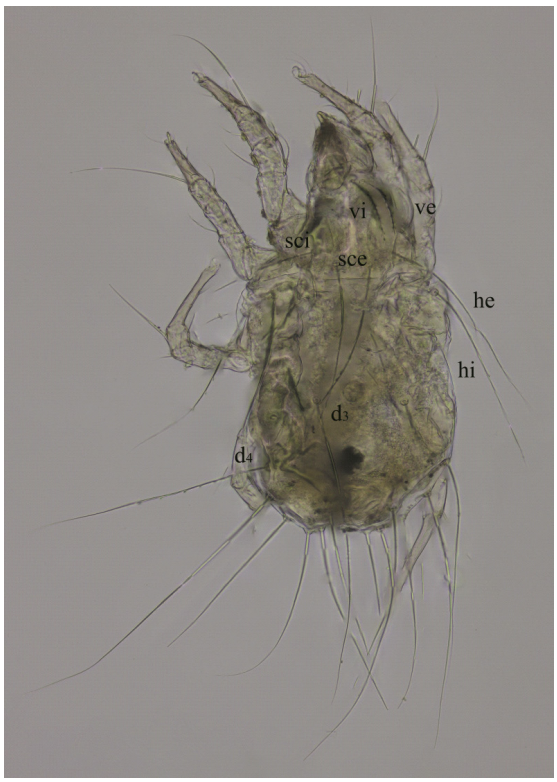
Şekil 6. *Tyrophagus putrescentiae* (Schrank, 1781)'da I. bacak görünümü (A-B) (×63- ×40)

Cins: *Tyrophagus* Oudemans, 1924
Tür: *Tyrophagus putrescentiae* (Schrank, 1781)
Sinonim: *Acarus putrescentiae* Schrank, 1781; *Tryophagus longior* var. *castellani* Hirst, 1912; *Tryophagus noxius* Zachvatkin, 1941; *Tryophagus brauni* E. & F.Türk, 1957.
Erkek (Şek. 5-9): İncelenen örneklerin idiozoma uzunluğu 125-150 µm.



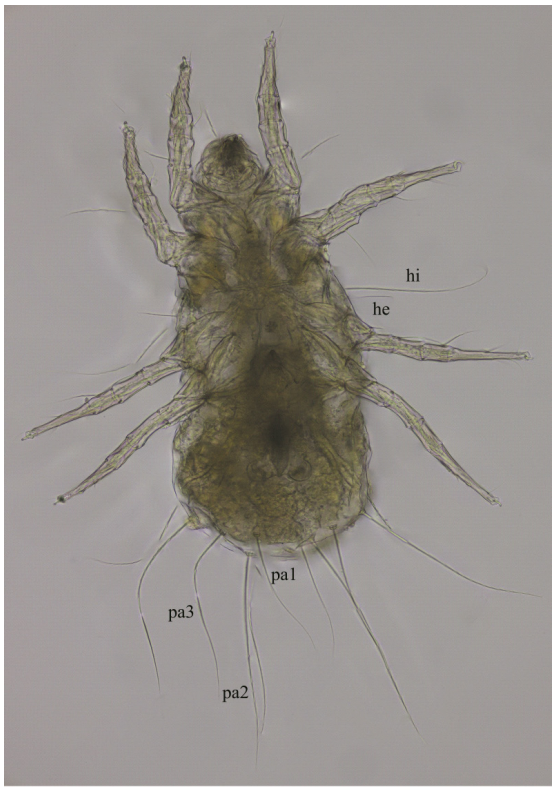
Şekil 7. *Tyrophagus putrescentiae* (Schrank, 1781)'da subracoxal seta görünümü (×63)

Vücutlarının koyulaşma derecesi gıdanın içeriğine göre pürüzsüz ve parlak kütikulu olan küçük bir türdür. Un üzerinde renksiz peynir üzerinde belirgin şekilde koyu renklidirler. Canlı iken vücut, diğer türlere göre daha yumuşak ve yüzeyinden çıkan uzun setalar da sert yapılı değildir (Hughes, 1976).



Şekil 8. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin erkek bireyin dorsal görünümü (×20)

Her bir keliser dişli ve mahmuz benzeri çıkıntılar taşır. Propodozomal plaka, koyulaşmaya bağlı olarak genellikle belirsiz ve düz bir posterior kenarla *sc* setalara kadar uzanır. Seta *vi*, keliserin uçlarından daha uzun ve diğer tüm uzun setalar gibi seyrek taraksı şeklindedir. Seta *ve*, *vi*'nin biraz arkasındadır. Seta *sc* propodozomadan, *sci* de *sce*'den daha uzundur (Şek. 8). Uzun ince bir noktaya uzanan yayılmış bir tabandan oluşum gösteren dik yatay uzantılara sahip subracoxal seta düz bir yapı oluşturmuştur (Şek. 7). İncelenen örneğe ve incelendiği açıya göre uzantıların uzunluğu ve tabanın genişliği değişkenlik gösterir. Biri çubuk şeklinde ve diğeri düzensiz bir hat

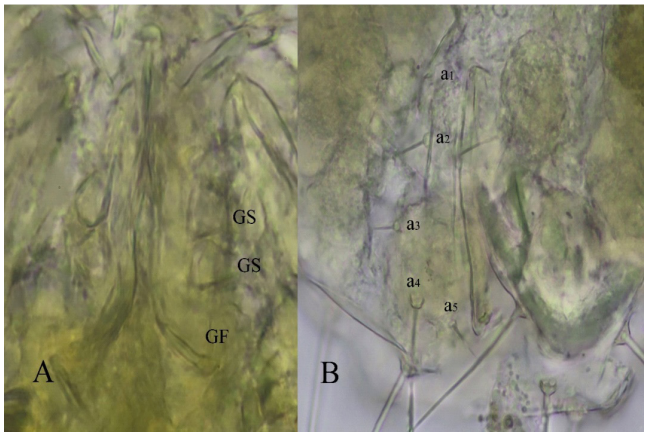


Şekil 9. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin erkek bireyin ventral görünümü (×20)

olmak üzere Grandjean organı iki temel dala sahiptir. Bu yapı *Tyrophagus*'un diğer türleri için de geçerlidir (Hughes, 1976).

Histerozomanın dorsal yüzeyinde yaklaşık aynı uzunlukta bulunan *d1* ve *la* setaları kısa, *d2* setası ise bu iki setadan daha uzundur. Seta *hi* (internal humeral), *he* (external humeral)'den daha uzun olup vücudun yanlarından dik açı yaparak çıkar (Şek. 9). Diğer setalar ise uzun ve birlikte yelpaze şeklinde bir silsile oluşturur.

Ap_1, düzensiz yapıya sahiptir. S şeklinde çift katlanma yapan ve kıyaslamalı bir şekilde kısa olan aedeagus, dışa



Şekil 10. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin dişi bireyin genital bölgesi (A) ve anal bölgesi (B) (×63)

Şekil 11. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin dişi birey dorsalden görünümü (×20)

Şekil 12. *Tyrophagus putrescentiae* (Schrank, 1781)'da ergin dişi birey ventral görünümü (×20)

dönük yanal skleritler tarafından desteklenir (Şek. 5A). Anüsün posterior tarafına doğru uzanan anal tutucu yapı

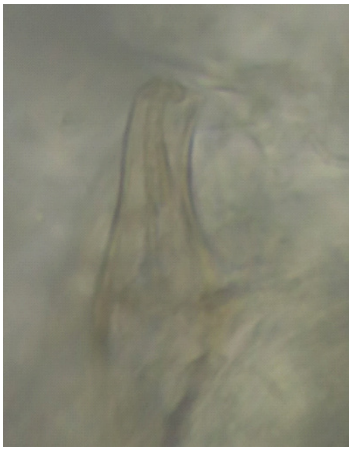
kubbe şeklindedir (Şek. 5B). Seta *pa1*; *pa2* ve *pa3*'ten kısa ve ince olup vücudun sonundan uzanır (Şek. 9). Vücut duruşu ve dorsal seta uzunlukları türler içerisinde değişiklik arz eder.

Bütün bacaklar uzun saplı bir tırnak ve çok iyi gelişmiş pretarsusla sonlanır. Tırnağın bittiği yerden ileriye uzanan solenidiyon *w3* ve *d*, seta *e*'den daha uzundur. İnce yapıda olan *p* ve *q* setaları tarafından desteklenen *u*, *s*, *v* dikenleri tarsusun önemli kısmıdır. I. bacak tarsus uzunluğu, genu ve tibianın toplam uzunluğundan daha kısadır (Şek. 6B). Bu tarsusdaki solenidiyon *w1* uca doğru hafifçe genişler ve famulusun yanından uzanır (Şek. 6A). Seta *aa*, solenidiyon *w1*'e oranla tırnağa daha yakın şekilde orijinlenmiştir. IV. bacak tarsusundaki iki tutucu yapı ise segmentin tabanından ve tepesinden eşit uzaklıkta bulunup tarsustaki *r* setasına yakın *w* setasına ise uzak konumlanmıştır. I. bacak genusundaki solenidiyon *σ1*, *σ2*'den uzundur.

Dişi (Şek. 10-12): İncelenen örneklerin idiozoma uzunluğu 200-425 µm.

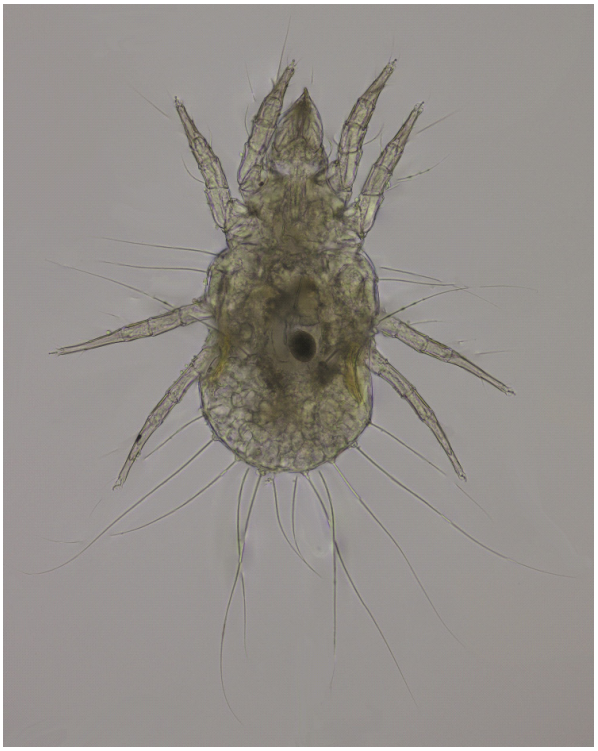
İdiozomanın şekli, setaların dizilimi ve uzunluğu erkek bireylere benzerdir. Anal açıklık vücudun posterior ucunda ve beş çift anal seta ile çevrilidir (Şek. 10B). Bu setalardan *a2* genellikle *a1*'den, *a4* de *a2*'den oldukça uzundur; *pa1* ve *pa2* setaları ise uzun olup bu seta dizisinin bir parçasını oluşturur.

İncelenen Materyal: Kuru incir: Merkez, 02.07.2020, 150 birey; Tuzluca, 16.11.2020, 1 ♀. Kaşar peynir: Merkez, 12.10.2020, 1 ♀; Merkez, 20.09.2020, 7 ♀; Merkez, 12.11.2020, 80 birey; Karakoyunlu, 28.08.2020, 2 ♀; Aralık, 09.10.2020, 11 ♀, 4 ♂; Aralık, 14.11.2020, 30 birey. Kuru kayısı: Merkez, 22.10.2020, 60 birey; Tuzluca, 16.09.2020, 5 ♀. Mısır: Merkez, 12.11.2020, 5 ♀. Nohut: Aralık, 14.11.2020, 6 ♀. Lepe (Nohut'un kırık hali): Aralık, 22.10.2020, 3 ♀. Un: Tuzluca, 16.09.2020, 2 ♀. Süzme peynir: Tuzluca, 16.09.2020, 3 ♂, 1 ♀. Fasulye: Tuzluca, 19.11.2020, 3 ♂; Karakoyunlu, 10.11.2020, 1 ♀. Kuru elma: Karakoyunlu, 13.10.2020, 1 ♂.



Şekil 13. *Tyrphagus perniciosus* Zachvatkin, 1941'da aedeagusun görünümü (×63)

Şekil 14. *Tyrphagus perniciosus* Zachvatkin, 1941'da I. çift bacak ve subracoxal setanın görünümü (×63)



Şekil 15. *Tyrphagus perniciosus* Zachvatkin, 1941'da ergin erkek bireyin dorsalden görünümü (×20)

Bu çalışmada, bu tür, Türkiye'de kaşar peynir, süzme peynir, nohut, fasulye ve kuru elmada ilk kez tespit edilmiştir.

Dünyadaki yayılışı: Kozmopolittir (Hughes, 1976).

Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999), Edirne (Çobanoğlu, 1996), İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017), Samsun (Kalay & Sullivan, 2013), Malatya (Çobanoğlu, 2008), Hatay (Aygün *vd*., 2007), Diyarbakır ve Şanlıurfa (Emekçi, 2001).

Tür: *Tyrophagus perniciosus* Zachvatkin, 1941

Erkek (Şek. 13-16): İncelenen örneklerin idiozoma uzunluğu 125-225 µm.

Subracoxal seta tedricen tabana doğru genişler. Taraksı yapıların uzunluğu tabandan uca doğru azalır (Şek. 14). Seta *d2*, *d1* setasından daha uzundur. Aedeagus; büyük, içe dönük kavisli ve uça doğru kesiktir (Şek. 13). Yanal skleritler tarafından desteklidir.

I. bacak tarsusunda, solenidiyon *w1* kalın ve uca doğru hafif genişler (Şek. 14). IV. bacak tarsusunda bulunan iki tutucu yapı, uca yakın olanı ventral yüzeyden çıkan setalarla hemen hemen aynı hizadadır.

Dişi (Şek. 17-18): İncelenen örneklerin idiozoma uzunluğu 250-325 µm. Dişi, erkek bireye benzer.

Şekil 16. *Tyrphagus perniciosus* Zachvatkin, 1941'da ergin erkek bireyin ventralden görünümü (×20)

Şekil 17. *Tyrphagus perniciosus* Zachvatkin, 1941'da ergin dişi bireyin dorsalden görünümü (×40)

Şekil 18. *Tyrphagus perniciosus* Zachvatkin, 1941'da ergin dişi bireyin ventralden görünümü (×40)

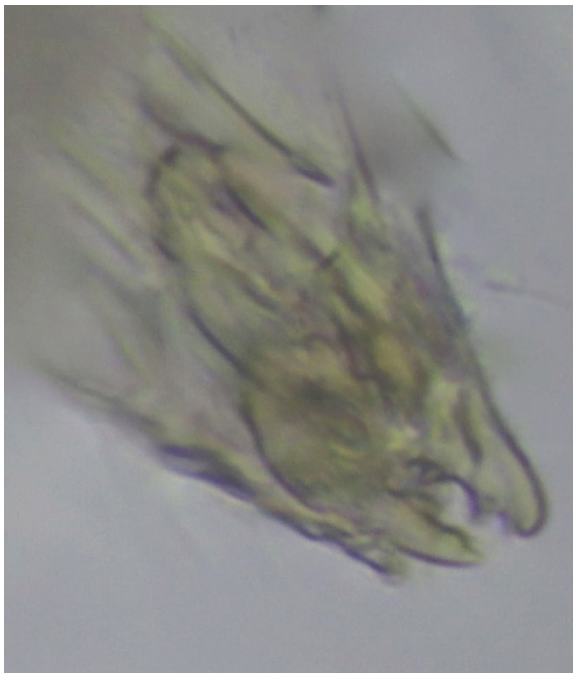
İncelenen Materyal: Buğday samanı: Merkez, 19.05.2020, 86 birey. Un: Merkez, 15.11.2020, 2 ♀, 2 ♂. Kuru kayısı: Merkez, 30.08.2020, 1 ♀. Fasulye: Merkez, 20.07.2020, 8 ♂, 3 ♀; Karakoyunlu, 25.06.2020, 3 ♀. Bulgur: Tuzluca, 16.09.2020, 3 ♀. Pirinç: Tuzluca, 20.08.2020, 8 ♀, 17 ♂.

Bu çalışmada, bu tür, Türkiye'de kuru kayısı, buğday samanı, fasulye, bulgur ve pirinçte ilk kez tespit edilmiştir.

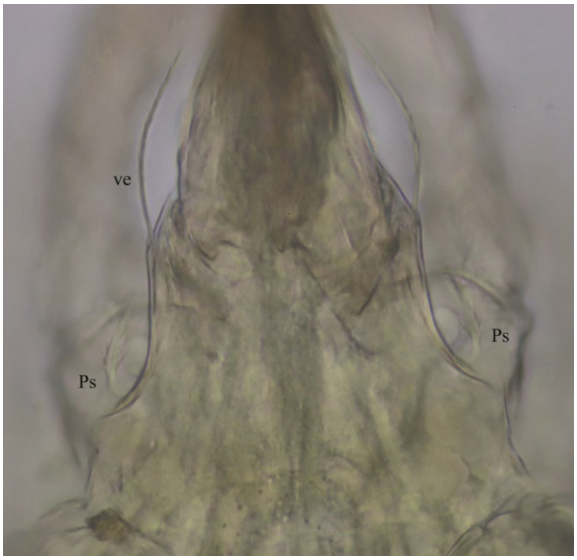
Dünyadaki yayılışı: İngiltere, Bulgaristan, SSCB, Avustralya (Hughes, 1976).

Türkiye'deki yayılışı: Samsun (Kalay & Sullivan, 2013).

Cins: *Tyroborus* Oudemans, 1924
Tür: *Tyroborus lini* Oudemans, 1924
Sinonim: *Tyrophagus lini* sensu Hughes, 1961.
Dişi (Şek. 19-23): İncelenen örneklerin idiozoma uzunluğu 125-250 µm.

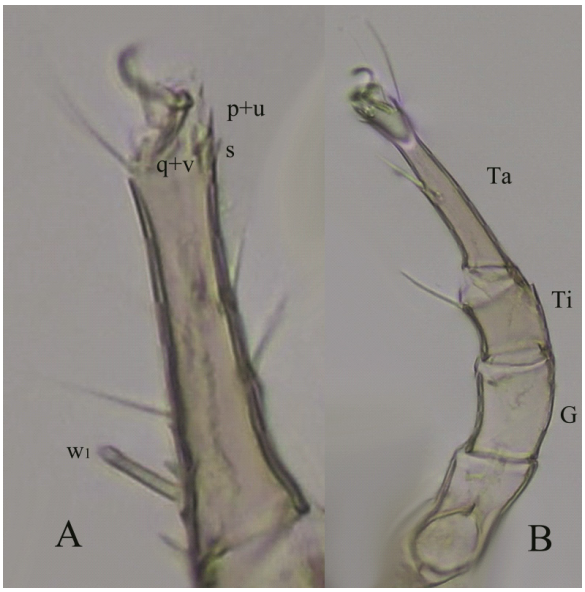


Şekil 19. *Tyroborus lini* Oudemans, 1924'de keliseranın görünümü (×63)

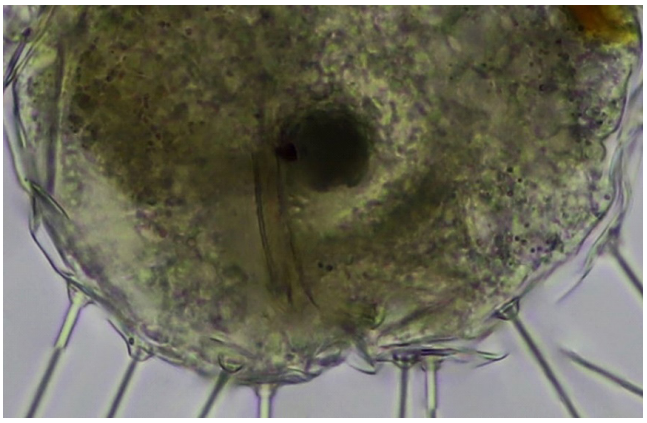


Şekil 20. *Tyroborus lini* Oudemans, 1924'de subracoxal setanın görünümü (×63)

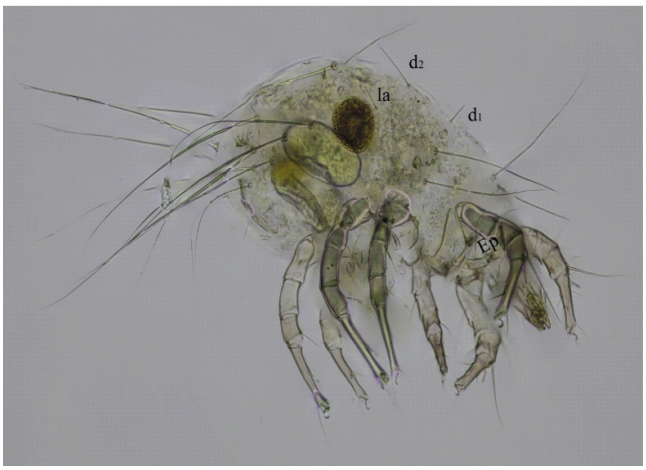
Keliser kalın ve iyi gelişmiş dişlere sahiptir (Şek. 19). Propodozomal plaka, hafifçe oluklu bir yüzeye sahip ve *sci* setasına kadar geriye uzanan beşgen şeklinde bir



Şekil 21. *Tyroborus lini* Oudemans, 1924'de I. bacak ve solenidiyon (×20) (A) ve IV. bacak (×20) (B)



Şekil 22. *Tyroborus lini* Oudemans, 1924'de dişi anal bölgesi (×20)



Şekil 23. *Tyroborus lini* Oudemans, 1924'de ergin dişi bireyin lateralden görünümü (×20)

yapıdır. Ventral yüzeydeki epimeral plakalar belirgin ve coxalsternal skleritlerden oluşur.

İdiozomal setalar, *Tyrophagus putrescenciae'*daki gibi dizilmiştir ancak uzun olan setalardan *ve* ve *vi* taraksıdır. Subracoxal seta tabanda geniş, büyük ve yan kenarları diken şeklindedir (Şek. 20). İdiozomanın dorsal yüzeyinde bulunan *d2* setası, *d1*'den dört kat daha uzundur. Kısa olan *d1*, *la* ve *hv* setaları ise eşit uzunluktadır (Şek. 23). Posteriordan uzanan setalar oldukça uzundur. Anüs, *Tyrophagus pucrescenciae*'ya göre vücudun posterior kenarından uzaktır (Şek. 22).

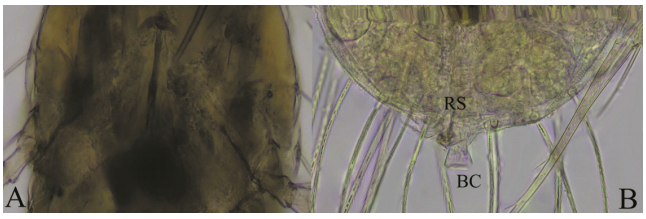
I ve II. bacak, tarsusundaki solenidiyon *w1*' in ucu sopa şeklindedir (Şek. 21A). Dorsal yüzeyde *e* dikeni ise genişlemiş bir seta gibi görünür. Tarsusun ventral yüzeyinden görünen *q+v*, *p+u* ve *s* olarak adlandırılan üç kalın diken mevcuttur (Şek. 21A). Bunlardan *q+ v* ve *p+ u* dikenleri *s*'den daha büyük ve kancalıdır. IV. bacak tarsus uzunluğu, tibia ve genunun toplam uzunluğundan daha kısadır (Şek. 21B). Tutucu yapılar ise tarsus segmentinin ortasında yer alır. Bacaklar oldukça kalındır.

Larva (Şek. 24): Subracoxal seta ergin bireye benzer. Ergin bireyden farklı olarak *sci* setası *sce*'den kısadır. Coxa silindir şeklindedir. Sakral setaların uzunluğu idiozoma uzunluğunun yarısından fazladır.

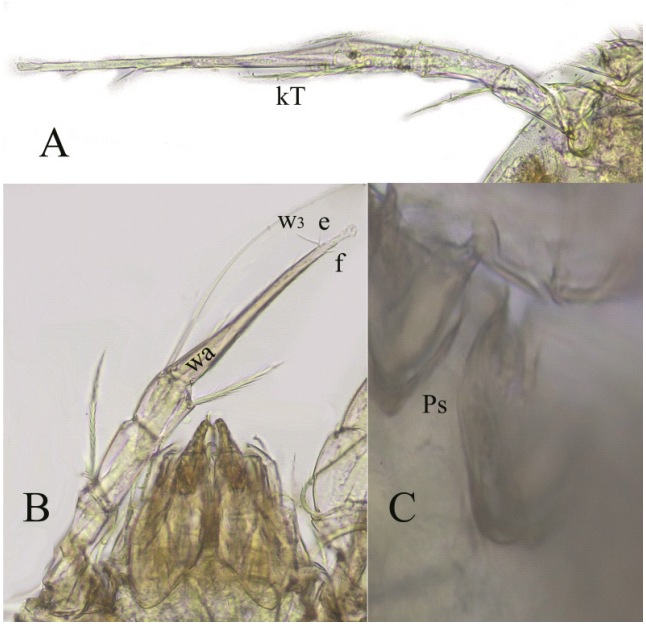
Şekil 24. *Tyroborus lini* Oudemans, 1924'de lateralden larva görünümü (×40)

İncelenen Materyal: Krem peynir: Merkez, 15.08.2020, 6 ♀. Kuru kayısı: Karakoyunlu, 27.11.2020, 6 ♀, 1 larva. Un: Karakoyunlu, 26.05.2020, 1 ♀; Aralık, 14.11.2020, 1 ♀. Bu çalışmada, bu tür, Türkiye'de krem peyniri, kuru kayısı ve unda ilk kez tespit edilmiştir.
Dünyadaki yayılışı: İngiltere, Yeni Zelanda, Türkiye ve Hollanda (Hughes, 1976).
Türkiye'deki yayılışı: İzmir (Özer *vd*., 1989).

Familya: Glycyphagidae Berlese, 1887
Cins: *Lepidoglyphus* Zachvatkin, 1936
Tür: *Lepidoglyphus destructor* (Schrank, 1781)
Sinonim: *Acarus destructor* Schrank,1781; *Acarus spinipes* Koch, 1841; *Glycyphagus anglicus* Hull, 1931; *Lepidoglyphus cadaverum* (Schrank, 1781) Türk ve Türk, 1957; *Glycyphagus destructor* (Schrank) Hughes, 1961.
Dişi (Şek. 25-28): İncelenen örneklerin idiozoma uzunluğu 400-475 µm.

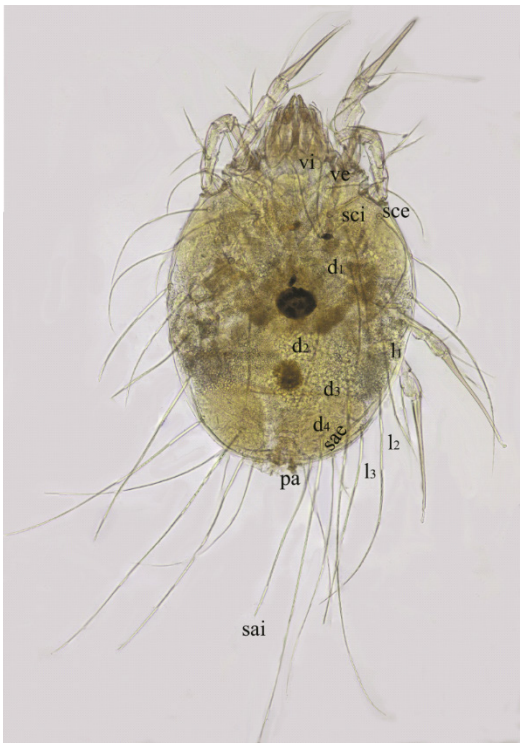


Şekil 25. *Lepidoglyphus destructor* (Schrank, 1781)'da ergin dişi bireyin genital bölgesi (×63) (A) ve bursa copulatrix (×63) (B)



Şekil 26. *Lepidoglyphus destructor* (Schrank, 1781)'da; ventralden IV. bacak (×20) (A), I.bacak ve kelisera (×40) (B) ve subracoxal seta (×63) (C)

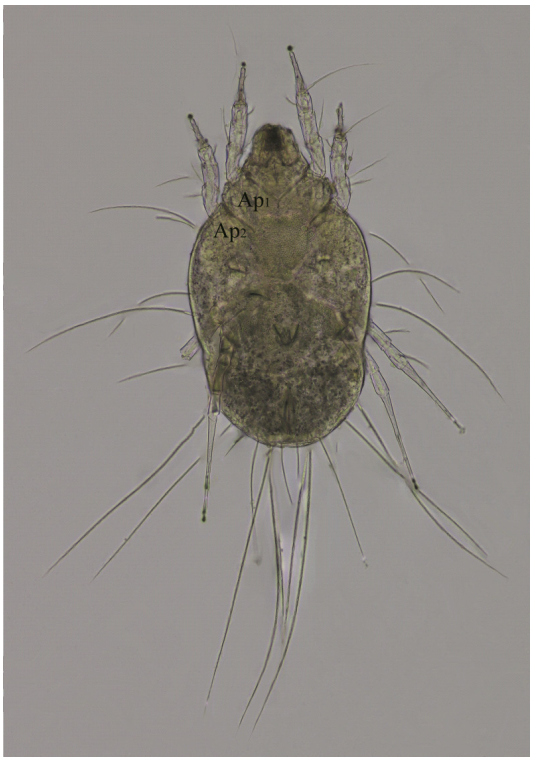
İdiozoma, uzun ve armut şeklindedir. Opistozoma, IV. çift bacaktan itibaren daralır. Kütikula, küçük papillalarla kaplı, mat ve beyazımsı renktedir. Dorsal yüzeydeki setalar, sert ve yoğun taraksı şeklindedir. Konum olarak *ve* setasının anteriorunda bulunan *vi* setası keliser ucundan ileriye uzanır (Şek. 27). Subracoxal seta çok dallanmış iki uçlu çubuk şeklindedir (Şek. 26C). II. çift bacak bölgesi ve idiozomanın anteriorunda bulunan *sc* setalar enine bir sıra halinde dizilmiştir. Seta *sci*'nin uzunluğu *vi* setası



Şekil 27. *Lepidoglyphus destructor* (Schrank, 1781)'da ergin dişi bireyin dorsalden görünümü (×10)

Şekil 29. *Lepidoglyphus destructor* (Schrank, 1781)'da hypopusun dorsalden görünümü (×20)

Şekil 28. *Lepidoglyphus destructor* (Schrank, 1781)'da ergin dişi bireyin ventralden görünümü (×10)



Şekil 30. *Lepidoglyphus destructor* (Schrank, 1781)'da hypopusun ventralden görünümü (×20)

ile aynı uzunluktadır. II. ve III. bacak arasında *hi* ve *he* setaları bulunur. Seta *d1*, *d2*'den uzun fakat vücudun

posterior kenarına kadar uzanmaz; seta *d2*'nin altında *d3* setası bulunur. Seta *d1* ve *d4* ise doğrusal hatta dizilir. Uzunlukları posteriora doğru artan üç çift lateral seta vardır. İdiozomadan çıkan en uzun setalar *d3*, *d4*, *l3* ve *sai*'dir (Şek. 27).

Ventral yüzeyde, Ap_1 birleşerek kısa bir sternum oluşturur. Ap_2 iyi gelişmiş, Ap_3 ve Ap_4 kısadır (Şek. 28). III. bacak coxa arasından uzanan ve anterior ucu üçgen şeklinde olan genitalya da üç çift seta bulunur (Şek. 25A). Bunlardan, iki çifti genitalyanın her iki tarafında, üçüncü çifti ise posterior kenarında bulunur. Anüs, vücudun posterior kenarına kadar uzanır ve iki çift setaya sahiptir. Bu setalar anüsün anterior ucunun her iki yanında yer alır. Dıştaki seta, içtekinden uzundur. Anüsün posteriorunda ise *sai*, *sae* ve üç çiftte *pa* setaları bulunur. Bu üç çift setanın bir çifti kısa ve düzdür. Bursa capulatrix, kenarı loblu, kısa bir tüptür (Şek. 25B).

Bacaklar pretarsus ve küçük bir tırnak ile sonlanır. III. ve IV. çift bacaklar uzun ve incedir. III. ve IV. bacak tibiasında bulunan *kT* setası ekleme ait zarın kenarından çıkmaz (Şek. 26A). Tarsuslar, tabandan itibaren taraksı yapıdaki *wa* (tarsal scale) ile kaplanmıştır (Şek. 26B). Pretarsusun taban kısmı; *d*, *e*, *f* setaları, üç küçük diken ve solenidiyon *w3* ile çevrilidir (Şek. 26B). Bunların arkasında *la*, *ba* ve *ra* setaları bulunur. Tarsusun tabanında bulunan solenidiyon *wl*, *w2* ve famulus birbirine yakın bir şekilde yükselir; *w2*'nin yarısından daha uzun olan *w1* eğimli bir çubuk şeklindedir. I. bacak genu ve tibiasının ventralinden görünen setalar taraksı şeklindedir. Genuda, *σ1* ve *σ2* bulunur; *σ2*'den dört kat daha kısa olan *σ1* uca doğru genişler.

Hipopus (Şek. 29-30): İncelenen örneklerin idiozoma uzunluğu 175-350 µm.

Hipopus inaktiftir. Ap_1 ve Ap_2 belirgin şekilde sklerotize olmamıştır. Genital açıklık IV. çift bacak arasındadır (Şek. 30). I., II. ve III. bacaklarda tırnak uzun, IV. bacakta ise kısadır. I. bacak tarsus tabanında uzun bir solenidiyon vardır.

İncelenen Materyal: Un: merkez, 15.08.2020, 1 ♀; Karakoyunlu, 26.06.2020, 1 ♀. Ceviz: Merkez, 09.11.2020, 45 ♀, 42 hypopus**.** Kuru kayısı: Karakoyunlu, 30.09.2020, 3 ♀. Kaşar peynir: Karakoyunlu, 26.06.2020, 1 ♀.

Bu çalışmada, bu tür, Türkiye'de kuru ceviz, kuru kayısı ve kaşar peynirde ilk kez tespit edilmiştir.

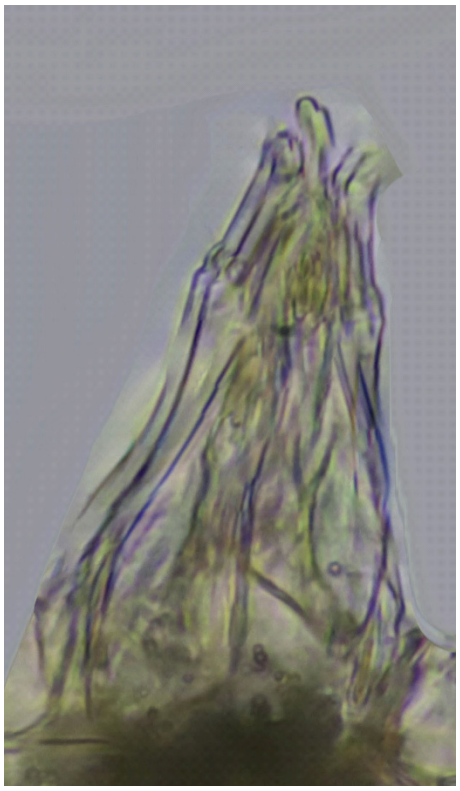
Dünyadaki yayılışı: Kozmopolittir (Hughes, 1976).

Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999), Edirne (Çobanoğlu, 1996), İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017), Samsun (Kalay & Sullivan, 2013), Diyarbakır ve Şanlıurfa (Emekçi, 2001).

Familya: Carpoglyphidae Oudemans, 1923
Cins: *Carpoglyphus* Robin, 1869
Tür: *Carpoglyphus lactis* (Linnaeus, 1758)

Sinonim: *Acarus lactis* Linnaeus, 1758; *Carpoglyphus passularum* Robin, 1869; *Glycyphagus anonymus* Haller, 1882.

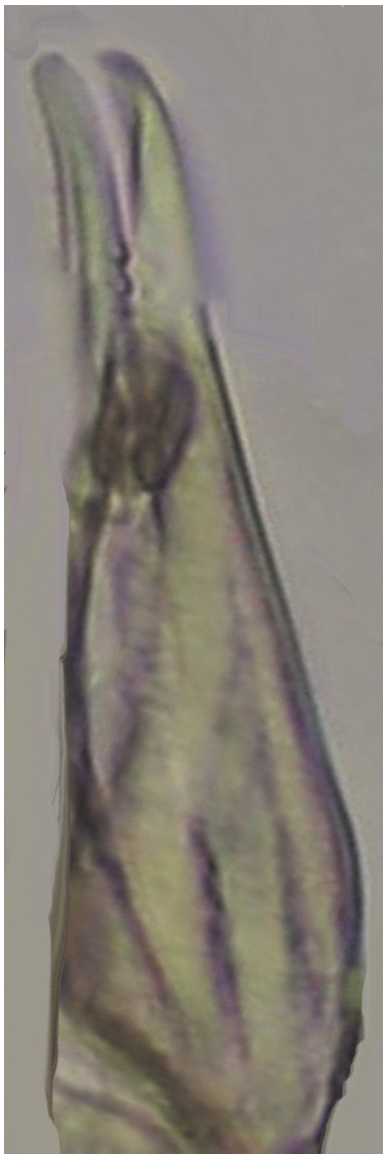
Erkek (Şek. 31-35): İncelenen örneklerin idiozoma uzunluğu 175-250 µm.



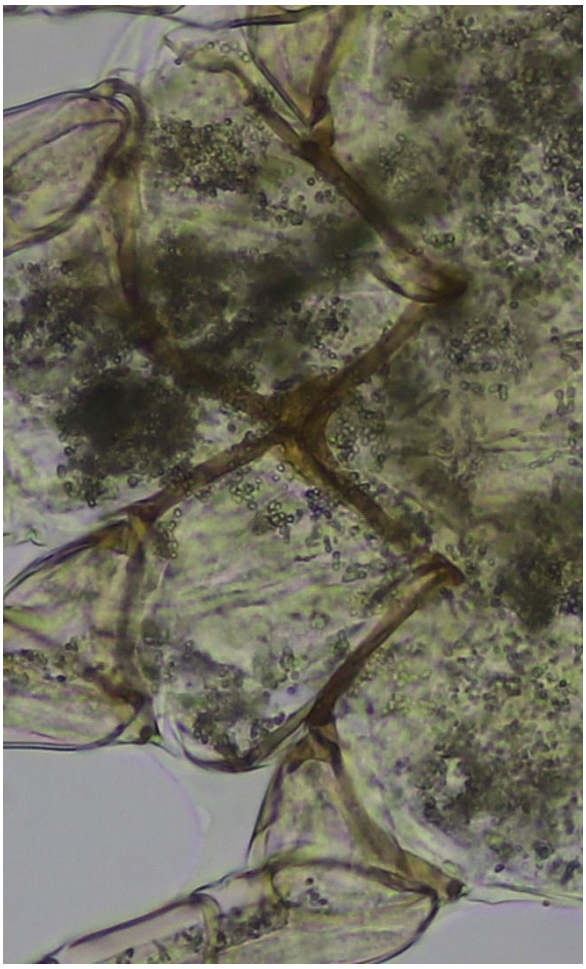
Şekil 31. *Carpoglyphus lactis* (Linnaeus, 1758)'de gnatozomanın görünümü (×63)

Sindirim borusunun içeriği ile renklenen idiozoma, yarı saydam kütikulalı, oval ve düzdür. Bacaklar ve gnatozoma hafif pembemsidir. Gnatozoma koni, keliser ise büyük makas şeklindedir (Şek. 31-32). İdiozomanın ön kenarı iyi gelişmiş posterior kenar ise kesik veya hafif içbükeydir. Propodozomal plaka yoktur. Propodozomada bulunan ve ile posteriordan uzanan iki çift seta hariç, bütün setalar kısadır. Seta *vi*, keliser ucuna kadar uzanmaz. Seta *ve* ise *vi* ile *sci* setalarının orta pozisyonunda yer alır. Subracoxal seta küt bir çubuk şeklindedir. İdiozomanın ortasından aşağıya doğru uzunlamasına iki sıra halinde sırasıyla *d1*, *d2*, *d3*, *d4* ve *sai* setaları dizilmiştir. İdiozomanın posteriorunda bulunan *pa1* ve *sae* setaları uzun ve iki çifttir (Şek. 35).

Ventral yüzeydeki apodemler ise iyi sklerotize olmuştur; Ap_1 orta kısımda birleşerek posterior ucunda çatallanan Ap_2



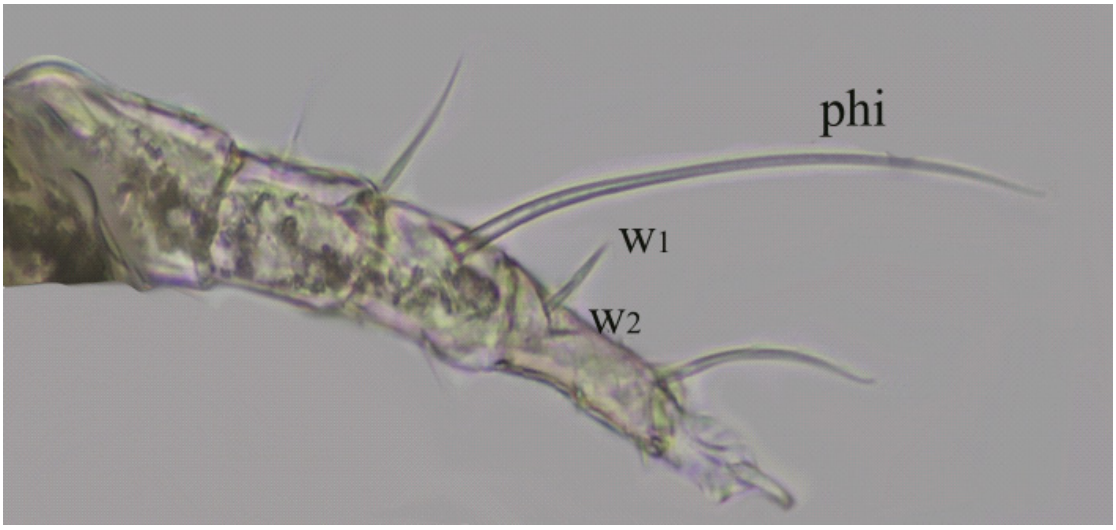
Şekil 32. *Carpoglyphus lactis* (Linnaeus, 1758)'de keliserin görünümü (×63)



Şekil 33. *Carpoglyphus lactis* (Linnaeus, 1758)'de coxasternalin görünümü (×63)

ile eklem yapmak üzere bir sternum oluşturmuştur (Şek. 33).

Genitalya, III. ve IV. bacak coxası arasında yer alır. Aedeagusun, ön ucu küt bir tüp şeklindedir. Eşit uzunlukta iki çift genital seta mevcuttur. Anüs, vücudun posterior



Şekil 34. *Carpoglyphus lactis* (Linnaeus, 1758)'de I. çift bacak (×63)

kenarına kadar uzanır. Bacaklar, tarsus ucundan tırnağa kadar uzanan orak şeklindeki iki ince 'tendon' tarafından kuvvetlendirilmiş pretarsus ile sonlanır. I. bacak tarsus segmentinin orta ve uçta bulunan bazı setaları diken şeklindedir. Solenidiyon *w1*, dıştan bükülmüş silindirik bir çubuk şeklindedir. Solenidiyon *w2* ile aynı tabandan çıkar. I. ve II. bacak tibia segmentinin orta hizasında solenidiyon *phi* mevcuttur (Şek. 34).

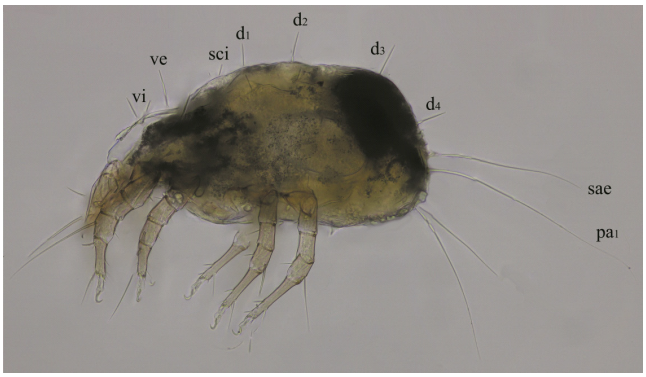
Dişi (Şek. 36-37): İncelenen örneklerin idiozoma uzunluğu 250 - 375 µm.

Dişi birey, erkek bireye benzemektedir. İdiozoma ventral yüzeyinde, sternum ve Ap_2 birleşmesiyle oluşan ve genital açıklığın anterior ucunu kaplayan bir epigynium oluşmuştur. II. ve III. coxanın arasına uzanan genital kıvrımlar sklerotize olmamıştır (Şek. 37). Sadece bir çift anal setası bulunan anal açıklık, idiozomanın posterior kenarına kadar uzanır. İdiozomanın dorsal posterioruna doğru olan bursa copulatrix yuvarlak bir açıklık şeklindedir. Bacaklar, erkek bireye göre daha ince bir pretarsusla sonlanır.

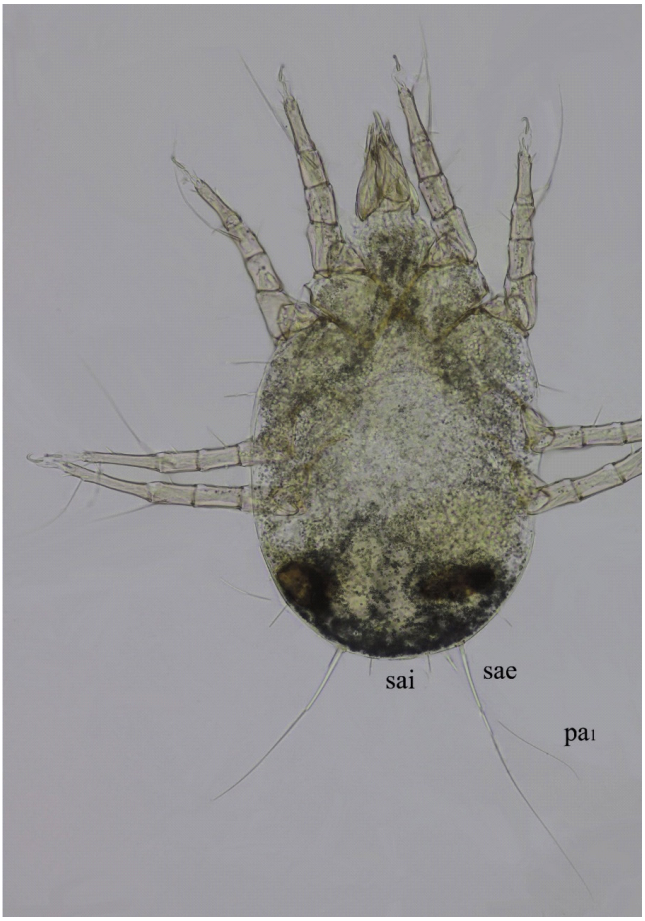
İncelenen Materyal: Un: Tuzluca, 27.05.2020, 20 ♀, 26 ♂. Kuru incir: Tuzluca, 16.08.2020, 9 ♂; Tuzluca, 27.05.2020, 200 birey. Pirinç: Karakoyunlu, 26.05.2020, 1 ♀.

Dünyadaki yayılışı: Avrupa, Kuzey Amerika, Arjantin (Hughes, 1976).

Türkiye'deki yayılışı: İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017), Malatya (Çobanoğlu, 2008) ve Elazığ (Çobanoğlu, 2008).



Şekil 36. *Carpoglyphus lactis* (Linnaeus, 1758)'de ergin dişi bireyin lateralden görünümü (×20)

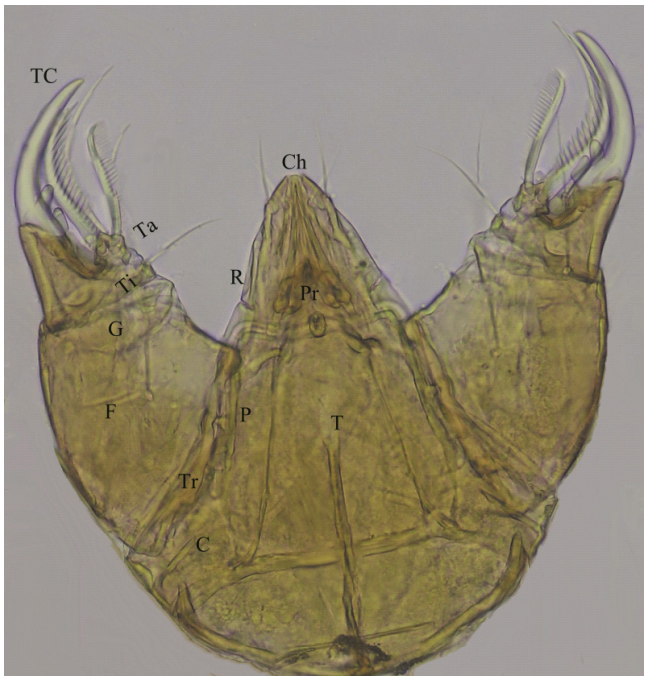


Şekil 35. *Carpoglyphus lactis* (Linnaeus, 1758)'de ergin dişi bireyin dorsalden görünümü (×20)

Şekil 37. *Carpoglyphus lactis* (Linnaeus, 1758)'de ergin dişi bireyin ventralden görünümü (×20)

Takım: Prostigmata
Familya: Cheyletidae Leach, 1815
Cins: *Cheyletus* Latereille, 1796
Tür: *Cheyletus eruditus* (Schrank, 1781)
Sinonim: *Eutarsus cancriformis* Hessling, 1852; *Cheyletus eburneus* Hardy, 1867; *Cheyletus ferox* Banks, 1906; *Cheyletus rabiosus* Rohdendorf, 1940; *Cheyletus butleri* Hughes, 1948.

Dişi (Şek. 38-41): İncelenen örneklerin idiozoma uzunluğu 400-600 µm'dir.



Şekil 38. *Cheyletus eruditus* (Schrank, 1781)'da gnatozomanın görünümü (×40)

Şekil 39. *Cheyletus eruditus* (Schrank, 1781)'da I. bacak (×40)

Şekil 40. *Cheyletus eruditus* (Schrank, 1781)'da ergin dişi bireyin dorsalden görünümü (×20)

Şekil 41. *Cheyletus eruditus* (Schrank, 1781)'da ergin dişi bireyin ventralden görünümü (×20)

Gnatozoma uzun ve dardır. Tegmen, tabanında bulunan katlanmalarla belirginleşir. Peritrem (P), iç bölmeli orta düzlemden lateral uzantılara sahip m harfine benzer şekildedir. Pedipalp tarsus segmentinin üzerindeki taraksı setalardan dıştaki 13-14 güçlü dişe, içteki ise 16 dişe sahiptir. Tibial tırnağın (TC) tabanında genellikle iki belirgin diş vardır. Pedipalp femur segmentinin dış kenarı orta derecede dışbükeydir. Femurun dorsal setası uzundur (Şek. 38).

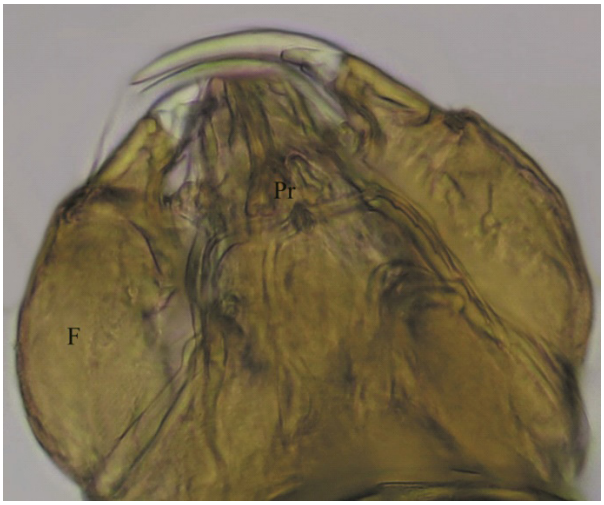
İdiozoma renksiz ve elmas şeklindedir. Propodozomal plakanın anterior kenarı, posterior kenardan daha kısadır ve dört çift taraksı marjinal seta (*R*) mevcuttur. Histerozomal plaka daha dar ve propodozomal plakadan görünür uzaklıktadır. Bir çift scapular setaya sahiptir. Sternal plaka yoktur (Şek. 40).

I.çift bacak normal uzunluktadır. Solenidiyon *w*, bacak tarsusunun dış kenarındaki tümsekten çıkar ve tabanına doğru genişlemez. Oldukça kısa olan *SS* (destek) setası solenidiyon *w*'nin tabanından çıkar (Şek. 39). Solenidiyon *w*, ventralden II. bacak tarsus segmentinin orta hizasında görünür. Solenidiyon, tibia ve genuda da mevcuttur. IV. bacak femurunda ise iki seta bulunur.

Erkek (Şek. 42-44): İncelenen örneğin idiozoma uzunluğu 350-375 µm.

Gnatozoma dişi bireye göre daha geniştir. Protegmen (Pr) uzunlamasına çıkıntılı ve birkaç tüberkül taşır. Tegmen (T) uzunlamasına çizgilidir. Pedipalp tarsus segmentindeki taraksı setaların dışta olanı 8 güçlü dişe, içte olanı ise 6 dişe sahiptir. Tibia segmenti genellikle tabanında iki dişe sahiptir (Şek. 42).

Propodozomal plaka, iki çift merkezi (*CS*) seta ve dört çift periferik (*PF*) setaya sahiptir. Setalar iğne şeklinde ve taraksı yapıdadır (Şek. 43). Histerozomal plaka, vücudun



Şekil 42. *Cheyletus eruditus* (Schrank, 1781)'da gnatozoma (×40)

Şekil 43. *Cheyletus eruditus* (Schrank, 1781)'da ergin erkek bireyin dorsalden görünümü (×20)

Şekil 44. *Cheyletus eruditus* (Schrank, 1781)'da ergin erkek bireyin ventralden görünümü (×20)

posterior kenarına uzanır ve altı çift periferik seta taşır. Genital açıklık posterior uçta ve aedeagus hafifçe kavislidir. Her iki tarafında da üç çift küçük diken vardır.

Tüm bacaklarda bulunan ambulacrum dişi bireye benzer. I. bacak tarsustaki solenidiyon, uca doğru incelmiş bir şekilde olup pedicelin tabanına kadar uzanır.

İncelenen Materyal: Buğday danesi; Merkez, 19.05.2020, 30 birey.

Dünyadaki yayılışı: Kozmopolittir (Hughes, 1976).

Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999), Edirne (Çobanoğlu, 1996), İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017) ve Samsun (Kalay & Sullivan, 2013).

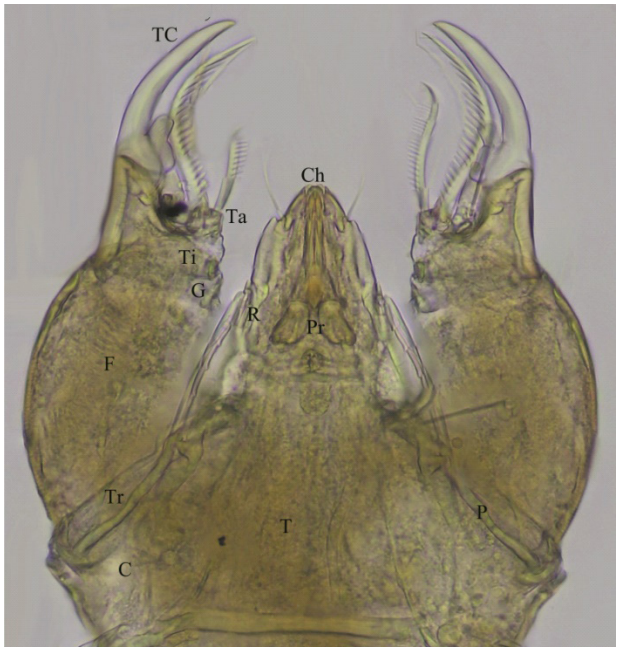
Tür: *Cheyletus malaccensis* Oudemans, 1903

Sinonim: *Cheyletus munroi* Hughes, 1948.

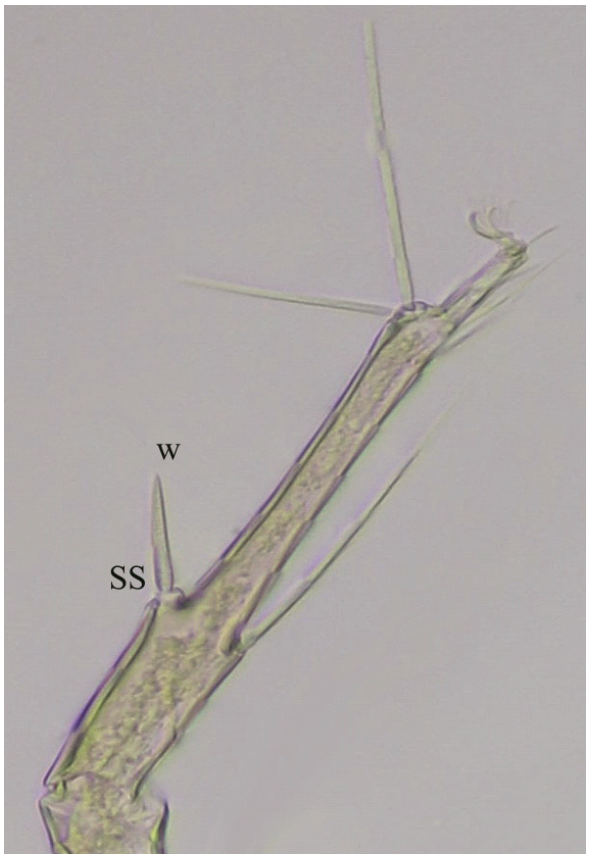
Dişi (Şek. 45-48): İncelenen örneklerin idiozoma uzunluğu 375-500 µm.

Tegmenin dorsal yüzeyi ince çizgilidir. Enine peritrem m harfi şeklindedir. Yanal kollar merkez bölge ile dar bir açı oluşturur. Peritremin orta düzlemi ve yanal kolları içinde beş bölüm mevcuttur. Pedipalp tarsus segmentinde olan taraksı setalardan içteki oldukça düz ve 24 ince dişe, dıştaki seta ise 18 dişe sahiptir. Tibial tırnağık tabanında, çift loblu bir diş mevcuttur (Şek. 45).

Düz ve taraksı olan seta dizilişi ve dorsal plaka şekli *Cheyletus eruditus*'a benzer. I. bacak tarsusunda bulunan solenidiyon *w* tabanda şişkin olup, kısa olan *SS* seta ile aynı hattan çıkar (Şek. 46).



Şekil 45. *Cheyletus malaccensis* Oudemans, 1903'de gnatozoma (×40)



Şekil 46. *Cheyletus malaccensis* Oudemans, 1903'de I. bacakda tarsus segmenti (×40)

Şekil 47. *Cheyletus malaccensis* Oudemans, 1903'de ergin dişi bireyin dorsalden görünümü (×20)

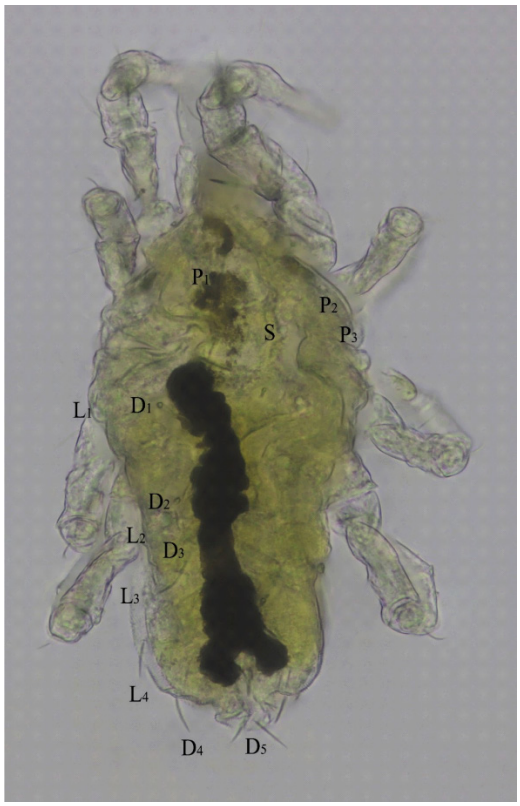
Şekil 48. *Cheyletus malaccensis* Oudemans, 1903'de ergin dişi bireyin ventralden görünümü (×20)

İncelenen Materyal: Mısır: Aralık, 23.09.2020, 15 ♀.
Dünyadaki yayılışı: İngiltere, Portekiz, Polonya, Çekoslovakya, Almanya, İran, Türkiye, ABD, SSCB ve Avustralya (Hughes, 1976).
Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999), İzmir (Özer *vd*., 1989) ve Samsun (Kalay & Sullivan, 2013).

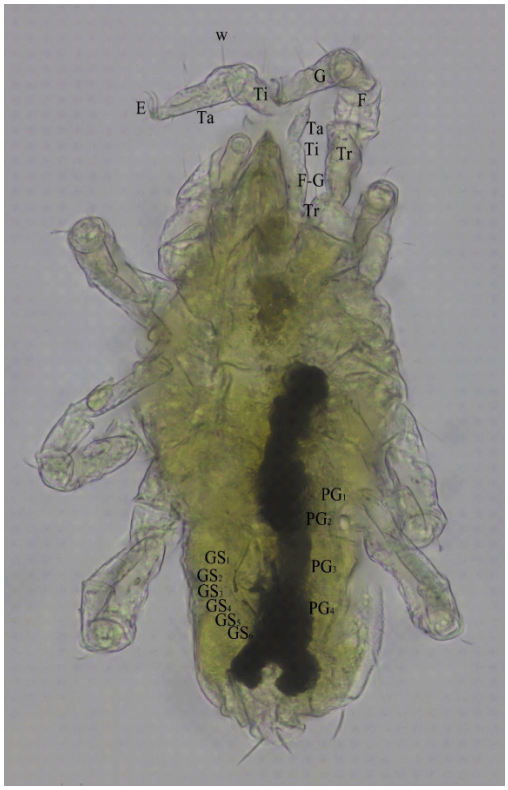
Familya: Tydeidae Kramer, 1877
Cins: *Tydeus* Koch, 1835
Tür: *Tydeus interruptus* Thor, 1932
Dişi (Şek. 49-50): İncelenen örneğin idiozoma uzunluğu 175 - 200 µm.

Gnatozoma kısa ve geniştir. Ventralden tepe noktası iki loblu görünür. Pedipalp tarsus segmentinin, uç kısmında beş seta ve tarsus segment tabanından çıkan küçük bir solenidiyon mevcuttur. Palp tibia ve birleşmiş yapıdaki femur-genu segmentlerinde ise birer çift seta bulunur.

İdiozoma elmas şeklinde ve sarımsı renktedir. Kütikula, buruşuk ve eşit aralıklı tüberküllerin oluşturduğu çizgilerden oluşur.



Şekil 49. *Tydeus interruptus* Thor, 1932'da ergin dişi bireyin dorsalden görünümü (×40)



Şekil 50. *Tydeus interruptus* Thor, 1932'da ergin dişi bireyin ventralden görünümü (×40)

Propodozoma, orta dorsal çizgide dar enine bir oluk ile histerozomadan ayrılır. Propodozomada, üç çift *P1*, *P2*, *P3* duyu setaları ve psödostigmataya yerleşmiş daha uzun bir çift dorsal *S* setası mevcuttur. Histerozomanın dorsalinde (*D*) beş çift, lateralinde (*L*) ise dört çift seta bulunur (Şek. 49). Genital açıklıkta, altı çift genital (*GS*) ve dört çiftte daha uzun paragenital (*PG*) seta bulunur. Anüsün yanlarında bir çift seta bulunur (Şek. 50).

Bacaklar ince ve uzundur. Her bacak çifti bir çift tırnak ve bir empodium ile sonlanır (Şek. 50). I. bacak tarsus segmentinin dorsal kenarındaki bir tümsekten uzunluğu eşit olmayan iki seta çıkar. Ayrıca aynı segmentin ucunda bu setalara uzak olan iki ek seta ve üç kısa seta mevcuttur. Tibia, genu ve femur segmentlerinde üçer, trochanterde ise bir seta bulunur.

İncelenen Materyal: Kuru incir: Merkez, 13.05.2020, 1♀. Un: Merkez, 22.10.2020, 1♀. Kuru kayısı: Aralık, 25.06.2020, 1♀.

Bu çalışmada, bu tür, Türkiye'de kuru incir, un ve kuru kayısıda ilk kez tespit edilmiştir.

Dünyadaki yayılışı: İngiltere, Norveç (Hughes, 1976).

Türkiye'deki yayılışı: Anadolu (Kalpaklıoğlu *vd*., 1997).

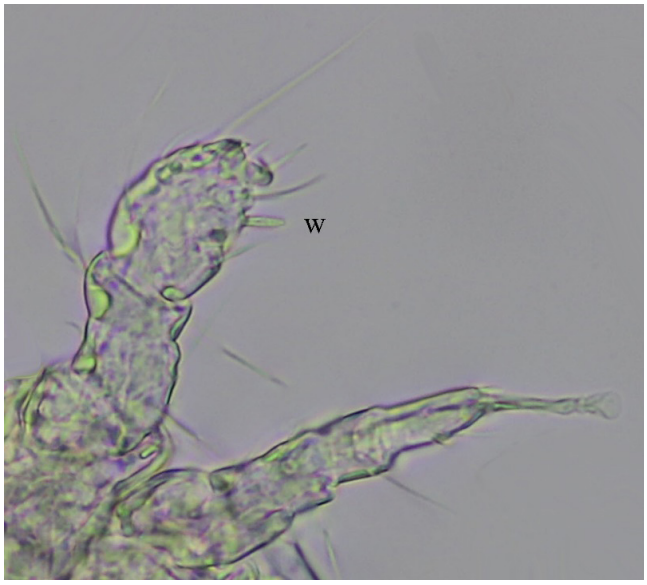
Familya: Pyemotidae Oudemans, 1937

Cins: *Acarophenax* Newstead & Duvall, 1918

Tür: *Acarophenax tribollii* Newstead & Duvall, 1918

Dişi: (Şek. 51-53): İncelenen örneklerin idiozoma uzunluğu 160-190 µm.

Gnatozoma çok küçük ve propodozoma ile tamamen kaplıdır. Ağız parçaları iki stilet şeklindeki kelisera ve yeterince gelişmemiş palplardan oluşur. Sarı renkli olan



Şekil 51. *Acarophenax tribolii* Newstead & Duvall, 1918'de ventralden I. ve II. bacak görünümü (×63)

Şekil 52. *Acarophenax tribollii* Newstead & Duvall, 1918'de ergin dişi bireyin dorsalden görünümü (×40)

Şekil 53. *Acarophenax tribollii* Newstead & Duvall, 1918'de ergin dişi bireyin ventralden görünümü (×40)

idiozoma yuvarlak ve kavislidir. Posterior uca doğru hafifçe daralan yapıdadır. Dorsal yüzeyde propodozomadan iki çift *sc* seta ve histerozoma'yı kaplayan her bir tergitten de bir çift dorsal seta çıkar. Histerozoma dorsalde dört tergit ile

kaplıdır. Birinci histerozomal tergitin lateral kenarında bir çift uzun *h* setası bulunur (Şek. 52). Opistozomada iki çift kısa seta mevcuttur. Ventral yüzeyde propodozomanın anterior kenarı, gnatozoma tabanını çevreleyen ve uzun sternumu birleştiren kalınlaşmış bir kütikula yaka tarafından desteklenir. Posteriorda, bu sternum çatallanır ve ep_2 (epimerit) ile birleşir. Ap_2 sternuma ulaşmaz. Ap_3 ve Ap_4 ise ileriye doğru eğik biçimdedir (Şek. 53). Coxal setalar, coxa I ve II'de yerleşmiştir. Coxal setaların dışında dört çift seta daha vardır. Bunlardan ilk iki çifti ep_2-Ap_3 ve diğer iki çifti ise Ap_3-Ap_4 arasında konumlanmıştır. Ayrıca genital açıklığın her iki tarafında da bir genital seta bulunur. İlk iki çift bacak, posterior çiftlerden geniş ölçüde ayrılır. I. çift bacak, düzensiz kalınlaşmış duvarları ile sadece dört segmentten meydana gelir. Kaynaşmış olan tibia-tarsus segmenti geniş ve kıvrık bir tırnağa sahiptir. Küt ve çizgili yapıya sahip olan solenidiyon *w*, tibia-tarsusun lateralinden çıkar (Şek. 51). Diğer bacak çiftleri beş serbest segmentli ve uzun bir pretarsus ile sonlanır.

İncelenen Materyal: Un: Merkez, 30.06.2020, 5♀; Tuzluca, 25.06.2020, 6♀; Aralık, 26.06.2020, 1♀; Aralık, 20.07.2020, 3♀.

Dünyadaki yayılışı: İngiltere (Hughes, 1976).

Türkiye'deki yayılışı: İzmir (Özer *vd*., 1989).

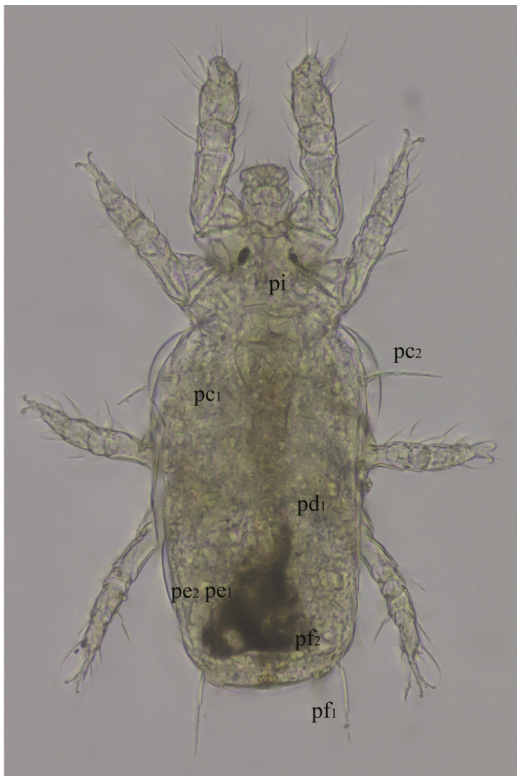
Familya: Pygmephoridae Cross, 1965

Cins: *Pediculaster* Vitzthum, 1931

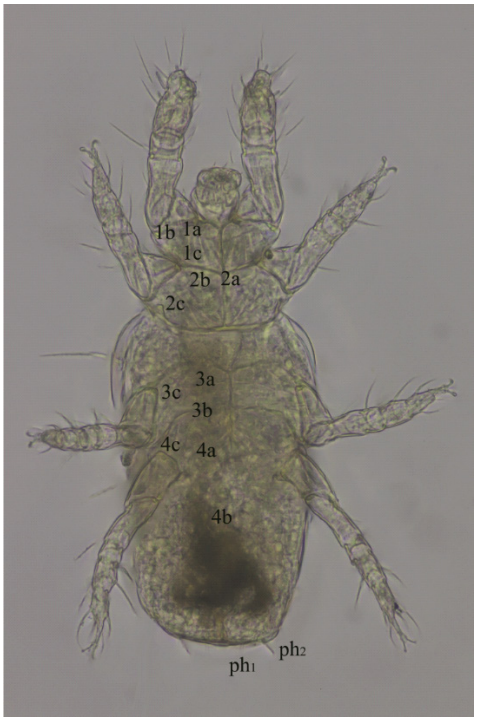
Tür: *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997)

Dişi (Şek. 54-55): İncelenen örneğin idiozoma uzunluğu 225 µm.

İdiozoması, uzunlamasına oval ve soluk, beyaz renkli olan akardır. Gnatozoma da ovaldir. Palpte; ventralden bir çift seta ve küçük çomak şelinde solenidiyon bulunur. İdiozoma, propodozoma ve histerozoma olmak üzere iki plakaya ayrılır. İntegüment dıştan delikli yapıdadır. Propodozomal plaka küçük dikdörtgen şeklindedir. Dorsal propodozomal plakanın posterior kısmı birinci histerozomal segmentle aynı düzlemde kesişir. Propodozoma dorsal yüzeyinde, büyük, damla şeklinde peritrem posteriorunda bir çift psödostigmata ve üç çift dikencikli dorsal seta bulunur. Propodozoma ventral yüzeyinde; basit ve eşit uzunlukta küçük, ince altı çift seta bulunur. Bunlar, *1a*, *1b*, *1c*, *2a*, *2b* ve *2c* setalardır. Bu setalardan *1a*, *1c* ve *2a* aynı hizada ventral plakanın anteriorunda yer alır (Şek. 55). Histerozomadaki dört segmentin ilkine ait setalar, dikenciklidir; lateral setalardan en uzun *pc2* olup *pi* setasına eşittir. Dorsal setalardan *pc1* dorsalde bulunan diğer dorsal setalardan daha uzundur. Seta, *pd1*, *pe1* ve



Şekil 54. *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997)'de ergin dişi bireyin dorsalden görünümü (×40)



Şekil 55. *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997)'de ergin dişi bireyin ventralden görünümü (×40)

pf1 yaklaşık eşit uzunluktadır. Dorsolateral setalardan olan *pe2* de, *pe1*'in 1/4' i kadar uzundur. Opistozma ventral yüzeyinde *ph1-ph2* olmak üzere iki çift basit seta bulunur

ve *ph2*, *ph1*'den uzundur (Şek. 54). Histerozomanın ventral yüzeyinde *3a*, *3b*, *3c*, *4a*, *4b* ve *4c* olarak isimlendirilen altı çift seta mevcuttur. I. ve II. bacak hemen hemen eşit uzunlukta olup III. bacaktan kısadır. IV. bacak ise diğer bacaklardan uzundur. I. bacakta kaynaşmış olan tibia-tarsus ucu güçlü kavisli bir tırnak ile sonlanır (Şek. 55).

İncelenen Materyal: Kuru kayısı: Merkez, 26.06.2020, 1♀.

Bu çalışmada, bu tür, Türkiye'de kuru kayısıda ilk kez tespit edilmiştir.

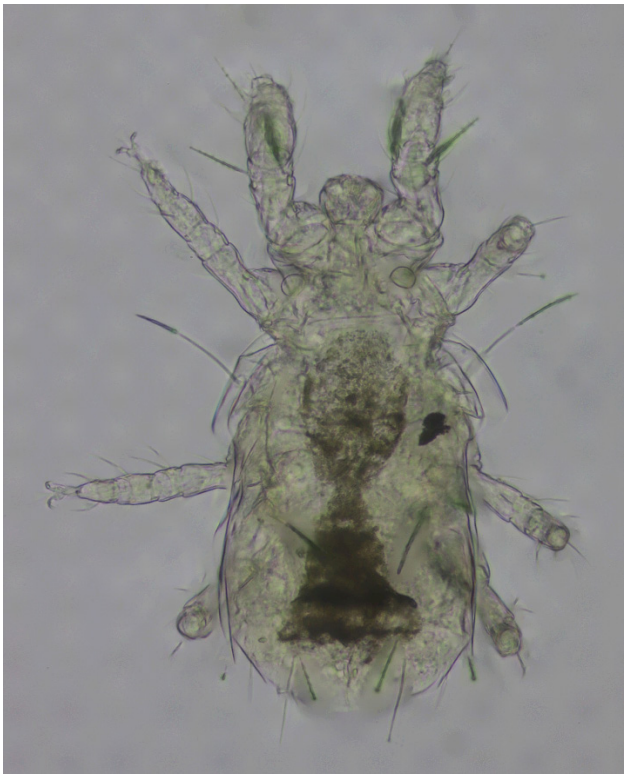
Türkiye'deki yayılışı: İzmir (Ramaraju & Madanlar, 1997).

Tür: *Pediculaster* sp.

Dişi (Şek. 56-57): İncelenen örneklerin idiozoma uzunluğu 150 µm.

İncelenen Materyal: Kuru kayısı: Merkez, 28.09.2020, 1♀.

Bu çalışmada, bu tür, Türkiye'de kuru kayısıda ilk kez tespit edilmiştir.



Şekil 56. *Pediculaster* sp.'de ergin dişi bireyin dorsalden görünümü (×40)

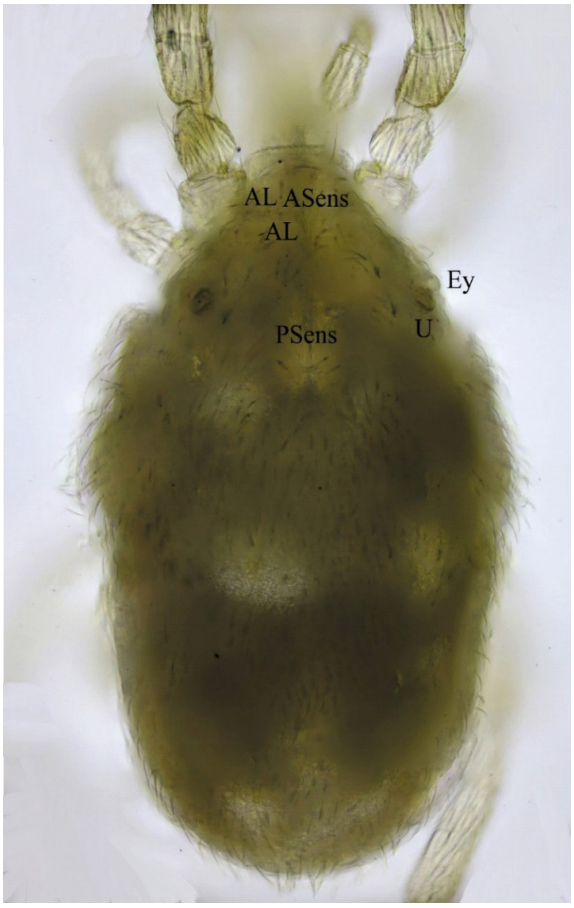
Familya: Erythraeidae Robineau & Desvoidy, 1828

Cins: *Balaustium* Von Heyden, 1826

Tür: *Balaustium* aff. *xerothermicum* Gabrys, 2000

Dişi (Şek. 58-59): İncelenen örneklerin idiozoma uzunluğu 800 µm.

Şekil 57. *Pediculaster* sp.'de ergin dişi bireyin ventralden görünümü (×40)

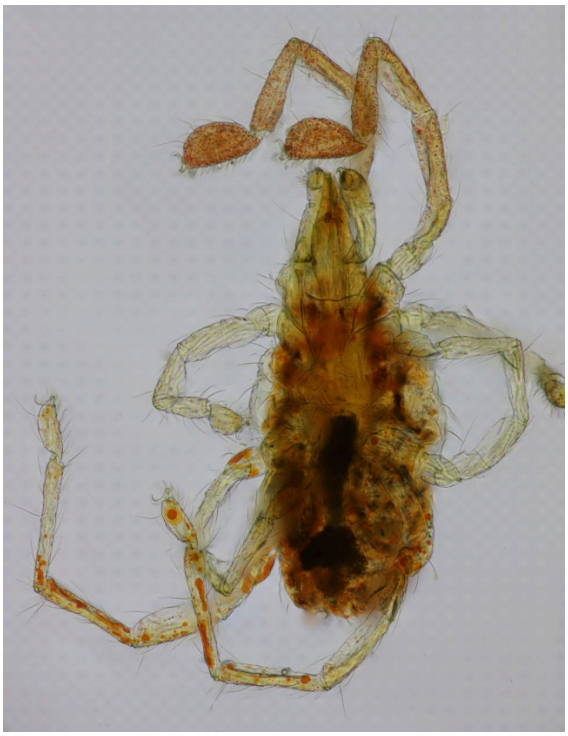


Şekil 58. *Balaustium* aff. *xerothermicum* Gabrys, 2000'da dişi bireyin dorsalden görünümü (×20)

Şekil 59. *Balaustium* aff. *xerothermicum* Gabrys, 2000'da dişi bireyin ventralden görünümü (×20)

Vücut oval olup dorsal ve ventral yüzeyleri yoğun, kısa setalarla kaplıdır. Kahverengimsi renktedir. Keliser, vücudun içine doğru hafif eğilmiş hançer benzeri yapıdadır. Rostrum, apikalinde çeşitli uzunluklarda birkaç seta mevcuttur. Palpin tarsusu, dar, silindirik, apikal olarakta dairemsi ve çok sayıda solenidiyon içerir. Palp tibiasında bulunan tırnak, diş benzeri çıkıntı şeklindedir. Palp genusu taraksı ya da yarı taraksı setaya sahip değildir. İdiozomanın dorsal yüzeyi, aspidozoma ve opistozoma olarak belli belirsiz bir olukla ayrılır. Crista metopika, *ASens* (anterior duyu setası) ve *PSens* (posterior duyu setası) 'in tabanları arasında bir çubuk şeklindedir. *ASens*, *PSens*'ten her zaman kısadır. İki çift olan *AL* (duyu) setası, diğer dorsal setalardan farklıdır. Birincisi ince, uzun, *ASens*'in önünde, ikincisi ise kısa, kalın ve *ASens*'in arkasında yer alır (Şek. 58). İdiozomanın ventral yüzeyi yoğun, ince, sade, iğne benzeri ve nispeten aynı uzunluktaki setalara sahiptir (Şek. 59). İdiozomanın dorsal kenarında bir çift sapsız göz (Ey), bir çiftte yarım küreye benzer yapıdaki urnula (U) mevcut olup gözün arkasında yer alır. *PSens*'le aynı seviyede görünür (Şek. 58). Sklerit içermeyen genital açıklık ince ve uzundur. Çevresinde bulunan setalar, ventral setalara benzer fakat daha kısadır. Anüs, oval ve çevresinde 10 tane seta bulunur. Bütün bacaklardaki coxa üç setaya sahiptir. Ortadaki seta ise kamçımsı görünümüyle karakteristiktir. I. ve IV. bacak çifti uzun, II. ve III. bacak çiftleri ise nispeten kısadır. Bütün bacaklarda tarsusun ventral yüzeyi karakteristik fırça şeklinde ve bir sap üzerinde iki tırnaklıdır. Tarsus üzerinde çok sayıda solenidiyon bulunur ve famulus yoktur.

Şekil 60. *Balaustium* aff. *unidentatum* (Tragardh, 1904)'da dişi bireyin dorsalden görünümü (×20)



Şekil 61. *Balaustium aff. unidentatum* (Tragardh, 1904)'da dişi bireyin ventralden görünümü (×20)

İncelenen Materyal: Kuru kayısı: Tuzluca, 25.10.2020, 1♀.
Bu çalışmada, bu tür, Türkiye'de kuru kayısıda ilk kez tespit edilmiştir.
Dünyadaki yayılışı: Orta Avrupa (Polonya) ve Güney Kafkasya (Azerbaycan) (Alizade, 2020).

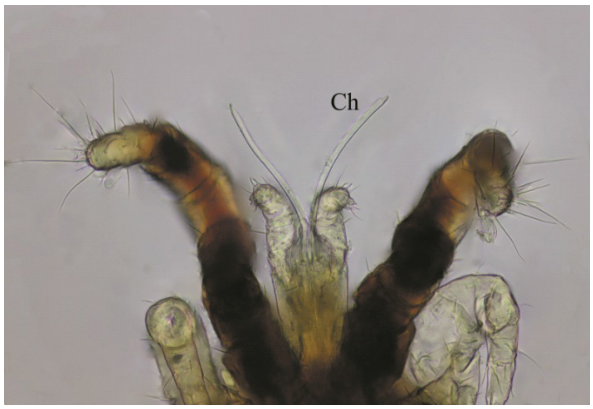
Tür: *Balaustium* aff. *unidentatum* (Tragardh, 1904)
Dişi (Şek. 60-61): İncelenen örneklerin idiozoma uzunluğu 425µm.

Dorsal opistozomal seta uzundur. Ventral opistozomal seta dorsal setaya benzerdir. Fakat setalar kısa, sert ve dardır. Palp ince ve palp genu belirgin bir şekilde genişliğinden uzundur. Palp genu, palp tibianın tabanından daha geniştir. Palp tibiadaki tırnak, çevresi güçlendirilmiş diş benzeri bir çıkıntıya sahiptir. En karakteristik özelliği palp genunun medial yüzeyinde güçlü ve taraksı seta kümesi bulundurmasıdır.

Dişi bireyler mayıs ayının sonlarına doğru yumurta bırakmak için kitlesel olarak toprak yüzeyine çıkarlar. Bu nedenle toprak ve kayaların yüzeyi koyu kırmızı görünür (Alizade, 2020).
İncelenen Materyal: Kepek: Merkez, 19.05.2020, 1♀.
Bu çalışmada, bu tür, Türkiye'de kepekte ilk kez tespit edilmiştir.
Dünyadaki yayılışı: Orta Avrupa (Polonya ve İsviçre), Kafkasya: Azerbaycan, Grönland Adası (Alizade, 2020).

Takım: Mesostigmata Canestrini, 1891
Familya: Dermanyssidae Kolenati, 1859
Cins: *Dermanyssus* De Geer, 1778
Tür: *Dermanyssus gallinae* (De Geer, 1778)
Sinonim: *Acarus gallinae* De Geer, 1778.

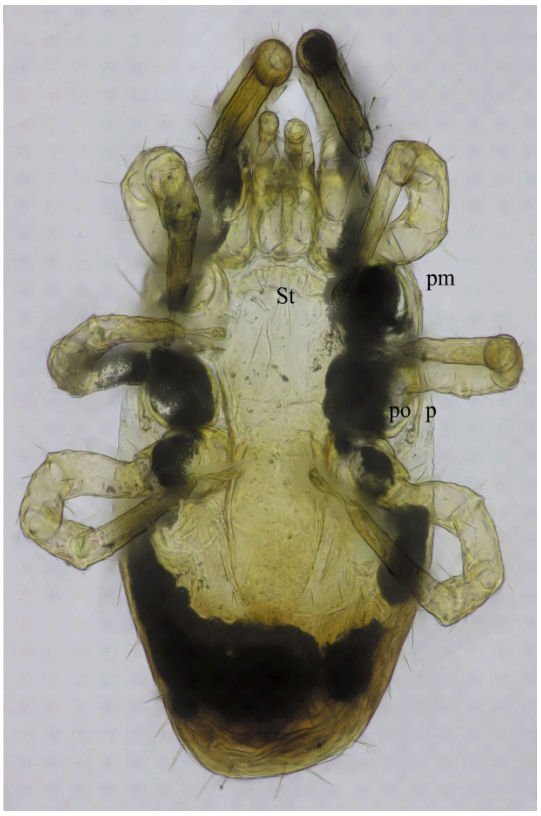
Dişi (Şek. 62-65): İncelenen örneklerin idiozoma uzunluğu 625-825 µm.



Şekil 62. *Dermanyssus gallinae* (De Geer, 1778)'de ergin dişi bireyde ventralden gnatozomanın görünümü (×40)

Şekil 63. *Dermanyssus gallinae* (De Geer, 1778)'de ergin dişi bireyin ventralden görünümü (×20)

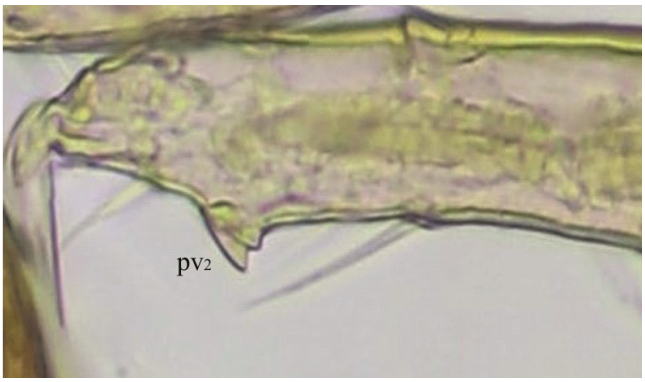
Şekil 64. *Dermanyssus gallinae* (De Geer, 1778)'de ergin dişi bireyin dorsalden görünümü (×20)



Şekil 65. *Dermanyssus gallinae* (De Geer, 1778)'de ergin dişi bireyin ventralden görünümü (×20)

Keliser uzunluğu, idiozomanın yarısı kadardır. Keliserin II. segmenti, I. segmentinden yaklaşık altı kat daha uzundur (Şek. 62).

Kanla beslendiğinde, idiozoma parlak kırmızıdır (Şek. 63). Kısmen sindirilmiş kan içeren bireyler siyah veya gri renkli olurlar. Yüzeyi ağ şeklinde görünen idiozomayı, kısmen kaplayan dorsal plaka, zayıf şekilde sklerotize olmuş ve kesik bir posterior kenar boşluğuna sahiptir (Şek. 64). Dorsal plakada 15 çift, sternal plakada ise iki çift seta bulunur. Genital plaka bir çift seta ve yuvarlak bir posterior kenar boşluğuna sahiptir. Anal bölgeyi yarım daire şeklinde çevreleyen üç anal seta mevcuttur. Peritrem,



Şekil 66. *Dermanyssus gallinae* (De Geer, 1778)'de ergin erkek bireyin IV. bacak tarsus segmentinin görünümü (×40)

Şekil 67. *Dermanyssus gallinae* (De Geer, 1778)'de ergin erkek bireyin dorsalden görünümü (×20)

Şekil 68. *Dermanyssus gallinae* (De Geer, 1778)'de ergin erkek bireyin ventralden görünümü (×20)

II. bacak coxa segmentinin anterior yarısına kadar uzanır, peritrematal plaka (pm) ise posteriorda IV. bacak coxa

segmentine ait podal plakaya (po) kadar devam eder (Şek. 65). Bacaklardaki chaetotaxy normalden farklılık gösterir. II. bacak coxa segmentinin anterior kısmında seta yoktur. Tüm bacaklarda tırnak ve yastık benzeri ambulacrum vardır.

Erkek (Şek. 66-68): İncelenen örneklerin idiozoma uzunluğu 500-625 µm.

Kelisera'nın II. segmenti, I. segmentin iki katından daha azdır ve sabit parça oldukça küçüktür. Spermadaktil hareketli parça ile tamamen kaynaşmıştır.

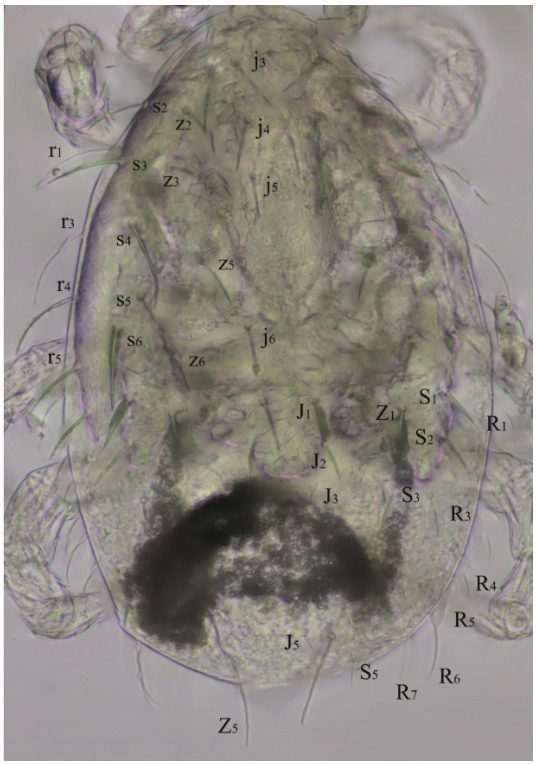
Dorsal plaka 19 çift seta bulundurur ve dişi bireye göre daha geniştir. Holoventral plakanın sterno-genital bölgesinde beş çift, ventralinde iki çift ve anal bölge çevresinde ise üç seta bulunur. Bacaktaki chaetotaxy dişi bireye benzer fakat III. ve IV. bacak tarsus segmenti üzerinde bulunan *pv2* setası, geriye doğru diş benzeri çıkıntı oluşturacak şekilde modifiye olmuştur (Şek. 66).

İncelenen Materyal: Kepek: Merkez, 19.05.2020, 3♀, 3 ♂. Buğday samanı: Merkez, 19.05.2020, 4 ♀. Buğday danesi: Merkez, 19.05.2020, 30 birey.

Bu çalışmada, bu tür, Türkiye'de kepek, buğday samanı ve buğday danesinde ilk kez tespit edilmiştir.

Dünyadaki yayılışı: Kozmopolittir (Hughes, 1976).

Şekil 69. *Proctolaelaps pomorum* (Oudemans, 1929)'da ventralden gnatozomanın görünümü (×63)



Şekil 70. *Proctolaelaps pomorum* (Oudemans, 1929)'da ergin dişi bireyde idiozomanın görünümü (×40)

Türkiye'deki yayılışı: Samsun (Kalay & Sullivan, 2013).

Familya: Ascidae Voigts & Oudemans, 1905
Cins: *Proctolaelaps* Berlese, 1923
Tür: *Proctolaelaps pomorum* (Oudemans, 1929)

Sinonim: *Typhlodromus pomorum* Oudemans, 1929; *Garmania pomorum* (Oudemans, 1929) sensu Nesbitt, 1951; *Proctolaelaps (P.) pomorum* (Oudemans, 1929) sensu Hughes, 1961.

Dişi (Şek. 69-72): İncelenen örneklerin idiozoma uzunluğu 375-525 µm.

Gnatozomadaki (Şek. 69) cornicul yakınsak değil, düzdür. Keliseranın, sabit parçasında 2-3 diş hareketli parçasında ise bir diş bulunur. Dorsal plaka, II. ve III. coxa arasında enine bir çizgi ile bölünmüştür. Bu çizginin anterioru, buruşuk yamaya benzer şekillere ve posterioru ise ağsı bir desene sahiptir. Dorsal plakada 45 çift düz seta bulunur (Şek. 70).

Erkek (Şek. 723-74): İncelenen örneklerin idiozoma uzunluğu 200 - 375 µm.

Dorsal plaka üzerinde bulunan setaların dizilim ve şekilleri dişi bireye benzer.

İncelenen Materyal: Un: Merkez, 15.11.2020, 3 ♀; Karakoyunlu, 30.10.2020, 1 ♀. Fasulye: Merkez, 20.07.2020, 2 ♂. Kuru kayısı: Tuzluca, 16.09.2020, 1 ♂. Kuru incir: Tuzluca, 16.08.2020, 5 ♂, 2 ♀; Tuzluca,

05.07.2020, 7 ♀. Pirinç: Tuzluca, 20.08.2020, 6 ♀. Bulgur: Karakoyunlu, 30.09.2020, 1 ♂. Küf peynir: Karakoyunlu, 25.08.2020, 1 ♀.

Bu çalışmada bu tür, Türkiye'de un, fasulye, kuru kayısı, kuru incir, pirinç, bulgur ve küf peynirinde ilk kez tespit edilmiştir.

Dünyadaki yayılışı: İngiltere, Hollanda, Avustralya (Hughes, 1976).

Türkiye'deki yayılışı: Erzurum (Gültekin & Özkan, 1999).

Şekil 71. *Proctolaelaps pomorum* (Oudemans, 1929)'da ergin dişi bireyin dorsalden görünümü (×20)

Cins: *Blattisocius* Keegan, 1944

Sinonim: *Paragarmania* Nesbitt, 1951.

Tür: *Blattisocius dentriticus* (Berlese, 1918)

Sinonim: *Lasius* (*L.*) *dentriticus* Berlese, 1918; *Seiulus amboinensis* Oudemans, 1925; *Garmania* (*Paragarmania*) *amboinensis* (Oudemans, 1925) sensu Nesbitt, 1951; *Melichares* (*Blattisocius*) *dentriticus* (Berlese, 1918) sensu Hughes, 1961.

Dişi (Şek. 75-78): İncelenen örneklerin idiozoma uzunluğu 325-475 µm.

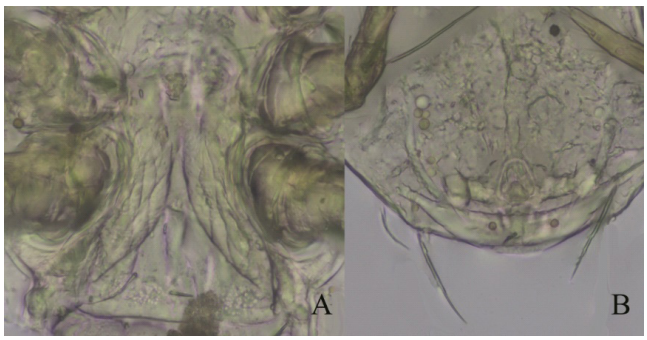
Keliseranın her iki parçası da dişli ve aynı uzunluktadır. Tektum düzgün bir şekilde yuvarlak bir kenara sahip corniculi ise ince ve yakınsaktır. İdiozoma soluk sarı

Şekil 72. *Proctolaelaps pomorum* (Oudemans, 1929)'da ergin dişi bireyin ventralden görünümü (×40)

Şekil 73. *Proctolaelaps pomorum* (Oudemans, 1929)'da ergin erkek bireyin dorsalden görünümü (×20)

renkte ve dorsal yüzeyi ağsı bir plaka ile kaplıdır (Şek. 77). Dorsal plakada bulunan 36 çift setanın, 15 çifti posterior bölgeden çıkar. Posteriorda uzun bir çift *Z5* (median) setası mevcuttur. Bu seta hariç, diğer setalar düz ve kavislidir. Plakanın posterior yarısına kadar olan kısmın dışındaki interskütal membranda yedi çift *R* setası bulunur. Sternal plakanın anterior yarısı hafifçe ağ şeklindedir ve ayrı plakalardan çıkan 2-3 çift seta, bulundurur. Bu plakalar, II.

Şekil 74. *Proctolaelaps pomorum* (Oudemans, 1929)'da ergin erkek bireyin ventralden görünümü (×20)



Şekil 75. *Blattisocius dentriticus* (Berlese, 1918)'da genital bölge (×40) (A) ve anal bölge (×40) (B)

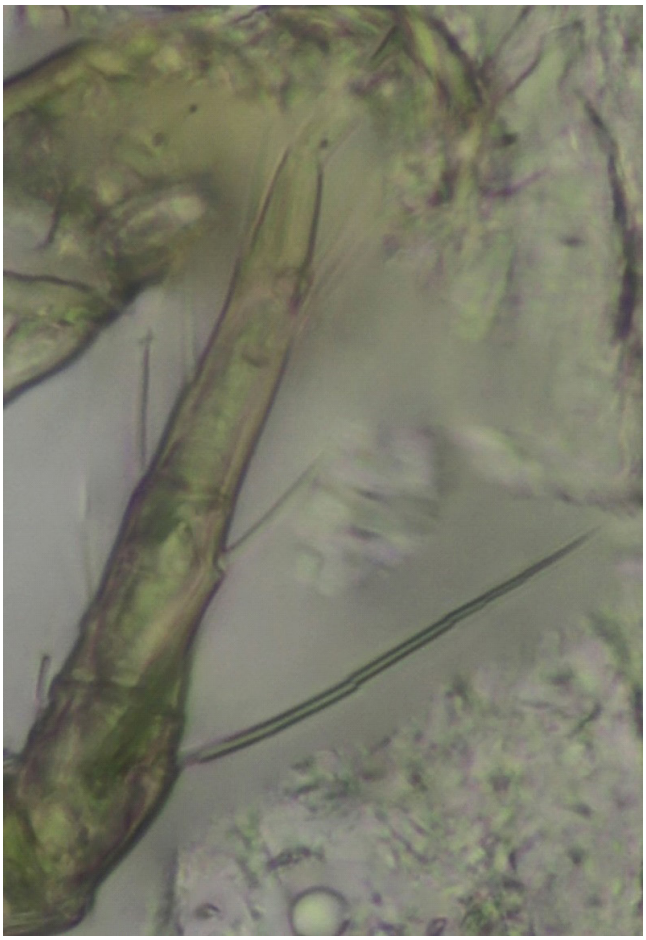
coxanın posterior kenarlarını kısmen çevreleyen sternum plakasına endopodal ile birleşir. Genital plakanın (Şek. 75A) yanı sıra anal bölge ağ şeklindedir (Şek. 75B) ve dört çift pre-anal seta bulunur. Anal plakanın dışındaki interskütal zarda dört çift seta daha mevcuttur. Bu setaların bir çifti daha uzundur. Peritrematal plaka, IV. coxanın posterior kenarını çevreleyen ekzopodala değecek şekilde posteriora doğru uzar. İki dar metapodal plaka bulunur (Şek. 78). IV. bacak tarsus segmentinin tabanında uzun bir makroseta bulunur (Şek. 76).

İncelenen Materyal: Kepek: Merkez, 19.05.2020, 1 ♀. Mısır: Aralık, 23.09.2020, 2 ♀.

Bu çalışmada, bu tür, Türkiye'de kepek ve mısırda ilk kez tespit edilmiştir.

Dünyadaki yayılışı: İngiltere, İtalya, İrlanda, Hollanda, ABD, Japonya, Sri Lanka, İsrail (Hughes, 1976).

Türkiye'deki yayılışı: Samsun (Kalay & Sullivan, 2013).



Şekil 76. *Blattisocius dentriticus* (Berlese, 1918)'da IV. bacağın tarsus segmentinin görünümü (×40)

Şekil 77. *Blattisocius dentriticus* (Berlese, 1918)'da ergin dişi bireyin dorsalden görünümü (×20)

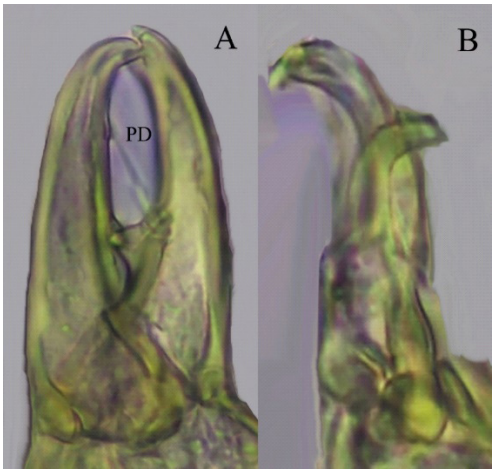
Şekil 78. *Blattisocius dentriticus* (Berlese, 1918)'da ergin dişi bireyin ventralden görünümü (×20)

Tür: *Blattisocius mali* (Oudemans, 1929)

Sinonim: *Typhlodromus mali* Oudemans, 1929; *Garmania* (*Paragarmania*) *mali* (Oudemans, 1929) sensu Nesbitt, 1951; *Melichares* (*B.*) *mali* (Oudemans, 1929) sensu Hughes, 1961.

Dişi (Şek. 79-81): İncelenen örneklerin idiozoma uzunluğu: 475-525 µm.

Her bir kelisera (Şek. 79A) büyük ve koyu renklidir; hareketli parçada iki küçük diş, ucu, üç kısma bölünmüş sabit parçada ise uzun bir pilus dentilis (PD) bulunur. Tektum yuvarlak bir kenara sahip ve curnicul uzun ve yakınsaktır. Dorsal plaka kahverengi-sarı renktedir,



Şekil 79. *Blattisocius mali* (Oudemans, 1929)'de kelisera (×63); (A) dişi ve (B) erkek

Şekil 80. *Blattisocius mali* (Oudemans, 1929)'de ergin dişi bireyin dorsal yüzeyi (×20)

Şekil 81. *Blattisocius mali* (Oudemans, 1929)'de ergin dişi bireyin ventral yüzeyi (×40)

neredeyse idiozomayı kaplar. Merkez ağsı yapıdadır. Dorsal plakada 34 çift düz seta vardır bunlardan apikal *j1* ve terminal *Z5*, diğer setalardan daha uzundur (Şek. 80). Ventral plakaları neredeyse pürüzsüzdür; sternal plakada üç çift seta ve genital plakada ise bir çift seta bulunur

Şekil 82. *Blattisocius mali* (Oudemans, 1929)'de ergin erkek bireyin dorsal yüzeyi (×20)

(Şek. 81). Metasternal setalar, interskütal membrandan çıkar. Anal plakada, üç anal setaya ilaveten dört çift seta daha mevcuttur. İki çift metapodal plaka vardır. Peritrem iyi gelişmiş ve stigmayı neredeyse tamamen kaplar. Peritrematal plaka, IV. coxa bölgesindeki ekzopodal ile birleşir (Şek. 81). IV. bacak tarsus segmentinde makroseta yoktur.

Erkek (Şek. 82-83): İncelenen örneklerin idiozoma uzunluğu yaklaşık 400 um.

Kelisera (Şek. 79B) da uç kısmı geriye doğru eğimli ve iyi gelişmiş bir spermadaktil bulunur. Curnicul dişi bireye göre daha kalın ve birbirine yakındır. Dorsalde ki chetotaxy dişi bireye benzer (Şek. 82). Ventral yüzeyin hemen hemen tamamı, genital ve anal plakalarla kaplıdır. Anal plaka, IV. bacak coxaları arasındaki ventral yüzeyi kaplamak için lateral olarak genişlemiştir. Bu plaka soluk renkli ağsı desenle kaplıdır (Şek. 83). Anal setalara ilaveten beş çift daha seta bulundurur.

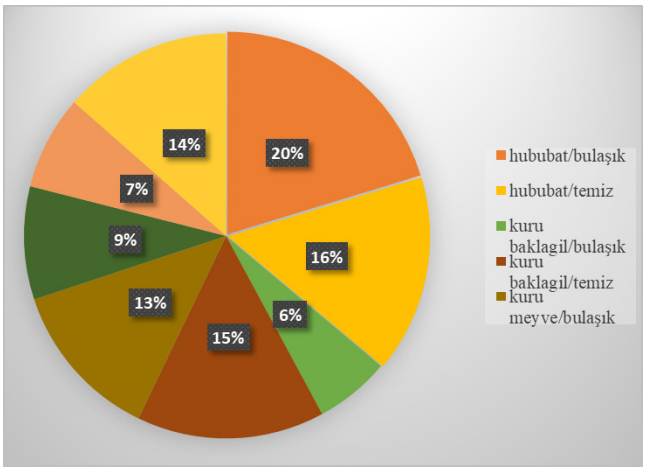
İncelenen Materyal: Kuru incir: Merkez, 02.07.2020, 32 birey; Tuzluca, 16.11.2020, 2 ♂. Un: Tuzluca, 16.11.2020, 3 ♀; Karakoyunlu, 25.06.2020, 1 ♂.

Dünyadaki yayılışı: İngiltere, Hollanda, Hindistan (Hughes, 1976).

Tablo 1. Iğdır ilinde depolanmış gıdalarda saptanan akar türleri

Takım	Familya	Cins	Tür
Astigmata	Acaridae	*Acarus*	*Acarus siro*
		Tyrophagus	*Tyrophagus putrescentiae*
			Tyrophagus perniciosus
		Tyroborus	*Tyroborus lini*
	Glycyphagidae	*Lepidoglyphus*	*Lepidoglyphus destructor*
	Carpoglyphidae	*Carpoglyphus*	*Carpoglyphus lactis*
Prostigmata	Cheyletidae	*Cheyletus*	*Cheyletus eruditus*
			Cheyletus malaccensis
	Tydeidae	*Tydeus*	*Tydeus interruptus*
	Pyemotidae	*Acarophenax*	*Acarophenax tribolii*
	Pygmephoridae	*Pediculaster*	*Pediculaster turkiensis*
			Pediculaster sp.
	Erythraeidae	*Balaustium*	*Balaustium* aff. *xerothermicum*
			Balaustium aff. *unidentatum*
	Dermanyssidae	*Dermanyssus*	*Dermanyssus gallinae*
Mesostigmata	Ascidae	*Proctolaelaps*	*Proctolaelaps pomorum*
		Blattisocius	*Blattisocius dentriticus*
			Blattisocius mali

Şekil 83. *Blattisocius mali* (Oudemans, 1929)'de ergin erkek bireyin ventral yüzeyi (x20)



Şekil 84. Iğdır ilinde depolanmış gıdaların akarlarla bulaşıklık oranı

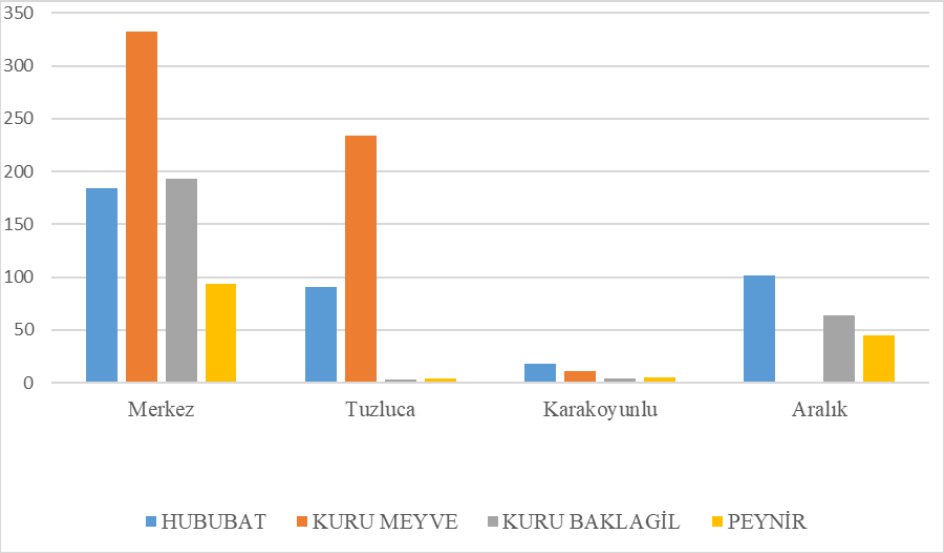
Türkiye'deki yayılışı: İzmir (Özer *vd*., 1989), Aydın (Dizlek & Çakmak, 2017), Samsun (Kalay & Sullivan, 2013) ve Malatya (Çobanoğlu, 2008).

Tablo 2. Iğdır ilinde depolanmış gıdalarda akar türlerinin birey sayıları

Türler	Hububat (Tahıl)	Kuru Baklagil	Kuru Meyve	Peynir	Toplam
A. siro	99	235	1	1	336 (%24,24)
T. putrescentiae	7	13	217	139	376 (%27,12)
T. perniciosus	118	14	1	-	133 (%9,59)
T. lini	2	-	7	6	15 (%1,08)
L. destructor	2	-	90	1	93 (%6,70)
C. lactis	47	-	209	-	256 (%18,47)
C. eruditus	30	-	-	-	30 (%2,16)
C. malaccensis	15	-	-	-	15 (%1,08)
T.interruptus	1	-	2	-	3 (%0,21)
A.tribolii	15	-	-	-	15 (%1,08)
P. turkiensis	-	-	1	-	1 (%0,07)
***Pediculaster* sp.**	-	-	1	-	1 (%0,07)
B.* aff. *xerothermicum	-	-	1	-	1 (%0,07)
B.* aff. *unidentatum	1	-	-	-	1 (%0,07)
D. gallinae	40	-	-	-	40 (%2,88)
P. pomorum	11	2	15	1	29 (%2,09)
B. dentriticus	3	-	-	-	3 (%0,21)
B.mali	4	-	34	-	38 (%2,74)
Toplam	**395 (%28,49)**	**264 (%19,04)**	**579 (%41,77)**	**148 (%10,67)**	**1386 (%100)**

Tablo 3. Iğdır ilinde depolanmış gıda çeşitlerinin akar dağılımı

Gıdalar		*A. siro*	*T.putrescentiae*	*T. perniciosus*	*T. lini*	*L. destructor*	*C. lactis*	*C. eruditus*	*C. malaccensis*	*T.interruptus*	*A.tribolii*	*P. turkiensis*	*Pediculaster* sp.	*B.aff. xerothermicum*	*B.aff. unidentatum*	*D. gallinae*	*P. pomorum*	*B. dentriticus*	*B.mali*	İncelenen toplam örnek sayısı
Hububat	Buğday Danesi	-	-	-	-	-	-	30	-	-	-	-	-	-	-	30	-	-	-	60 (%4,32)
	Un	92	2	4	2	2	46	-	-	1	15	-	-	-	-	-	4	-	4	172 (%12,4)
	Kepek	-	-	-	-	-	-	-	-	-	-	-	-	-	1	6	-	1	-	8 (%0,57)
	Buğday Samanı	-	-	86	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	90 (%6,49)
	Pirinç	5	-	25	-	-	1	-	-	-	-	-	-	-	-	-	6	-	-	37 (% 2,66)
Kuru Baklagil	Mısır	2	5	-	-	-	-	-	15	-	-	-	-	-	-	-	-	2	-	24 (%1,73)
	Bulgur	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	4 (%0,28)
	Nohut	5	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11 (%0,79)
	Lepe	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 (%0,21)
	Kırmızı Mercimek	180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	180 (%12,98)
	Fasülye	50	4	14	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	70 (%5,05)
Kuru Meyve	Kayısı	-	65	1	7	3	-	-	-	1	-	1	1	1	-	-	1	-	-	81 (%5,84)
	İncir	1	151	-		-	209	-	-	1	-	-	-	-	-	-	14	-	34	410 (%29,58)
	Ceviz	-	-	-	-	87	-	-	-	-	-	-	-	-	-	-	-	-	-	87 (%6,27)
	Elma	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 (0,07)
Peynir	Süzme Peynir	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4 (%0,28)
	Kaşar Peynir	1	135	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	137 (%9,88)
	Küf Peynir	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1 (0,07)
	Krem Peynir	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6 (%0,43)



Şekil 85. Iğdır il merkezi ve ilçelerine göre akar türlerinin birey sayısının dağılımı

Tespit Edilen Akar Türleri ve Bulaşma Oranları

Tespit Edilen Akar Türleri

Bu çalışmada, Arachnida sınıfında üç takıma ait 10 familyaya bağlı 18 akar türü tespit edilmiştir. Tespit edilen akar tür listesi ve bağlı oldukları takım, familya ve cinsler Tablo 1' de verilmiştir.

Bulaşma Oranları

Bu çalışmada Iğdır ilinde depolanmış gıdalardan alınan numunelerin %54'nün temiz, %46'sinin ise akarlarla bulaşık olduğu görülmüştür (Şek. 84). Depolanmış ürünler üzerinde bulunan akar türlerinin tespiti ile ilgili yapılan çalışmalarda bulaşıklık oranının İzmir ilinde %47,81 (Özer *vd*.,1989), Edirne ilinde %58,46 (Çobanoğlu, 1996), Erzurum ilinde %18,1 (Gültekin & Özkan, 1999), Tekirdağ ilinde %47,02 (Kılıç & Toros, 2000), Diyarbakır ve Şanlıurfa illerinde %28,04 (Emekçi, 2001) olduğu tespit edilmiştir.

Iğdır ilinde yürütülen bu çalışmanın sonuçlarına göre, 18 akar türünün; 15'i hububatta, 4'ü kuru baklagilde, 12'si kuru meyvede ve 5'i de peynirde tespit edilmiştir. Toplam 1386 bireyden 395'i hububattan, 264'ü kuru baklagilden, 579'u kuru meyveden ve geriye kalan 148 birey ise peynirden ayıklanmıştır. Bunlardan hububatın, %28,49'u, kuru baklagilin %19,04'ü, kuru meyvenin %41,77'si ve peynirin ise %10,67'sinin bulaşık olduğu tespit edilmiştir (Tablo 3). Ülkemizde yapılan bir çalışmada İzmir ili ve çevresinde depolanmış hububat, un ve mamullerinden alınan numunenin %49,9'unun akarlarla bulaşık olduğu kaydedilmiştir (Özer *vd*.,1989). Aynı şekilde İzmir ili için yapılan bir diğer çalışmada ise bulaşma oranı kuru meyvede %53,3, hububatta %50 ve unda %80 olarak gözlenirken baklagil ve tütün depolarında akar gözlenmemiştir (Genç & Özar, 1986). Erzurum ilinde incelenen peynir numunelerinin %0,5'i (Aygün *vd*., 2007), Niğde'de %0,88'i (Karatepe *vd*., 2017) ve Ankara'nın Mamak ilçesinde ise %0,84 (Karadere & Karatepe, 2019) oranında akar bulaşıklığı tespit edilirken Kayseri'nin Develi ilçesinde bulaşıklık görülmemiştir (Solmaz & Karatepe, 2020). Akdeniz bölgesinden ithal edilen kuru meyvelerin %13'ünün akarla bulaşık olduğu ortaya konulmuştur (Hubert *vd*., 2011).

Iğdır ili için yapılan bu çalışmada, *Tyrophagus putrescentiae*, %27,12 oranıyla en fazla saptanan tür olmuştur. Bunu %24,24 oranı ile *Acarus siro* ve %18,47 ile de *Carpoglyphus lactis* takip etmiştir. Diğer türler ise daha düşük oranda tespit edilmiştir (Tablo 2). Çobanoğlu (1996)'nun Edirne ili için yaptığı çalışmada, %31,03 oranı ile *Acarus siro* depolarda en yaygın tür olurken, bu oran %24,14 ile *Lepidoglyphus destructor* ve %12,07 ile de *Tyrophagus putrescentia* türleri izlemiştir.

Bu çalışmada alınan 29 çeşit üründen; arpa şehriye, pirinç unu, buğday irmiği, yeşil mercimek, fındık, hurma, iğde, lor peynir, beyaz peynir ve otlu peynir olmak üzere 10 gıda çeşidinde akara rastlanmamıştır. Akarlarla bulaşık olan 19 gıda çeşidinden kuru incirin %29,58 oranı ile en bulaşık ürün olduğu tespit edilmiştir. Bu oranı en yakın kırmızı mercimek (%12,98), un (%12,40), kaşar peynir (%9,88), buğday samanı (%6,49) ve diğer gıda çeşitlerinin izlediği görülmektedir (Tablo 3). Aydın ilinde kuru incirlerde bulaşıklık oranı %94,3 olarak gözlenmiştir (Dizlek & Çakmak, 2017). Diyarbakır ve Şanlıurfa'da ise en bulaşık gıda çeşidinin darı (%64,29) olduğu, bunu da kepek (%50), bulgur (%47,17), mercimek (%45,19), nohut (%44,83), buğday (40,55) ve diğer gıda çeşitlerinin

takip ettiği tespit edilmiştir (Emekçi, 2001). Iğdır ilinde kuru kayısıda bulaşıklık oranı %5,84 olarak saptanırken, Malatya ilinde %12, Elazığ ilinde %14,51 ve İzmir ilinde %36,82 olarak kaydedilmiştir (Çobanoğlu, 2008).

Merkez ve ilçelerdeki akar dağılımına bakıldığında incelenen numunelerin akarla bulaşık olma durumunun Iğdır il merkezinde daha yoğun olduğu görülmüştür. En az akar birey sayısı ise Tuzluca ilçesinden alınan peynirde 4 birey, kuru baklagillerde 3 birey, Aralık ilçesinden alınan kuru meyvede 1 birey, Karakoyunlu ilçesinden alınan kuru meyvede 11 birey ve hububatta 18 birey olarak tespit edilmiştir (Şek. 85). Birey sayısı az olan türlerin gıda için zararlı olmadığı kanısındayız.

Sonuç

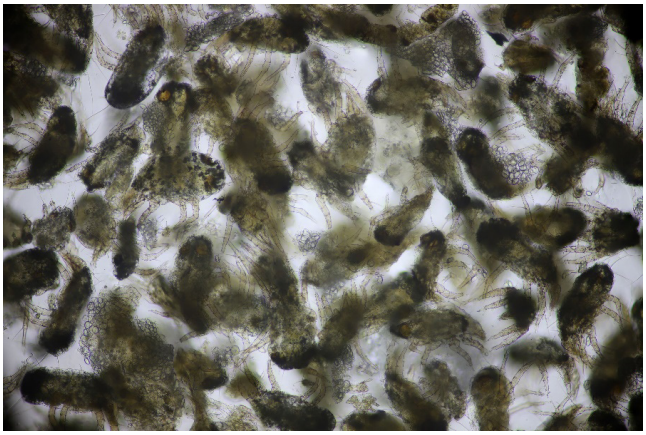
Yapılan çalışmaların incelenmesi ile 47 gıda akar türünün Türkiye'de yayılış gösterdiği ve en yoğun türün ise *Acarus siro* Linnaeus, 1758 olduğu tespit edilmiştir (Gültekin, 2022). İlk kez bu çalışmayla Iğdır ilinde 29 depolanmış gıda grubundan, 10 familyaya bağlı ve 13 cinse ait *Acarus siro* Linnaeus, 1758, *Tyrophagus putrescentiae* (Schrank, 1781), *Tyrophagus perniciosus* Zachvatkin, 1941, *Tyroborus lini* Oudemans, 1924, *Lepidoglyphus destructor* (Schrank, 1781), *Carpoglyphus lactis* (Linnaeus, 1758), *Cheyletus eruditus* (Schrank, 1781), *Cheyletus malaccensis* Oudemans, 1903, *Tydeus interruptus* Thor, 1932, *Acarophenax tribolii* Newstead ve Duvall, 1918, *Pediculaster turkiensis* (Ramaraju & Madanlar, 1997), *Pediculaster* sp., *Balaustium* aff. *xerothermicum* Gabrys, 2000 *Balaustium* aff. *unidentatum* (Tragardh, 1904), *Dermanyssus gallinae* (De Geer, 1778), *Proctolaelaps pomorum* (Oudemans, 1929), *Blattisocius dentriticus* (Berlese, 1918) ve *Blattisocius mali* (Oudemans, 1929), olmak üzere 18 tür tespit edilmiştir. Bu akar türlerinin tespit edildiği yeni gıda kayıtları, *T. putrescentiae* için kaşar peynir, süzme peynir, nohut, fasulye ve kuru elma; *T. perniciosus* için buğday samanı, kuru kayısı, fasulye, pirinç ve bulgur; *T. lini* için krem peynir, kuru kayısı ve un; *L. destructor* için kuru ceviz, kuru kayısı ve kaşar peyniri; *T. interruptus* için kuru incir, kuru kayısı ve un; *P. turkiensis* için kuru kayısı; *Pediculaster* sp. için kuru kayısı; *B.* aff. *xerothermicum* için kuru kayısı; *B.* aff. *unidentatum* için kepek; *D. gallinae* için kepek, buğday samanı ve buğday danesi; *P. pomorum* için un, fasulye, kuru kayısı, kuru incir, pirinç, bulgur ve küf peynir ve *B. dentriticus* için kepek ve mısırdır.

Çalışmalar sonucunda, 2020 yılında 133 gıda örneğinden toplam 1386 akar bireyi ayıklanmıştır. Bu gıda çeşitlerinin akarla bulaşıklık oranı ise şöyledir; kuru incir %29,58, kırmızı mercimek %12,98, un %12,4, kaşar peynir %9,88, buğday samanı %6,49, ceviz %6,27, kuru kayısı %5,84, fasulye %5,05, buğday danesi %4,32, pirinç %2,66, mısır %1,73, nohut %0,79, kepek %0,57, krem peynir %0,43, bulgur %0,28, süzme peynir %0,28, lepe %0,21, küf peynir %0,07 ve kuru elma %0,07.

Bu çalışmada, mikroskobik canlılar olan akarların tanıtımı ve teşhisinde önem arz eden morfolojik karakterler verilmiş ve dijital fotoğraflar hazırlanmıştır. Bu çalışma kapsamında oluşturulan veriler tarım teşkilatları, üniversiteler, eğitim ve araştırma birimleri, teknik eleman ve öğrenciler için faydalı olacaktır. Sonuç olarak oluşturulan bilgiler toplumun her kesiminden bireylerin daha sağlıklı ürünlerle beslenmesi için katkı sağlayacaktır.

Depolanmış gıdaların akarla bulaşma oranını ve zararını en aza indirebilmek için zararlıların depo veya gıda içine girişi önlenmeli ve gıdaların uygun depolama koşullarında saklanması gerekmektedir. Havalandırma ve kurutma uygulamaları özellikle toplu halde depolanan tahıl gibi ürünlerde böcek ve akarların gelişiminin sınırlandırılması açısından önemlidir. Nem ve sıcaklığın da kontrol edilmesi gerekir. Çünkü yüksek nemde depolanan gıdalarda küflenme görülebilir. Aynı zamanda böcek ve akarların gelişimini de tetikler. Gıdalar temiz depo ve ambarlara konulmalı, kırık ve çatlak yerler onarılmalıdır. Bu temizliğin vakumlu elektrikli süpürgeler kullanılarak yapılması uygundur. Aksi takdirde, depo ortamındaki yarık ve çatlaklarda varlığını rahatlıkla sürdüren böcek ve akarlar depoya konulan yeni gıdayı uygun koşullarda kısa sürede bulaştırarak önemli ölçüde zararlara neden olurlar. Depolanma koşulları kötü olan yerlerden alınan örneklerde akarlar yoğun olarak tespit edilmiştir (Şek. 86).

Sonuç olarak, depolanmış gıda zararlısı olan böceklerin oluşturduğu zarar nispeten bilinmesine rağmen akarlar hakkında insanların yeterli bilgiye sahip



Şekil 86. Gıda ile bulaşık yoğun akar bireylerinin görünümü (×10)

olmadığı gözlenmiştir. Bu yüzden akarların tanıtılması ve depolanma şartlarının daha iyi oluşturulması için toplumun bilinçlendirilmesi gerekmektedir.

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Kaynaklar

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RESEARCH ARTICLE

Present Status, Impact, and Challenges of Fish Farming at Bhaluka Upazila in Bangladesh

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Abstract

Objective: The current investigation was conducted to identify existing fish culture practise, livelihood condition of fish farmers, and the major challenges faced by fish farmers in Bhaluka upazila, Bangladesh.

Materials and Methods: Data were collected through surveys, monitoring, and participatory rural appraisal (PRA) tools like focus group discussions (FGD), using a pre-planned questionnaire survey. A group of 5 fish farmers was interviewed from each of the six villages.

Results: In the study, majority of fish farmers were between the ages of 41 and 60 years. Fish farming was their major occupation; however, they did not receive any formal training in fish culture. Fish ponds were large (> 4000 m^2) and medium in depth (1-2 m), and the most popular fish culture system was polyculture. Commercial feeds were used to supply nutrients, fertilisers (organic and inorganic) were also applied to the pond water to produce natural food. Salt, lime, zeolite, potassium permanganate, and oxygen tablets were used to maintain water quality. Epizootic ulcerative syndrome, argulosis, and tail and fin rot are most prevalent in the winter. Increasing feed costs, lack of financial support, and disease outbreaks were critical challenges in fish farming in the study area. The socioeconomic status of fish farmers was found to improve with fish farming.

Conclusion: Fish farming substantially improved the livelihoods of fish farmers in the study area, despite many constraints. Government support, including microcredit support, the supply of high-quality inputs, including fish fry, feed, vaccinations, and the provision of training facilities could increase fish production in the region.

Keywords: Bhaluka upazila, Constraints, Fish culture, Fish farmer, Livelihood status

Introduction

Bangladesh is considered a favourable region for fish culture worldwide based on its existing resources and climatic conditions (Hasan *et al.*, 2016; Hossain & Ali, 2014). Since ancient times, the socioeconomic development of this region has been significantly influenced by the fish and fisheries industry, which is also part of our cultural legacy (Ali *et al.,* 2008). The fisheries and aquaculture sectors play a dynamic role in ensuring employment generation, foreign exchange earnings, poverty alleviation, and nutritional security of the country (Ali *et al.,* 2014). It is also remarkable that fish alone contributes approximately 60% of animal protein consumption in Bangladesh (DoF, 2019). More than 10 million people directly depend on the fisheries sector for their livelihood (Hoque *et al.,* 2021). This sector contributes 1.24% of total export earnings, 3.57% of gross domestic product (GDP), and 26.50% of agricultural GDP. The total annual fish production in Bangladesh was 4,621,228 metric tonnes (MT) in 2020-2021 and ranked third position in global aquaculture production (DoF, 2022). The aquaculture sector in Bangladesh has been expanded, diversified and technologically advanced day by day.

A significant percentage of rural families participate in part-time fishing (Hughes *et al.,* 1994). About 400,000 ha of freshwater ponds/ditches and more than 900,000 households are directly engaged in aquaculture (ADB, 2010). Fish farming has become a secondary occupation for many aquaculture practitioners in rural areas, and as a result, their socioeconomic situation has improved (Ara, 2005). It has been demonstrated that aquaculture is a more profitable industry than rice farming. Thus, many farmers in rural areas are turning their rice fields into aquaculture ponds (Islam *et al.,* 2017). The production of fish from ponds is rising daily because of rising consumer demand (Ahmed, 2010). Freshwater fish farming is a significant source of income for rural people in Bangladesh (Mazid, 2002). This approach opened up a variety of career options for individuals living below the poverty line (Ahmed & Rahman, 2005). Pond owners have a great opportunity to improve their socioeconomic conditions through fish culture following scientific techniques.

Bhaluka is one of the most important upazila (an administrative region functioning as a sub-unit of a district) for aquaculture and fish culture propagation in the division of Mymensingh, Bangladesh. There are approximately 15,342 ponds (small man-made waterbody) and more than 329 beels (large natural wetlands formed by monsoon flooding) in the Bhaluka upazila (Hasan *et al.,* 2021). Its location makes it one of Bangladesh's best places for fish production. Despite the fact that fish farming involves a significant number of people and has access to abundant fisheries resources, remarkably little research has been done on the present status of fish farming, available fisheries resources and emerging constraints in the study area. Current information about resources, prospects, current status, and constraints is necessary for effective

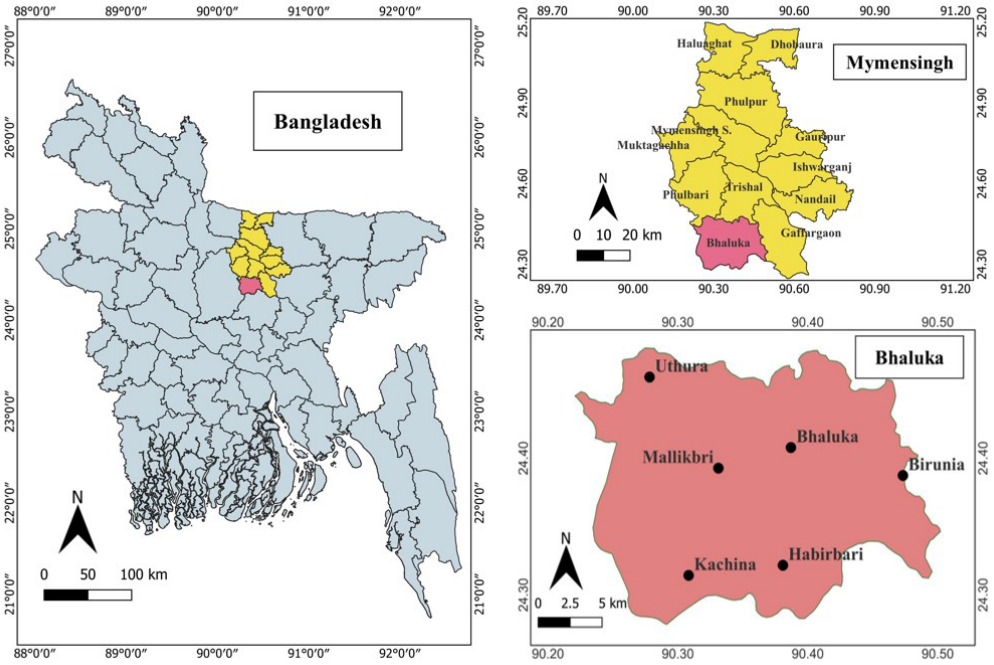

Figure 1. Map of the Bhaluka Upazila study area.

planning and development in any production sector. Lack of appropriate information and socioeconomic data frequently results in the failure of the developmental programme (Das *et al.,* 2018). Therefore, the present study was carried out to assess the present fisheries resources, fish farming conditions, livelihood status of fish farmers, and major constraints faced in the fisheries sector in Bhaluka upazila, Bangladesh.

Materials and Methods

Study area

The current study was conducted in Bhaluka upazila, Mymensingh district (Fig. 1). This upazila is bordered on the north by Fulbaria and Trishal upazila, on the south by Sreepur upazila, on the east by Gafargaon upazila, and on the west by Sakhipur and Ghatail upazila. Five fish farmers from each of the six villages (Uthura, Mallikbari, Bhaluka, Birunia, Kachina, and Habirbari) were chosen at random depending on their cooperation to provide information on fish farming.

Primary data collection

Primary data were gathered through surveys, monitoring, and participatory rural appraisal (PRA) tools like focus group discussions (FGD), and consultations with resource users and stakeholders. A pre-planned questionnaire survey was used to gather primary data on a variety of issues of fish farms, culture practises, production, livelihood status, and constraints related to culture practises. A well-defined and pre-tested questionnaire was used to collect primary data from 30 fish farms. The fish farmers were interviewed at their homes or farms. FGDs were conducted with a group of 5 fish producers from each village.

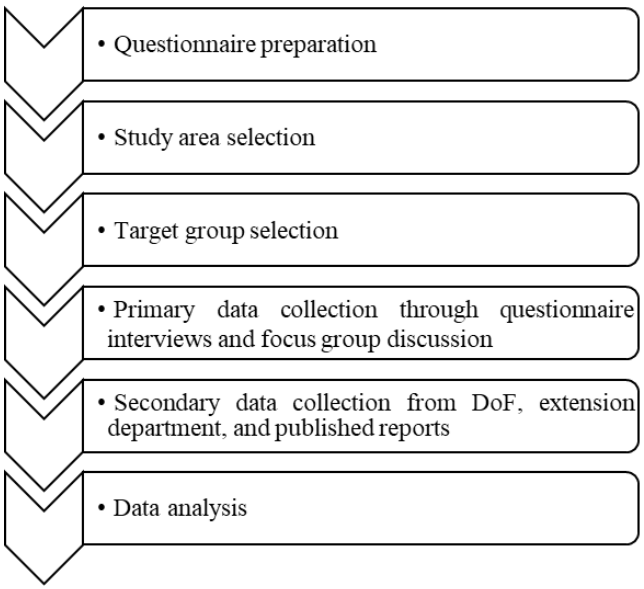

Figure 2. Methodological approach of the study.

Secondary sources

Additionally, secondary information on fish production and fisheries resources was obtained from the Department of Fisheries (DoF). Quarterly and annual reports were also used as secondary sources. Fig. 2 displays a summary of the methodological approach.

Data analysis

Percentage and chi-squared tests were performed using MS Excel and SPSS software (version 25.0). The research area map was generated using QGIS (version 3.22). A Likert scale with values of 4, 3, 2, and 1 was used to rate the constraints faced by farmers in the study area. A variable mean score of 2.5 or above was considered critical, whereas variables with less than 2.5 were not considered critical. The final results are presented in textual, tabular, and graphic representations to illustrate the current state of fish farming practises and the socioeconomic conditions of the farmers in the study area.

Results and Discussion

Demographic characteristics of the fishermen

Demographic characteristics of fish farmers, such as age, education level, occupation, financial support, and source of training, are presented in Table 1. Among all fish farmers, the middle-aged farmers had the highest percentage (53.33%), followed by the young group (36.67%) and old group (10.00%) respectively, in the study area. According to Khatun *et al.* (2013), 46% of fish farmers in the Noakhali district are between the ages of 36 and 50. In another study, Hossen *et al.* (2020) and Ali *et al.* (2009) reported that 52% and 50% of the fish farmers in Barishal Sadar upazila and Tarakanda upazila, respectively, of the Mymensingh district are aged between 31 and 40, respectively, which supports the findings of this study. This information indicates that the majority of the sample farmers were in the active age range and spent more physical energy on fishing.

Education levels among fish farmers aid in the development of conceptual skills and make it easier to acquire technical skills, which can have a direct impact on production generation. In the study area, 53.33% of fish farmers have a secondary education, 23.33% have a primary education, and 10% have a graduate degree or higher. Only 13.33% of farmers are illiterate. According to

Hossen *et al.* (2020), most farmers in Barishal (49%) had a secondary education, whereas only a small percentage (7%) of fish farmers were illiterate. Rahman *et al.* (2016) found that just 15% of pond owners in the study area had a bachelor's degree, 20% of fish farmers had primary-level education, and 32.5% had a high school diploma in Dhumki upazila in the Patuakhali district.

Pond fish farmers were involved in different kinds of activities in addition to raising fish. In the study area, the majority (73.33%) of fish farmers were engaged in fish culture as their primary occupation, while the remaining (26.67%) had it as a secondary occupation. However, in other areas of Bangladesh, fish farmers are engaged in fish culture as a secondary occupation and are involved in business, agriculture, and services as a primary occupation (Ali *et al*., 2009; Hossen *et al*., 2020; Rahman *et al*., 2017). Unlike other areas in the current study area, fish farming is the primary occupation of fish farmers in Bhaluka upazila because it is an important fish farming cluster in the country.

Financial support is crucial for fish culture. In this study, it was observed that roughly 43.33% of farmers used their own funds for fish farming, while 33.33% collected bank loans and 23% collected other sources, such as non-government organisations (NGOs), company loans, moneylenders, and loans from relatives. The findings of this study are similar to those of other studies (Ali *et al*., 2009; Das *et al*., 2018; Hossen *et al*., 2020; Pravakar *et al*., 2013; Quddus *et al*., 2000; Sheheli *et al*., 2013). In the study area, 76.67% of the participants had no prior experience in fish farming. They began fish farming on their own initiative, and 16.67% received training from GOs and 6.67% from other NGOs. Farmers receive training on fish culture from the Bangladesh Fisheries Research Institute (BFRI), the DoF, and various NGOs (Ali et *al.,* 2008; Das *et al.*, 2018; Sheheli *et al*., 2013). Most of the time, farmers used non-scientific methods of fish farming that they learned from their ancestors and neighbours (Ali *et al.,* 2009).

Table 1. Demographic characteristics of fisherman.

Category	Percentage (%)
Age group (age in year)	
Young (20-30)	10.00
Middle (31-40)	36.67
Old (41-60)	53.33
Education level	
Illiterate	13.33
Primary	23.33
Secondary	53.33
Graduate or above	10.00
Occupation	
Fish culture as primary occupation	73.33
Fish culture as secondary occupation	26.67
Source of Financial support for fish farming	
Own	43.33
Bank loan	33.33
Others	23.33
Source of training	
No formal training	76.67
Training from government organizations	16.67
Training from non-government organizations	6.67

Characteristics of the fish pond and culture system

Table 2 lists the characteristics of the fish ponds and fish culture systems in the study area. Pond size is crucial for keeping fish production costs low. According to the study, 26.67% of respondents have pond areas smaller than 2000 m^2, 33% have pond areas between 2000 m^2 and 4000 m^2, and 40% have pond areas larger than 4000 m^2. Although there are variations in pond size throughout the country (Das *et al*., 2018; Pravakar *et al*., 2013; Rahman *et al*., 2022), most of the ponds are larger than 4000 m^2 in the study area. However, farmers believe that smaller to medium sized ponds are suitable for effective management.

Among the studied fish ponds, 60% were within a depth of 1–2 m, followed by shallow (< 1, 23.33%), and deep (> 2, 16.67%). The DoF (2012) stated that the typical pond depth in Bangladesh is between 2 and 5 m, which is consistent with the findings of the current study.

In the research area, 23.33% of the ponds were seasonal and 76.67% were perennial. During the dry season, the water level of the perennial ponds drops but remains suitable for fish farming. In contrast, seasonal ponds are completely unsuitable for fish farming during the dry season. It has been reported that most of the fish ponds in Dinajpur, Chandpur, Rajshahi, and Tangail are perennial ponds (Ali *et al.,* 2008; Fatema *et al*., 2018; Pravakar *et al*., 2013; Saha, 2004). However, Das *et al.* (2018) reported that most (79.09%) fish ponds in Gazipur are seasonal. Moreover, the water-holding capacities of fish ponds are probably dependent on the geographical location.

In this study, it was found that 30% of the fish farmers raised fish in their own ponds, 20% of the fish ponds have multiple ownership, and 50% of the fish ponds are leased. According to Hossain *et al.* (2002), multiple pond ownership is a significant barrier to pond aquaculture. Polyculture of carp, tilapia, and catfish was found to be the major (80%) type of fish culture system, and 20% of the fish farmers were found to carry out pangas monoculture in the survey area. In comparison, polyculture uses available

Table 2. Characteristics of the fish pond and fish culture system.

Category	Percentage (%)
Area (Square meter, m^2)	
Small (< 2000)	26.67
Medium (2000 - 4000)	33.33
Large (> 4000)	40.00
Depth (m)	
Shallow (< 1)	23.33
Medium (1-2)	60.00
Deep (> 2)	16.67
Type	
Seasonal	23.33
Perennial	76.67
Ownership	
Own	30.00
Multiple	20.00
Leased	50.00
Culture system	
Polyculture	80.00
Monoculture	20.00

space and food supplies more efficiently than monoculture (Anil *et al.,* 2010; Hossen *et al.,* 2020). According to other studies, polyculture is also the most popular fish culture system in Bangladesh (Halim *et al.,* 2017; Hossen *et al*., 2020; Pravakar *et al*., 2013; Siddiqua *et al*., 2019).

Major fish species

The popular fish species cultured in the survey area are presented in Fig. 3. The investigation revealed that carp (locally known as Bangla fish) were the most popular species in the study area, including rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*), calibaus *(L. calbasu*), and bata (*L. bata*). The fishermen were also found to raise exotic fish such as silver barb (*Barbonymus gonionotus*), silver carp (*Hypophthalmichthys molitrix*), catfish as pangus (*Pangasius pangasius*), magur (*Clarias batrachus)*, and shing (*Heteropneustes fossilis*), and various other fish, including tilapia (*Oreochromis niloticus*) and koi (*Anabas testudineus)*. Pangus was primarily found growing in monocultures, while other species were mostly grown

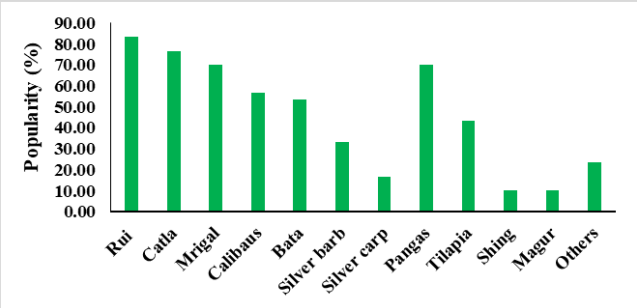

Figure 3. Popular species of fish cultured in monoculture and polyculture systems at Bhaluka upazila.

in polyculture systems. Fatema *et al.* (2018) reported that farmers engaged in carp polyculture, including major carp, exotic carp, and other fish, due to faster growth, high consumer demand, easy production systems, and the availability of fish seeds.

Management of the fish pond

The pond management techniques used in the study area are listed in Table 3. Farmers were found to use both commercial and homemade feed in their ponds. Although commercial diet is expensive, it was found to be the most popular because homemade feed preparation is time-consuming and tedious. Farmers were found to apply both organic (compost, cow dung, and chicken manure) and inorganic (urea, and TSP) fertilisers in the surveyed fish farms. Das *et al.* (2018) reported that fertiliser application is crucial to boost natural food (phytoplankton, zooplankton, and benthic creatures) production and thus increase fish yield. Salt and lime were regularly used chemicals in the fish ponds. In addition, zeolite, $KMnO_4$, oxygen tablets, and other commercial drugs were also found to be used to maintain water quality, prevent, and control fish disease. Kawsar *et al.* (2019) also reported that salt and lime are the most frequently used chemicals in fish culture in Bangladesh. Fish farmers partially harvested (80%) their fish when they grew to marketable size, and 20% of them were found to completely harvest their stock at the end of their culture period. Seine nets (80%) and cast nets (20%) were the most popular fishing gear for harvesting fish.

The management approaches applied in the fish farms of Bhaluka upazila are more or less similar to those applied in other parts of the country (Das *et al*., 2018; Fatema *et al*., 2018; Pravkar *et al*., 2013; Rahman *et al*., 2016; Rahman *et al*., 2022; Siddique *et al*., 2019).

Table 3. Pond management techniques in the study area.

Category	Percentage (%)
Fish culture system	
Extensive	13.33
Semi-intensive	80.00
Intensive	6.67
Feed type	
Homemade feed	20.00
Commercial Feed	60.00
Both	20.00
Harvesting method	
Partial harvest	80.00
Complete harvest	20.00
Fishing gear	
Seine net	80.00
Cast net	20.00

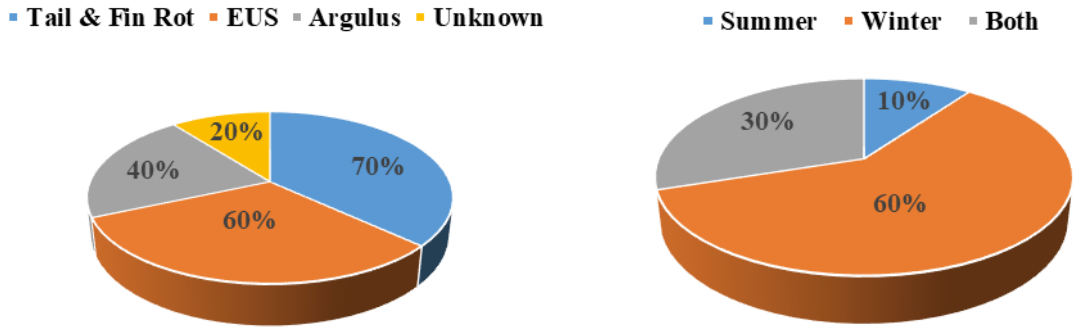

Figure 4. Type and season of occurrence of fish disease.

Chi-squired test to compare demographic factors and fish culture practises

The interrelationships between demographic variables and fish farming practises in the study area are presented in Table 4. In the current study, the age of fish farmers has a statically significant ($P < 0.03$ and $P < 0.01$) association with the source of training on fish culture and pond type, respectively. This indicates that different age groups tend to receive training from different sources and prefer different types of ponds. These findings align with a previous study that reported that older farmers rely more on traditional practises, whereas younger farmers are more inclined to adopt modern techniques and training programmes (Wabbi, 2002). Furthermore, financial support showed a significant association ($P < 0.04$) with pond size. This relationship underscores the importance of financial capital in developing and expanding aquaculture operations. Previous research has similarly noted that financial constraints can limit the scale and productivity of fish farming (Kumar *et al.,* 2018). On the other hand, pond size was significantly associated with feed type ($P < 0.02$). Different management strategies may be required depending on the pond size, which may affect feed type selection. This finding is consistent with studies that emphasise the impact of pond size on aquaculture management strategies (Kumar *et al.,* 2018). Moreover, pond ownership showed a significant ($P < 0.02$) association with the harvesting method. This finding indicates that ownership structures affect operational decisions. Individually owned ponds potentially allow more flexibility for implementing management strategies than jointly owned or leased ponds (Leonard & Mahenge, 2022).

Table 4. Chi-square test (non-parametric data) between demographic variables and fish farming practises.

Variable	Chi-squired value	*P*-value
Age and source of training	14.163	0.03
Age and pond type	11.070	0.01
Financial support and pond size	9.289	0.04
Pond size and feed type	11.222	0.02
Ownership and harvesting method	7.500	0.02

Disease outbreak

Commercial fish farming in Bangladesh faces significant challenges in managing fish disease. Farmers in the study area reported an increase in disease occurrence. In this study area, tail and fin rot was reported in 70% of the farms, epizootic ulcerative syndrome (EUS) in 60%, argulosis in 40%, and an unknown disease in 20% of farms (Fig. 4). Tail and fin rot is a bacterial disease caused by *Flavobacterium columnare*, and EUS is a fungal disease caused by *Aphanomyces invadans* (Arshad & Arockiaraj, 2020; Rahman *et al*., 2010). Diseases were most prevalent during winter. At low temperatures, the physiological activity of fish decreases and they become more susceptible to fish disease (Snieszko, 1974).

Table 5. Impact of fish farming on the living standards of fish farmer (n=30).

Statement	Farmers Opinion (%)		
	Improved	Same as before	Deteriorated
Household income	86.67	13.33	0.00
Position in the family	70.00	26.67	3.33
Housing condition	63.33	36.67	0.00
Health situation	23.33	76.67	0.00
Water facilities	30.00	70.00	0.00
Participation in social activities	86.67	10.00	3.33
Freedom in cash expenditure	60.00	33.33	6.67
Overall livelihood	76.67	23.33	0.00

Table 6. Major constraints in fish farming.

Constraints	Very critical	Critical	Moderately critical	Not critical	Score	Average	Remarks
Increasing feed cost	18	8	4	0	104	3.47	Critical
Lack of financial support	9	12	5	4	86	2.87	Critical
Disease outbreak	9	14	5	2	90	3.00	Critical
Lack of quality seed	3	13	10	4	75	2.50	Critical
Poaching and vandalism	0	2	7	21	41	1.37	Not critical
Transportation cost	3	7	11	9	64	2.13	Not critical
Water supply	6	5	13	6	71	2.37	Not critical
Electricity supply	0	1	8	21	40	1.33	Not critical
Fishing accessories	0	1	6	23	38	1.27	Not critical
Natural calamities	2	5	7	16	53	1.77	Not critical

Impact of fish farming on livelihoods

Table 5 summarises the significant changes in livelihood areas in view of fish farmers. About 76.67% of fish farmers said that fish farming enhanced their quality of life. The family position, housing condition, participation in social activities, and freedom in cash expenditures improved remarkably. However, 23.33% of farmers reported that participation in fish farming has no effect on their overall standard of living, whereas no one reported a deterioration in their livelihood. Rahman *et al.* (2017) and Ali *et al.* (2009) also reported that fish farming has a beneficial impact on income generation and food security. Hossen *et al.* (2020) also found that farmers' socioeconomic circumstances improved after switching from agricultural to fish farming.

Major constraints in fish farming

The major constraints faced by fish farmers are presented in Table 6. Increasing feed costs, lack of financial support, disease outbreaks and lack of quality seeds were identified as critical problems in the study area. Daniel (2018) reported that feed costs represent up to 70% of the total production cost of a fish farm. Due to rising prices for different raw materials, the cost of feed is increasing annually (Prodhan & Khan, 2018). Disease outbreaks and lack of quality fish seeds were also reported as major constraints in fish culture in Chadpur, Gazipur, and Barishal districts, however, farming constraints are more or less similar everywhere (Das *et al*., 2018; Hossen *et al*., 2020; Pravakar *et al*., 2013).

Conclusion

Fish farming substantially improved the livelihoods of fish farmers in the study area, despite many constraints. High feed costs, lack of quality fish seeds, lack of financial support, and disease outbreaks were the critical constraints of fish farming in the study area. The government should provide microcredit support, high-quality inputs, including fry, feed, vaccinations and the provision of training facilities to support fisheries and aquaculture activities in this region.

Ethics Committee Approval: In Bangladesh, ethical approval is generally not required for studies involving invasive procedures, nor have clinical trials or any physical interventions been performed.

Peer-review: Externally peer-reviewed.

Authors Contributions: Conception/Design of Study- S.S.M., M.R.I., M.S.I.; Data Acquisition- S.S.M., M.R.B., A.S.I.; Data Analysis/Interpretation- S.S.M., M.R.I., M.N.H.; Drafting Manuscript- S.S.M., M.R.B., A.S.J.; Critical Revision of Manuscript- M.R.I., M.S.I., M.N.H.; Final Approval and Accountability- S.S.M., M.R.B., A.S.J., M.S.I., M.N.H., M.R.I.

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RESEARCH ARTICLE

Growth and Reproductive Capacity of the Endemic Fish Species *Egirdira nigra* (Teleostei: Leuciscidae)

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Abstract

Objective: In this study, various characteristics of the Eğirdir minnow, an endemic species of Anatolia that inhabits specific/narrow areas, were determined from 142 individuals sampled between 2021 and 2022. These characteristics include length-weight relationship, Von Bertalanffy growth equation, condition factors, spawning season, first spawning size, and fecundity attributes.

Materials and Methods: A monthly sampling of 142 specimens of *Egirdira nigra* was conducted using multi-mesh gill nets between March 2021 and April 2022.

Results: The sampled *E. nigra* population consists of individuals aged II-V, with 57.75% female and 42.25% male. The length-weight relationships were as follows: $W = 0.0059 L^{3.5445}$, $R^2 = 0.9312$ (female + male), $W = 0.009 L^{3.3077}$, $R^2 = 0.9353$ (male), and $W = 0.0058 L^{3.5679}$, $R^2 = 0.9233$ (female). The condition factors were calculated as 1.67 (male) and 1.87 (female). The gonadosomatic index was highest in March (13.95) and lowest in August (0.5073). The population's mean fecundity was calculated as 4787 individuals/egg.

Conclusion: Although the population exhibits a wide age range and positive growth values, it is believed to be under significant threat from invasive/exotic species sharing the same environment, such as *Atherina boyeri, Gambusia holbrooki, Pseudorasbora parva*, and *Carassius gibelio*. Therefore, the conservation of species and their habitats is of paramount importance.

Keywords: Conservation, Eğirdir minnow, endemic, growth, reproduction

Introduction

Spring minnows of the cyprinid genus *Pseudophoxinus* inhabit regions spanning Central Anatolia to Azerbaijan and south to Israel. Their distribution is often confined to limited streams or springs, making them one of the most challenging fish groups for conservation within the heavily impacted Middle Eastern landscape (Güçlü & Küçük, 2017; Hrbek *et al.,* 2004). Recent phylogenetic analyses have delineated *Pseudophoxinus* into two distinct lineages, each corresponding to a specific geographic region. Past isolation within Anatolia's inland systems has been identified as a significant factor shaping the speciation process of this genus, with central and southwestern Anatolia's lake basins proposed as potential centres of origin (Küçük *et al.,* 2012). Taxonomic investigations conducted in Anatolia have identified 22 species, among which *P. handlirschi*, endemic to Lake Eğirdir, became extinct in the early 1970s, purportedly because of the introduction of pikeperch (*Sander lucioperca*). With the exception of *P. libani* and *P. zeregi*, all *Pseudophoxinus* taxa, which are crucial components of Anatolia's inland water fish fauna, are endemic to the region. Major threats to *Pseudophoxinus* species include water abstraction, dam-induced flow alterations, heightened drought occurrences linked to climate change, invasive alien species, agricultural pollution, and habitat degradation (Güçlü & Küçük, 2017).

Egirdira nigra, which is endemic to Eğirdir Lake and its basin in Central Anatolia, has undergone taxonomic revision over the years. Initially described as *Pararhodeus niger* by Kosswig and Geldiay in 1952, it was later reclassified as *Phoxinellus egridiri, Pseudophoxinus egridiri* (Bogutskaya, 1997). In the latest morphology-based taxonomic study by Freyhof (2022), the species was redefined as *E. nigra* (Fig. 1). The species is known to inhabit not only Lake Eğirdir and certain streams (Çayköy and Yalvaç streams) that feed into the lake but also karstic spring water (Yeşilyurt village-Sütçüler) located approximately 35-40 km south of Lake Eğirdir, which is currently disconnected from the lake (Küçük & Gülle, 2016). An increase in the population of this species has been observed in the lake over the last 20 years. However, recent field studies and observations over the past five years indicate that many of the conservation criteria set by the IUCN (2013-2014) have changed adversely. In fact, it has been determined that some taxa (due to factors such as climate change, drought, habitat loss, pollution, predation, agricultural irrigation, etc.) could completely disappear from nature. It is also believed that *E. nigra* will be under significant medium-term threat for similar reasons (Güçlü, 2022; Küçük *et al*., 2021).

There are not sufficient research available regarding the biology of *E. nigra*. Thus far, studies have been limited to length-weight relationship analyses (Apaydın Yağcı *et al*., 2022; Saç & Özuluğ, 2018). The only detailed study conducted on the species' growth characteristics is by Yeğen & Sarı (2021). There are no studies on the reproductive features of this species. Therefore, our study emphasises the necessity of investigating the reproductive biology and growth characteristics of the *Egirdira nigra* population, an endemic species of Anatolia, using samples collected between 2021 and 2022 from 142 individuals. Recommendations for the conservation of the species are also proposed.

Materials and Methods

The samples were collected from Eğirdir Lake in Akkeçili Village (38°08'27.28"N 30°47'40.49"E) between March 2021 and April 2022. For fish sampling, sampling equipment and beach seine nets (5 and 15 mm mesh size) were used in accordance with the European Standard methodology EN 14757 (Water quality - Sampling of fish with multi-mesh gillnets) determined by the European Union for pelagic and demersal sampling. According to EN 14757 standards, these multi-mesh gillnets are designed to catch freshwater fish of all sizes and species. Each net consists of eight panels with mesh sizes ranging from 10 mm to 100 mm (10, 15, 20, 40, 55, 70, 80, and 100 mm mesh size). The length of the nets was 35 m, and their depths ranged from 1.5 to 6 m (35×1.5 m and 35×6 m). Individual specimens underwent precise measurements of total length (TL) to the nearest 0.01 cm and total weight (W) to the nearest 0.01 g. Age was determined by examining scales extracted from the left lateral side of each specimen, specifically from the region between termination of the pectoral fin and commencement of the dorsal fin. Observations were conducted using a stereoscope equipped with transmitted light, ensuring optimal visualisation and accurate data acquisition.

Figure 1. *Egirdira nigra*, 83.21 mm SL, male (+3 age).

The distribution of female and male participants was assessed according to age. The male to female ratio was evaluated using chi-square tests (with a significance level of 0.05) following the methodology described by Düzgüneş *et al.* (1995). The frequency distributions of total length and weight in centimetres were computed for all specimens. An exponential regression equation of the form $W = a \times L^b$ was employed to establish the relationship between weight (W) and length (TL), where *W* is body weight in grammes and *TL* denotes total length in centimetres. In this equation, *a* represents the intercept, and *b* denotes the regression coefficient. Additionally, the coefficient of determination (R^2) was calculated to assess the goodness of fit of the regression model, as outlined by Ricker (1975). The growth of the *E. nigra* population was estimated using the following Von Bertalanffy growth equations: $L_t = L\infty (1 - e^{-k(t - to)})$, where *Lt* is the total length in cm at age *t*, *L*∞ the average asymptotic length in mm, and *k* is the body growth coefficient, *to* the hypothetical age and *a* and *b* constants (Le Cren, 1951). The statistical significance level of the coefficient of determination (R^2) and the 95% confidence intervals (95% CI) of the regression coefficient *b* were calculated following the methodology outlined by Zar (1999). To compare the deviation of the slope value from the expected value of *b* = 3, which represents isometric growth, Pauly's *t*-test was conducted for all species, as described by Pauly (1984). Pauly's *t*-test was calculated as follows:

$$t = \frac{Sd_{\log TL}}{Sd_{\log W}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2},$$

where Sd_{logTL} is the standard deviation of the *logTL* values, Sd_{logW} is the standard deviation of the *logW* values, and *n* is the number of fish species used in the computation. If the calculated *t* value exceeds the critical *t* value from the *t*-distribution table for degrees of freedom (n-2), as outlined by Pauly (1984), then slope parameter (*b*) is deemed significantly different from 3, indicating non-isometric growth. Furthermore, a *t*-test with a significance level of 0.05 was employed to assess the agreement between the measured total length and total length calculated using the Von Bertalanffy growth equation. The average growth performance (Ø ', phi prime) was calculated with the formula $Ø' = \text{Log } k + 2 \times \text{Log } L_\infty$ (Gayanilo *et al*., 1988). Fulton's coefficient of condition factor was calculated using $CF = (W/TL^3) \times 100$ (Sparre & Venema, 1989). The gonadosomatic index (GSI) was calculated as: GSI= GW / W × 100, where *GW* was the gonad weight and *W*, the total body weight of the fish (Gibson & Ezzi, 1980). The spawning period was determined from the monthly evaluation of the GSI. Fecundity was determined gravimetrically based on the number of mature oocytes in 82 females at the spawning stage. The diameter of each egg was measured using a microscopic micrometre, following the protocol outlined by Nikolsky (1980). The maturity level of the female participants was assessed using the sigmoid logistic curve fitting method. The estimation of length at first sexual maturity was conducted according to the approach described by De Martini *et al*. (2000): Firstly, it was plotted against $\ln [(1-P_x)/P_x]$ using simple linear regression to estimate values for *a* and *b*. Here, *Px* is the observed proportion of mature at length *x*. Second, the mean length at 50% maturity was calculated using $L_m = a/b$. Subsequently, the proportions of maturity at various lengths (L) were estimated using the formula $PL = 100 / [1+e^{b(L-Lm)}]$, allowing for a graphical representation of the onset of first sexual maturity. Here, *PL* denotes the estimated proportion of maturity at length *L*, as defined by De Martini *et al*. (2000).

Ethics committee approval was obtained for this study from the ethics committee of Isparta University of Applied Sciences Local Ethics Committee for Animal Experiments (Date: 12.03.2020, No: 001). The experimental conditions did not disturb the fish involved in our experiments.

Results

The sampled population of *E. nigra* consisted of 57.75% females and 42.25% males within the age range of II-V (Table 1).

Table 1. Age and sex distributions of the *E. nigra* population in Lake Eğirdir.

Age group	F		M		F+M		F:M
	N	%N	N	%N	N	%N	
II	6	4.22	17	11.97	23	16.19	0.35:1.00 (p<0.05)
III	38	26.76	31	21.83	69	48.59	1.22:1.00 (p<0.05)
IV	34	23.95	11	7.74	45	31.69	3.09:1.00 (p<0.05)
V	4	2.81	1	0.7	5	3.52	4.00:1.00 (p<0.05)
∑	**82**	**57.75**	**60**	**42.25**	**142**	**100**	**1.36:1.00 (p<0.05)**

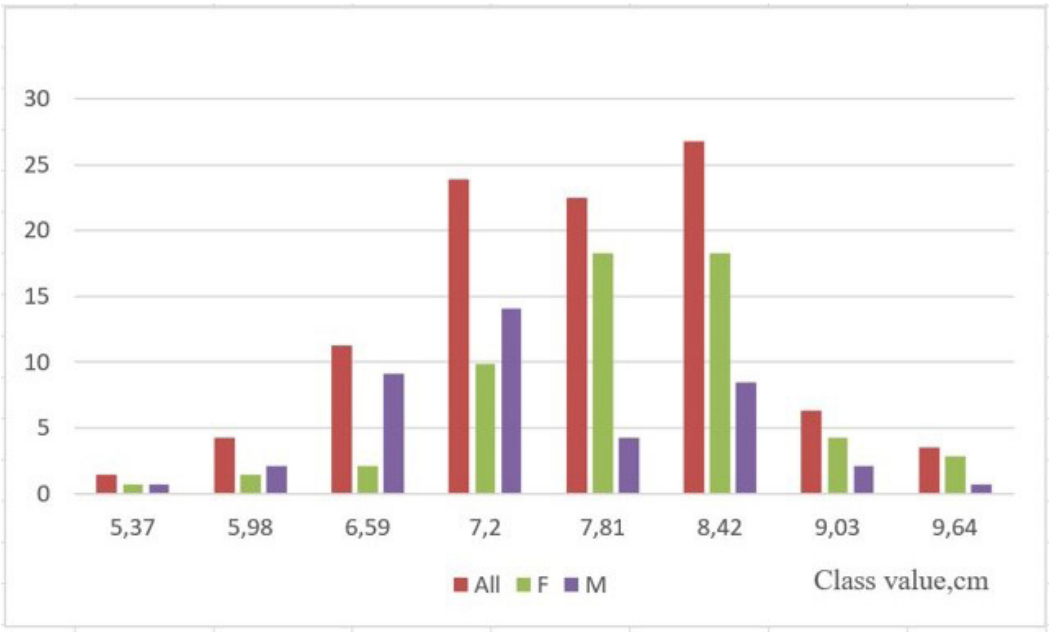

Figure 2. The size (cm) distribution (%) of the *E. nigra* population in Lake Eğirdir.

According to the data obtained from samples comprising 142 individuals, the size distribution of the population ranged from 5.07 cm to 9.90 cm, with individuals between 6.90 cm and 8.72 cm constituting 73.23% of the population (Fig. 2, Table 2). Regarding weight distribution, in the population ranging from 1.91 g to 19.89 g, individuals between 6.43 and 13.20 g accounted for the majority of the population (77.46%) (Table 3).

When examining the age-size distribution of the sample population, it is evident that the majority of specimens (114 individuals) belonged to the age group III-IV, reaching a size range of 7.51-8.72 cm (Table 2). A similar pattern was observed in the age-weight distribution, where the majority of the population (114 individuals) fell within the III-IV age group, ranging between 6.43 and 13.20 g in weight (Table 3).

Table 2. Distribution of total length and age among female (F) and male (M) *E. nigra* specimens.

Age class	**II**		**III**		**IV**		**V**		**Total**
Total Length cm)	♀	♂	♀	♂	♀	♂	♀	♂	
5.07-5.67	1	1	-	-	-	-	-	-	**2**
5.68-6.28	2	3	-	1	-	-	-	-	**6**
6.29-6.89	2	11	1	2	-	-	-	-	**16**
6.90-7.50	1	2	12	18	1	-	-	-	**34**
7.51-8.11	-	-	19	6	7	-	-	-	**32**
8.12-8.72	-	-	6	4	20	8	-	-	**38**
8.73-9.33	-	-	-	-	6	2	-	1	**9**
9.34-9.94	-	-	-	-	-	1	4	-	**5**
∑	**6**	**17**	**38**	**31**	**34**	**11**	**4**	**1**	**142**
	TL ± SD(min-max)								
♀+♂	6.40±1.00 (5.07-7.09)		7.53±0.57 (6.07-8.54)		8.41±0.61 (7.41-9.52)		9.44±1.17 (9.08-9.90)		7.94±0.80 (5.07-9.90)

Table 3. Distribution of weight and age among female (F) and male (M) *E. nigra* specimens.

Age class	II		III		IV		V		Total
Weight (g)	♀	♂	♀	♂	♀	♂	♀	♂	
1.91-4.16	4	10	-	-	-	-	-	-	**14**
4.17-6.42	1	6	-	1	-	-	-	-	**8**
6.43-8.68	1	1	21	26	2	-	-	-	**51**
8.69-10.94	-	-	12	3	12	3	-	-	**30**
10.95-13.20	-	-	5	1	15	7	-	1	**29**
13.21-15.46	-	-	-	-	5	1	-	-	**6**
15.47-17.72	-	-	-	-	-	-	3	-	**3**
17.73-19.98	-	-	-	-	-	-	1	-	**1**
∑	**6**	**17**	**38**	**31**	**34**	**11**	**4**	**1**	**142**
				W ± SD (min-max)					
♀+♂	4.26±0.27 (1.91-6.80)		7.79±0.23 (4.36-12.73)		11.31±0.23 (7.71-14.90)		16.44±1.00 (12.95-19.89)		9.95±0.43 (1.91-19.89)

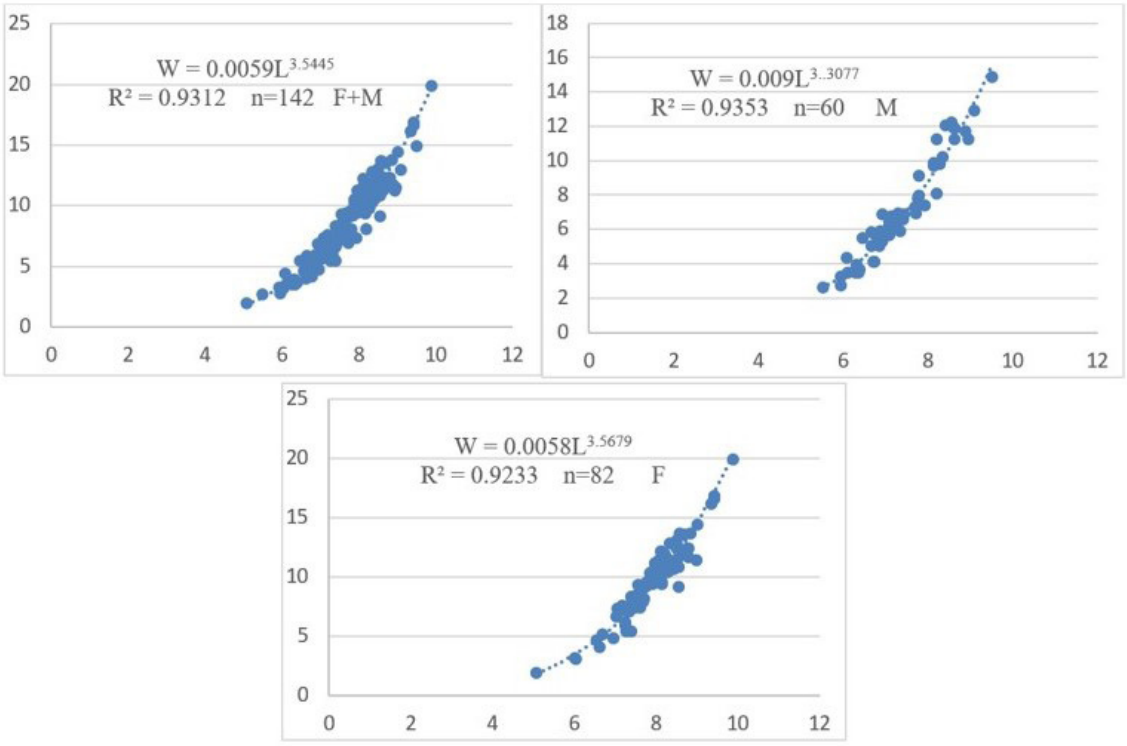

Figure 3. The length-weight correlation values for the population of *E. nigra* (F: Female, M: Male, n: Number of individuals).

The length-weight relationships; $W = 0.0059\ L^{3.5445}$, $R^2 = 0.9312$ (male + female), $W = 0.009\ L^{3.3077}$, $R^2 = 0.9353$ (male), and $W = 0.0058\ L^{3.5679}$, $R^2 = 0.9233$ (female) (Fig. 3, Table 4); the condition factor is calculated as 1.67 (male) and 1.87 (female).

The following Von Bertalanffy growth equation was obtained for all $L_t=11.76\ (1-e^{-0.2357(t-1.329)})$ and $W_t=38.24\ (1-e^{-0.2357(t-1.329)})^{3.5679}$ (Fig. 4). The differences between the observed and expected total lengths were not statistically significant in all age groups (*t*-test, $p>0.05$) (Table 5). The average growth performance (Ø ‘, phi prime) was calculated as 1.51.

Table 4. Growth characteristics of the *E. nigra* population.

	a	b	R^2	95% Confidence interval *b* (±SH)	Pauly's *t*-test	P	CF	Growth type
Female	0.0058	3.5679	0.9233	3.4214-3.6247 (±0.0012)	4.526	<0.001	1.87	+ Allometry
Male	0.009	3.3077	0.9353	3.2957-3.3201 (±0.0125)	8.259	<0.001	1.67	+ Allometry
All	0.0059	3.5445	0.9312	3.5403-3.5526 (±0.0542)	5.361	<0.001	1.74	+ Allometry

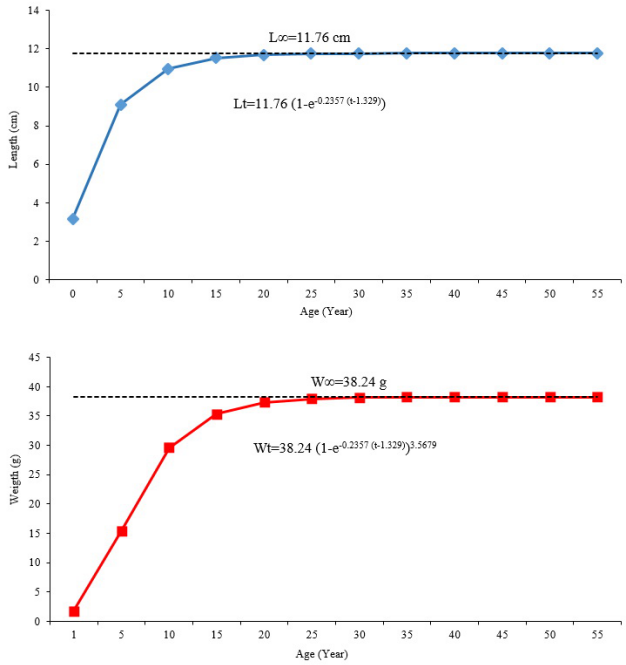

Figure 4. L_∞ and W_∞ value according to Von Bertalanffy growth equation of *E. nigra.*

Table 5. Measured total average length and calculated total average length values by age groups in the Von Bertalanffy growth equation of *E. nigra.*

Age groups	Measured average length (cm)	Calculated average length (cm)	*t*-test
II	6.40	6.39	p>0.05
III	7.53	7.52	p>0.05
IV	8.41	8.41	p>0.05
V	9.12	9.11	p>0.05

The Gonadosomatic Index (GSI) exhibits its highest value in March (13.95) and lowest in August (0.5073) (Fig. 5). Through observation of gonad development and monthly fluctuations in the GSI, intermittent spawning of the population has been identified, occurring between March and August. The population's fecundity was determined to be 4787.112 ± 202.52 individuals/eggs (Table 6). The size at first spawning (L_{mat}) was calculated to be 6.11, representing 50% maturity (Fig. 6). Additionally, the mean diameter of eggs was measured at 0.88 ± 0.02 mm.

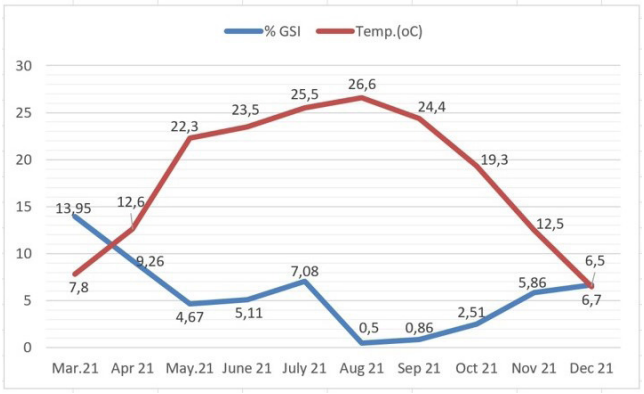

Figure 5. GSI (%) and water temperature (°C) values of *E. nigra* population.

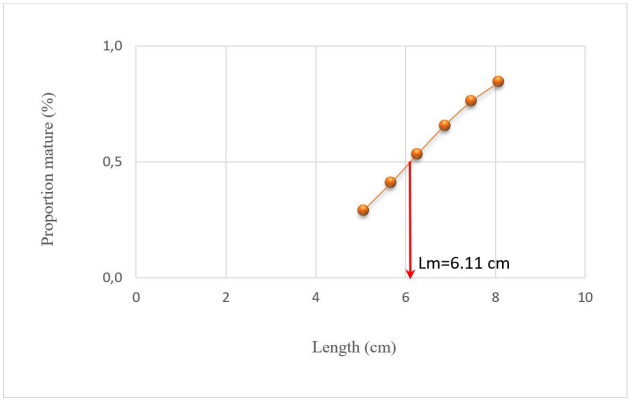

Figure 6. Length at first maturity of male and female *E. nigra* in Lake Eğirdir.

Discussion

Numerous investigations have been undertaken to elucidate the molecular taxonomic and population attributes of *E. nigra*. Nevertheless, the majority of efforts aimed at delineating its ecological traits have remained confined to the analysis of length-weight correlations. Only 1-2 studies have comprehensively disclosed all bio-ecological characteristics pertinent to the species.

Table 6. Average total length (TL, cm), weight (W, g), gonad weight (GW, g), and fecundity (F, number/individual/year) values of female individuals with eggs according to age of *E. nigra* (SE= Standart error, n= number of samples)

Age	n	TL± SE	W ± SE	GW± SE	F ± SE
II	6	6.23±1.30	3.91±1.01	0.18±0.05	2696.15±593.67
III	38	8.58±0.64	8.58±0.94	0.70±0.08	3423.12±592.16
IV	34	8.34±0.98	11.24±0.86	1.16±0.04	6616.21±412.23
V	4	9.53±0.28	17.33±0.63	2.41±0.11	6413.02±284.02
Σ	82	8.17±0.80	10.26±0.86	1.11±0.07	4787.11±202.52

The age range of the species was consistent with the limited possible age range of small fish species (Nikolsky, 1980). The reason why there are no 0 and I age groups is due to the selective nature of the fishing equipment used. If the eye openings used in fishing were smaller, it would be possible to identify age groups 0 and I. The ability of individuals of a species capable of reaching a maximum size of 11-12 cm can grow up to 5 years old is considered a significant achievement in terms of the current population and future of the species. In the only growth study conducted on the species between 2010 and 2011, the 0-V age range was determined, and approximately 80% of the population consisted of individuals in the II and III age groups (Yeğen & Sarı, 2021). Nikolsky (1980) proposed that a population with a diverse age distribution could serve as an indicator of adequate nutrient levels within aquatic ecosystems. The decline in older age cohorts within the population is anticipated to result in a corresponding rise in younger cohorts, thereby mitigating food competition. Such dynamics also signify successful reproductive endeavours, as evidenced by the influx of new individuals into the population. However, in our study, the opposite situation was observed. Small individuals could not be caught due to the selective nature of the hunting equipment or the lack of fishing with small mesh nets. Thus, most population consisted of individuals in the III-IV age group.

In their research, Yeğen & Sarı (2021) observed that the *E. nigra* population exhibits a length ranging from 2.1 to 10.0 cm, with weights ranging from 0.11 to 17.38 g, and attains maturity within a 5-year timeframe. Furthermore, the study revealed that a significant proportion (79.7%) of the population comprised individuals aged between two and three years. Apaydın Yağcı *et al*. (2022) determined, based on 551 samples, that the population had a total length of 4.7-10 cm and a weight of 2.4-17.4 g and showed isometric growth ($b = 2.9425$). Our study is similar to other studies.

The sex ratio of females to males in *E. nigra* was 1.36:1.00 (χ^2, $p<0.05$). Nikolsky (1980) asserted that sex ratios vary significantly among species, although most species tend to exhibit ratios close to unity. Discrepancies in sex ratios may stem from various factors, such as differences in lifespan and early maturation rates between sexes, differential growth patterns, mortality rates, and reproductive energy expenditure. Additionally, the dominance of one sex over the other could be attributed to divergent behaviours facilitating the preferential capture of one sex and discrepancies in mortality rates between sexes (Ghafouri *et al*., 2019). The deviation from the expected male-to-female (M:F) ratio observed in our study may be ascribed to the sampling approach used.

Variations in growth parameters could arise from ecological disparities among research regions, including differences in water temperature, water quality, and nutrient levels within the environment. The disparity between observed and anticipated total lengths of *E. nigra* was not statistically significant (*t* test, $p > 0.05$). The population reached a length of 11.76 cm, denoted as L_∞, at approximately 20 years of age. Variations in L_∞ are hypothesised to be influenced by species-specific factors, water temperature, environmental conditions, and nutritional availability. The infinite weight has been determined as 38.24 g, and it is thought that it will reach infinite weight in the next 25 s. The data of our study are compatible with those of another study conducted ($L\infty$=11.22 cm) in 2010-2011 (Yeğen & Sarı, 2021).

The exponents derived from the total length-weight relationship of *E. nigra* exhibit positive allometry (Table 4). Typically, a narrower length range and lower abundance of smaller fish may lead to a higher b value, as smaller juvenile fish tend to possess a more rounded body shape, gradually elongating as they mature (Froese, 2006). In contrast, other studies by Yeğen & Sarı (2021) reported positive allometric growth, whereas Apaydın Yağcı *et al*. (2022) observed negative allometric growth (Table

7). The regression coefficient (R^2) for the total length-weight relationship across all samples is 0.93, indicating a negligible deviation from the expected increase in regulation within total length-weight relations. Although the R^2 value aligns closely with findings from prior studies (Saç & Özuluğ, 2018; Yeğen & Sarı, 2021), it surpasses the value reported in the study by Apaydın Yağcı *et al*. (2022) (Table 7).

In the reproductive strategies of fish, there is considerable diversity in characteristics such as reproductive system, mating system, sex, spawning habitat, spawning season, and fecundity (Helfman *et al.,* 1997). Spawning typically occurs from March to August, with the first maturation observed at age II. The initial maturity length (L_m) was estimated as 6.11 cm. In addition, the phenomenon of repeated spawning over an extended reproduction period may serve as an adaptation to mitigate food competition between juvenile and adult individuals. Early attainment of sexual maturity and reproductive strategies among fish inhabiting dynamic ecosystems (Nikolsky, 1980). The way to terrestrial environments. The numerous narrowly distributed endemic aquatic organisms in the region have been significantly affected by these changes, both due to sharing specialised habitats and limited living spaces. According to a study on "The Effects of Climate Change on Endemic Fish Species in Central Anatolia," similar to other regional endemics, *E. nigra* is expected to be affected by the prevailing climate change in our country, with a projected decline in its population during the period 2041-2060 (Güçlü, 2022). *Egirdira nigra,* which is endemic to the Lake Eğirdir basin, thrives particularly in areas with abundant underground water sources, especially in the northern region of the lake. The decrease in the piscivorous pressure exerted by *S. lucioperca* over the past 20-30 years in the lake indicates a positive development for *E. nigra* and A*natolichthys iconii* populations. On the other hand, as is the case worldwide, the disappearance of aquatic habitats due to prevailing drought conditions in most parts of our country pose a threat to the future of specialised species like *E. nigra*.

Table 7. Research findings on the growth characteristics of the *E. nigra* population in Lake Eğirdir.

Ref.	N	Age	TL (cm)	M:F	L∞	k	to	Ø'	*a*	*b*	R^2	CF	Growth Type
1	85	-	2.3-6	-	-	-	-	-	0.019	3.10	0.97	-	-
2	544	0-V	2.1-10	0.82:1.00	11.22	0.30	-0.64	1.57	0.009	3.27	0.95	1.48	+A
3	551	-	4.7-10	-	-	-	-	-	0.018	2.94	0.88	-	-A
This Study	**142**	**II-V**	**5.07-9.9**	**1.36:1.00**	**11.76**	**0.23**	**-1.32**	**1.51**	**0.005**	**3.54**	**0.93**	**1.79**	+A

Ref: 1- Saç & Özuluğ, 2018; 2-Yeğen & Sarı, 2021; 3- Apaydın Yağcı *et al*., 2022

data obtained regarding the reproductive characteristics of *E. nigra* possess the attributes of being initial data. Reproductive potential is a measure of a population's capacity to produce viable eggs and larvae and can be considered the primary outcome of a reproductive strategy. Reproductive potential is defined by various factors, including spawning stock biomass (Bagenal, 1973; Myers & Barrowman, 1996), age distribution and diversity of adults (Alheit *et al*., 1983; Cardinale & Arrhenius, 2000), proportion of first-time spawners and repeat spawners within the population (Evans *et al*., 1998; Trippel, 1998), nutritional status (Brooks *et al*., 1997; Hislop *et al*., 1978), as well as size at age and sexual maturity (Morgan & Hoening, 1997; Roff, 1981).

The aquatic habitats of Central Anatolia have been steadily shrinking since the Pleistocene period, giving

According to these results, despite the wide age range of the population and positive growth values, it is believed that the species may be under significant threat from invasive/exotic species such as *A. boyeri*, *G. holbrooki*, *P. parva*, and *C. gibelio*, which share the same environment. Therefore, the conservation of species and their habitats is necessary.

Peer-review: Externally peer-reviewed.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Isparta University of Applied Sciences Local Ethics Committee for Animal Experiments (Date: 12.03.2020, No: 001).

Author Contributions: Conception/Design of Study – F.K., S.S.G.; Data Acquisition- F.K., S.S.G., U.G.Y., E.B.; Data Analysis/ Interpretation- F.K., G.Ş.; Drafting Manuscript- F.K., S.S.G., U.G.Y.; Critical Revision of Manuscript- F.K., S.S.G., E.B., G.Ş.; Final Approval and Accountability- F.K., S.S.G.

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RESEARCH ARTICLE

Gobies on the Turkish coast of the Black Sea, and first record of the yellow-headed goby, *Gobius xanthocephalus* Heymer & Zander, 1992

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Abstract

Objective: Challenges in identifying species of the Gobiidae family and their high tolerance to salinity, which makes it difficult to determine their distribution boundaries, have prevented the achievement of a common checklist for these species in the Turkish waters of the Black Sea. In this study, we present a checklist of marine gobies, including the first record of the yellow-headed goby, *Gobius xanthocephalus* Heymer & Zander, 1992, in this region.

Materials and Methods: On July 29, 2019, one individual of *G. xanthocephalus* was observed and photographed at a depth of 12 m by SCUBA diving on the coast of Giresun Island (40°55'41.75"N - 38°26'14.15"E), the southeastern Black Sea Basin. The other individual was photographed on November 4, 2023, at a depth of 3 m in Kapuz Beach (41°28'15.64"N - 31°48'2.56"E), the southwestern Black Sea Basin.

Results: A list of species belonging to the Gobiidae family in the Turkish waters of the Black Sea was presented by reviewing the relevant literature, and the distribution of the yellow-headed goby was updated. Two new photo records of *G. xanthocephalus* from the Black Sea coasts of Türkiye are provided on Giresun Island and Zonguldak, between the depths of 3-12 m.

Conclusion: Although the number of gobiid species reported in the relevant literature ranges between 16 and 35, the presence of 16 species was confirmed after excluding freshwater and brackish water species with the addition of the yellow-headed goby to this revised list. To accurately determine the distribution of these species with high salinity tolerance, comprehensive studies of freshwater, transitional, and marine waters in the southern Black Sea are necessary.

Keywords: Gobiidae, yellow-headed goby, Black Sea gobies, first record

Introduction

The Black Sea, being nearly enclosed, experiences significant anthropogenic pressure on coastal biodiversity. The unique ecological characteristics, coupled with limited knowledge of marine biodiversity, make this region a high priority for research (Yildiz *et al.,* 2019). While scientific efforts have primarily focused on pelagic fish species due to their economic importance (FAO, 2023), demersal and coastal species have received comparatively less attention, leaving gaps in our understanding of marine biodiversity within the Black Sea.

Gobies are important components of coastal ecosystems, and play crucial roles in ecological interactions and food webs (Depczynski & Bellwood, 2003). They tend to follow coastlines, and the distribution boundaries of these species are mostly determined by salinity, temperature, and sea currents, which facilitate the spread of larvae (Kovačić & Patzner, 2012). Gobies evolved physiological responses to constantly fluctuating salinity and temperature, which are believed to represent adaptation strategies for living in salinity-varying environments (Mazzoldi *et al.,* 2012). They also exhibit several morphological adaptations, including the number and type of fins and the shape of the head and body, all of which are heavily influenced by their benthic lifestyle. The merging of the two pelvic fins into a single distinct pelvic disc is one of the most distinctive characteristics (Miller*,* 1986).

Among the gobiids found in the Black Sea, the yellow-headed goby, *Gobius xanthocephalus* Heymer & Zander, 1992 has long been misidentified due to its close morphological affinities to *Gobius auratus* Risso, 1810 and *Gobius fallax* Sarato, 1889. However, it can be distinguished by its unique coloration, size and shape of its' pelvic fin, and specific body proportions and meristic characteristics (Heymer & Zander, 1992). The Atlantic and Mediterranean Islands are home to yellow-headed goby populations. In the Mediterranean, the species is found continuously from the Strait of Gibraltar to the Cyprus (Yalgın & Türker, 2023). It has also been recorded in the north Aegean (Gökalp, 2011) and the Sea of Marmara (Tsagarakis *et al.,* 2021). In addition, isolated populations exist in the Black Sea, including Crimea (Boltachev *et al.,* 2009; Vasil'eva & Bodorodsky, 2004).

Because of the lower salinity levels in the northern and northwestern parts of the Black Sea compared to the southern region (Krivoguz *et al.,* 2002), it is expected that fewer gobiid species favoring freshwater and transitional habitats will be found in the southern Black Sea. However, Engin & Seyhan (2009) reported 35 gobiid species from the Black Sea basin, including a significant number of freshwater species not previously recorded along the Black Sea coast of Türkiye. Bilecenoğlu *et al.* (2014) provided a more refined checklist, noting that 16 of these species were specifically found in the Turkish waters of the Black Sea. This study aimed to present an updated and revised checklist of the Black Sea fish fauna of Türkiye, including the first record of the yellow-headed goby *G. xanthocephalus.*

Materials and Methods

On July 29, 2019, one individual of *G. xanthocephalus* was observed and photographed at a depth of 12 m during SCUBA diving on the coast of Giresun Island (40°55'41.75"N - 38°26'14.15"E), the eastern Black Sea Basin (Fig. 1). The other individual was photographed on November 4, 2023, at a depth of 3 m in Kapuz Beach (41°28'15.64"N - 31°48'2.56"E), western Black Sea Basin. The specimens were photographed by diver Tolga Taymaz, using a digital camera (CANON 500D with 18-55 lens) in an underwater housing.

Diagnoses correspond to the minimum combination of characters that distinguishes the species from confamiliars in the area (Kovačić *et al.,* 2022). The taxonomic nomenclature follows that of Fricke *et al.* (2024).

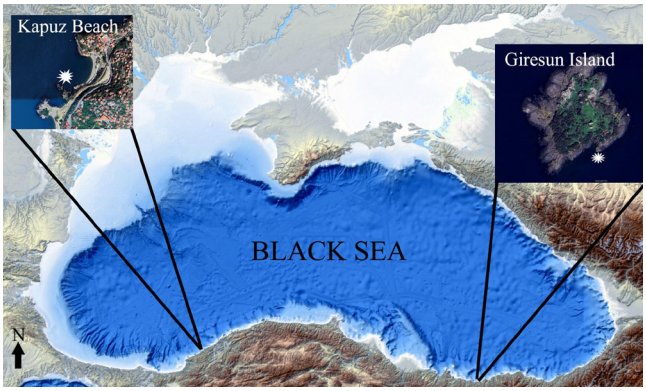

Figure 1. Map of the Black Sea showing locations where individuals of *Gobius xanthocephalus* were photographed.

Results and Discussion

The Gobiidae family has the highest number of species among marine fishes, with 1,417 species currently identified (Fricke *et al.,* 2024). These fish are integral to coastal ecosystems, contributing significantly to ecological dynamics (Beldade *et al.,* 2006) and are frequently used as models for studying various evolutionary and ecological patterns (Thacker, 2011). Despite their ecological importance and widespread use in research, gobies in the

marine waters of the Black Sea have been less thoroughly studied than their inland waters of the surrounding regions. This disparity highlights the need for more comprehensive research to better understand the role and diversity of gobies in the Black Sea marine environment.

Yankova *et al.* (2014) reported 35 gobiid species in the Black Sea, whereas Vasil'eva & Bogorodskii (2004) documented 29 species in the Azov–Black Sea Basin. However, a review of marine fish studies has revealed that several species documented in the Black Sea basin have not yet been observed in the Turkish waters of the Black Sea (Artuz, 1974; Bilecenoğlu *et al.,* 2014; Keskin, 2010; Mavruk & Ak Örek, 2017). Bilecenoğlu et *al.* (2014) identified 16 species in the Black Sea waters of Türkiye. In this study, after a thorough review of the relevant literature and exclusion of questionable records, 16 gobiid species were confirmed in the Turkish waters of the Black Sea. Because the northern and northwestern areas of the Black Sea have lower salinity than the southern part (Krivoguz *et al*., 2002), it is natural that gobiids favoring freshwater and transitional habitats are less represented in the southern Black Sea.

Among the gobies reported so far in Turkish waters of the Black Sea, the earlier geographic range of *G. bucchichi* in the Black Sea is likely based on misidentifications of *G. incognitus*, as noted by Kovačić & Kovtun (2022). Besides, the only record of *G. bucchichi* in the Black Sea is known to be attributed to Miller (1986). Therefore, it was not included in the present list due to its questionable occurrence in the area. Although *Babka gymnotrachelus*, *Knipowitschia caucasica*, *K. longecaudata*, *Neogobius fluviatilis*, *Ponticola eurycephalus*, *P. kessleri,* and *Proterorhinus marmoratus* have freshwater records in Türkiye, they were not included in the list because there are no records from the Turkish waters of the Black Sea (Table 1).

Underwater fish photography has expanded considerably over the past ten years (Kovačić *et al.,* 2021), serving as a valuable source of information on the geographic and ecological distribution of species (Kovačić & Svensen, 2019). *Gobius xanthocephalus* prefers hard substrates such as bedrock and coralligenous formations, as well as mixed bottoms such as sandy patches with pebbles, boulders, and seagrass (Kovačić *et al.,* 2022; Renoult *et al.,* 2022). Both specimens recorded in this study were photographed in biogenic habitats on bedrock at depths 3-12 m (Figs. 2-3).

Although the presence of *G. xanthocephalus* in the Mediterranean has been known since 1982 (Castillo & Brito, 1982), it was first observed in the Turkish waters in 2011. The first record of this species was presented as photographic evidence by Gökalp (2011) from the coasts of the North Aegean Sea. Later, the species was reported by Tsagarakis *et al.* (2021) from the Sea of Marmara. This study reports two new sightings that occurred on the southern coasts of the Black Sea.

It has been 20 years since the first record was obtained from the northern Black Sea (Vasil'eva & Bodorodsky,

Table 1. Previously published gobiid list in the Turkish waters of the Black Sea with the updated list.

Species	Artuz (1974)	Keskin (2010)	Bilecenoğlu *et al.* (2014)	Mavruk & Ak Örek (2017)	Present Study
Aphia minuta (Risso, 1810)	+	+	+	+	+
Babka gymnotrachelus (Kessler, 1857)	-	+	-	-	-
Gobius bucchichi Steindachner, 1870	-	+	+	-	-
Gobius cobitis Pallas, 1814	+	+	+	-	+
Gobius cruentatus Gmelin,1789	+	+	+	-	+
Gobius niger Linnaeus,1758	+	+	+	+	+
Gobius paganellus Linnaeus, 1758	+	+	+	+	+
Gobius xanthocephalus Heymer & Zander, 1992	-	-	-	-	+
Knipowitschia caucasica (Berg, 1916)	-	+	-	-	-
Knipowitschia longecaudata (Kessler, 1877)	-	+	-	-	-
Mesogobius batrachocephalus (Pallas, 1814)	+	+	+	-	+
Neogobius fluviatilis (Pallas, 1814)	-	+	-	-	-
Neogobius melanostomus (Pallas, 1814)	+	+	+	-	+
Pomatoschistus marmoratus (Risso, 1810)	-	+	+	-	+
Pomatoschistus microps (Krøyer, 1838)	-	-	-	+	+
Pomatoschistus minutus (Pallas, 1770)	-	+	+	+	+
Ponticola eurycephalus (Kessler, 1874)	-	+	+	-	-
Ponticola kessleri (Günther, 1861)	+	+	-	-	-
Ponticola platyrostris (Pallas, 1814)	+	+	+	-	+
Ponticola ratan (Nordmann, 1840)	+	+	+	-	+
Ponticola syrman (Nordmann, 1840)	+	+	+	-	+
Proterorhinus marmoratus (Pallas, 1814)	-	+	-	-	-
Zebrus zebrus (Risso, 1827)	-	+	+	-	+
Gobius ophiocephalus Pallas, 1814	+	+	+	-	+

Figure 2. Observed specimens of *Gobius xanthocephalus* on the Black Sea coasts of Türkiye. Photo credits: Tolga Taymaz.

Figure 3. Observed specimens of *Gobius xanthocephalus* on the Black Sea coasts of Türkiye. Photo credits: Tolga Taymaz.

2004). Records from the North Aegean and the Sea of Marmara have also recently been reported. This situation increases the likelihood that the population located south of the Black Sea may have dispersed from the Sea of Marmara.

In the Black Sea Basin, there is an urgent need for more comprehensive studies on gobies, as their distribution is influenced by key environmental factors such as salinity, temperature, and sea currents. Understanding these dynamics is crucial for assessing the ecological roles of gobies and ensuring their conservation. Enhanced research efforts will contribute significantly to our understanding of gobies and their importance in the Black Sea Basin marine ecosystem.

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RESEARCH ARTICLE

Antibacterial Efficiency of Quaternary Ammonium Silane-Coated Shoe Insoles Using the Sol-Gel Technique

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Abstract

Objective: Foot microbial infections are a common concern, particularly among individuals with diabetes, athletes, and those with compromised immune systems. Traditional methods for managing these infections include topical treatments and oral antibiotics. Diabetes mellitus patients, sportsmen and women, postoperative foot/ankle patients, and people who wear shoes for longer periods require extra attention due to the increased risk of microbial infection. The microenvironment of footwear, including its humidity, temperature, and aeration, supports the growth of pathogenic or opportunistic microorganisms. However, these approaches can not provide continuous protection against emerging infectious diseases and can not prevent antibiotic-resistant infections. Antimicrobial-incorporated shoe insoles present a novel and promising solution for preventing and managing foot microbial infections through their sustained release, which ensures long-term antimicrobial activity and reduces the risk of infection recurrence. These insoles are embedded with antimicrobial agents, like silver nanoparticles, copper ions, or organic antimicrobial compounds that provide continuous protection against a broad spectrum of microorganisms (bacteria, fungi and viruses). The occurrence of common foot infections like athlete's foot, fungal nail infections, and bacterial infections associated with diabetic foot ulcers can also be mitigated.

Materials and Methods: This study was conducted to examine the possibility and efficacy of the application of antibacterial quaternary ammonium silane compound-treated shoe insole materials in the mitigation of foot microbial infections. EN ISO 20645:2004, AATCC 147-2019, ISO 16187:2013, and fluorescence staining (CTC/DAPI) test methods were used in this study to analyze the antibacterial efficacy of the tested insole foam against *Klebsiella pneumoniae, Escherichia coli*, and *Staphylococcus aureus*.

Results: Antimic®[(3-(trimethoxysilyl)-propyl, cocodimethylammonium chloride] compound-incorporated shoe insoles resulted in total bacteria reduction (92-96%) after 24-hour contact time, without triggering a viable but non-culturable (VBNC) state in the tested bacteria.

Conclusion: Antimic® compound-incorporated shoe insoles represent a significant advancement in the prevention and management of foot microbial infections, providing a continuous, effective, and convenient method for maintaining good foot health.

Keywords: Shoe insoles, antibacterial activity, foot, footwear, functional materials

Introduction

Shoes, like most footwear, protect the feet and legs against various risks that would otherwise be detrimental to the person. The morbidity of disorders related to foot and ankle skin infections is influenced by the quality of footwear (Hsu & Hsu, 2012). Therefore, foot infections are common, although their frequency differs according to the various conditions. Foot and footwear hygiene is an important aspect whose negligence affects a variety of shoe wearers (Messina *et al*., 2015; Nguyen *et al*., 2023).

Patients with diabetes mellitus need extra attention due to the increased risk of developing diabetic foot infections (Li *et al*., 2011). A diabetic foot infection in patients with diabetes refers to a bone or soft tissue infection mostly due to peripheral arterial disease or neuropathy leading to a lack of sensation in the legs. Blood flow is also affected by diabetes, leading to longer healing times for sores, cuts, and wounds, subsequently leading to the development of ulcers or tissue death due to blood inaccessibility. Forming foot ulcers in patients with diabetes predispose them to foot infection, leading to polymicrobial foot infections. Microorganisms like *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Streptococcus agalactiae*, *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus anthracis*, and *Bacillus thuringiensis* (Li *et al*., 2011; Matheson *et al*., 2021; Steglińska *et al*., 2019) are among the species isolated from shoes.

Sportsmen and women are also affected by foot infections due to the nature and vigorous nature of sports, which lead to foot sweating and an increased risk of leg injuries. A study in some European countries (spring 1997-1998) found that 50% of participants had foot disease, whereas 66.7% had superficial fungal infections (Caputo *et al*., 2001). However, children were largely affected compared with the other age groups.

The importance of the feet and legs to the body in carrying and sustaining body weight necessitates hygienically and ergonomically appropriate shoes to avoid foot and leg injuries or worsening of already wounded feet. The presence of wounds on the foot, such as foot cuts and abrasions, blisters that could burst, ulcers, chronic wounds, and punctures caused by sharp objects, increases the susceptibility of the foot to infection by microorganisms. The incidence and morbidity of shoe and insole foot infections are influenced by the presence of sweat/moisture, improper foot wound hygiene, weakened immune system, and environmental exposure (e.g. walking barefooted) (Hsu & Hsu, 2012).

Shoes and shoe insoles are conducive environments for microbial growth due to the favorable humidity/moisture that is provided by sweat and the warmth created during wear. Thus, proper disinfection is paramount to mitigate infections by foot pathogens. Being reservoirs of different microorganisms, frequent cleaning of shoe insoles reduces the microbial load on the insole (Messina *et al*., 2015).

Antimicrobial components whose effects on microorganisms are persistent for extended periods (Akpınar *et al*., 2024) would be suitable for application on shoe insoles. This antimicrobial application method can help to readily eliminate microorganisms during the initial microbial attachment to shoe insoles, thus reducing the possibility of persistent colonization and biofilm formation. Regular sanitization of infected shoes, textiles, and socks is important for preventing infection (Gupta *et al*., 2022), re-infection, and cross-infection of footwear or mutual users. Footwear sanitization approaches used so far have involved the use of formaldehyde fumigation, foot powder application, silver-light irradiation, ozone application, and UV irradiation (Gupta & Versteeg, 2019).

The use of topical, oral, or combined topical and oral treatments for foot infections is an important strategy for mitigating foot infections. Factors like the severity of the foot infection, previous antibiotic response (Kimiran Erdem *et al*., 2007), and local antimicrobial sensitivity should be considered. Mild infections might require oral or topical antibiotic therapy, whereas severe infections might require intravenous antibiotic therapy (Matheson *et al.*, 2021).

The use of antimicrobial-treated shoe insoles and other footwear alongside oral or topical antimicrobial treatment for foot wounds and infections could be a promising strategy in foot infection management. However, deep infections require debridement of dead tissue from the wound before antimicrobial treatment (Bengalorkar, 2011).

In our study, it was aimed to evaluate the antibacterial effect of shoe insoles treated with quaternary ammonium silane [Antimic®] compound using the sol-gel technique. The antibacterial activity of the produced insoles was evaluated using qualitative and quantitative methods against *Staphylococcus aureus, Klebsiella pneumoniae*, and *Escherichia coli* bacteria selected as representative organisms.

Materials and Methods

The footwear products used in this study were made of foam and used in shoe insoles. Antimicrobial Antimic® compound was incorporated into insole materials using the sol-gel technique.

Since the insole material was porous, slightly modified qualitative AATCC 147-2019 and semi-quantitative EN ISO 20645:2004 methods were used in this study. ISO 16187:2013 test and fluorescence staining methods were used for quantitative evaluation. *Staphylococcus aureus, K. pneumoniae,* and *E. coli* bacteria were used as representative organisms.

Testing Antibacterial Activity of Samples

1. AATCC 147-2019 Test Method **(Antibacterial Activity of Textile Materials: Parallel Streak Method)**

The AATCC 147-2019 method used in this study was used to qualitatively determine the bacteriostatic and antibacterial activity of the samples.

Footwear samples, antibacterial-treated (test sample) and untreated (control sample), were prepared in a rectangular shape with dimensions of 25 × 50 mm using sterile forceps, scissors, scalpel, and mold. Suspensions of test organisms were prepared individually by adding 1.0 ± 0.1 ml of the 24-hour liquid bacterial culture to a sterile test tube containing 9.0 ± 0.1 ml of sterile water.

A loopful of the bacterial inoculum was taken with a 4 mm diameter loop and 5 lines were marked on the surface of the sterile agar plate. The lines were prepared in the center of the Petri dish, approximately 60 mm long, with a 10 mm gap between them. During the line inoculations, bacterial culture samples were collected only once with a loop, and care was taken to ensure that there was no damage or tear to the plate surface.

Sterile insole test and control samples were placed transversely to the 5 lines of the inoculated bacteria, ensuring full contact of the samples with the inoculated bacterial lines. Sterile glass coupons were then placed on the samples to prevent them from curling during incubation and contact with the test organism. Petri plates were incubated at 37 ± 2°C for 18-24 hours.

At the end of the incubation period, Petri plates were evaluated for the presence of interruptions (inhibition zones) in the bacterial inoculum lines and a clear growth inhibition zone around the edges of the sample (AATCC, 2019). The inhibition zone formed along an inoculum line on one side of the tested sample was calculated using the following formula:

$$W = \frac{T - D}{2}$$

(W: Inhibition zone- mm, T: Sum of sample and inhibition zone- mm, D: Test sample- mm)

The size of the inhibition zone was not used to quantitatively evaluate antibacterial activity, however, the presence of the inhibition zone and the absence of bacterial growth under the sample indicated the presence of antimicrobial activity in the test sample. For acceptable antibacterial activity, no bacterial colonies should be present below the sample at the contact area (AATCC 147-2019).

2. EN ISO 20645:2004 Test Method **(Textile Fabrics - Determination of Antimicrobial Activity - Agar Diffusion Plate Test Method)**

The EN ISO 20645:2004 standard allowed the semi-quantitative determination of antibacterial activity in samples. Antibacterial-treated test samples and untreated control samples were prepared in circular forms with 25 ± 5 mm diameters using sterile forceps, scissors, a scalpel, and a mold. Suspensions of the test organisms were prepared by transferring the 24 hour bacterial culture prepared from the lyophilized bacterial strain to the solid medium.

In this test, the samples were placed between two agar layers, enabling analysis of both sides of the samples. Although the lower agar layer did not contain bacteria, the upper layer was inoculated with the selected test bacteria. The lower layer contained 10 ± 0.1 ml of nutrient agar poured onto the Petri dish. However, the upper layer contained a mixture of 1 ml of the bacterial suspension (1.5×10^8 cfu (colony forming unit)/ml) and nutrient agar, which was mixed with bacteria in the molten form at 45˚C before solidifying. 5 ml of agar solution containing bacteria was poured onto the samples that were placed with sterile forceps on the lower agar layer. After solidifying the upper agar layer, the Petri dishes were incubated at 37 ± 2°C for 18-24 hours. Both test and control samples were evaluated after the required incubation period for the presence of a clear growth or inhibition zone around the edges of the sample and growth below the sample (ISO 20645: 2004; Kimiran Erdem & Sanli Yurudu, 2008).

The inhibition zone formed around the tested sample was calculated using the following formula:

$$H = \frac{(D - d)}{2}$$

(H: Inhibition zone- mm, D: Sum of sample and inhibition zone- mm, d: Test sample- mm).

After measuring the inhibition zone, the samples were lifted using sterile forceps to evaluate the presence of growth below the sample. Evaluation was performed according to Table 1:

Table 1. EN ISO 20645:2004 test method evaluation criteria (ISO 20645:2004).

Inhibition zone (mm)	Growth[a]	Evaluation
> 1	No growth	Good Effect
1-0	No growth	
0	No growth	
0	Weak growth	Limited Effect
0	Mild growth	Insufficient Effect
0	Intensense growth	

[a]Growth under the sample

3. ISO 16187:2013 (Footwear and footwear components — Test method to assess antibacterial activity) Test Method

A quantitative static challenge method (ISO 16187:2013) was used to determine the percentage reduction in the test bacterial load of footwear and its components. The study involved samples with dimensions of 25 × 25 × 1 mm for both the Antimic® compound-treated test samples and control samples. Each sample was placed in a sterile glass flask, followed by the addition of 1 ml of a 5.0×10^5 cfu/ml bacterial concentration on each sample and incubation for specific contact times. 1- and 24-hour contact times were used in this study. At the end of the contact times, test and control samples were collected, and 20 ml of soybean casein lecithin polysorbate (SCDLP) neutralizing medium was added to each sample, and the sample was incubated for 5 minutes. Followed by ten-fold serial dilution with a sterile 0.85% NaCl aqueous solution. 100 µl of each diluted bacterial solution was spread out and cultured on tryptic soy agar (TSA, Oxoid) plates. The surviving bacterial colonies on the plates were enumerated after a 24-hour incubation at 37°C (ISO 16187:2013). The percentage reduction in bacterial counts was measured using the following equation:

$$R(\%) = \frac{C - T}{C} x100$$

where R is the bacterial percentage reduction, and C and T are the average number of colonies of three control (C) samples and three test (T) samples after 1- and 24- hour contact times, respectively, cfu/ml.

4. Fluorescence staining (CTC/DAPI) Test Method

This method was used to determine whether the bacteria died from the effect of the antibacterial agent. The method is based on the use of fluorescent dyes that allow the differentiation of dead and living organisms, and samples are examined under an epifluorescence microscope. This study assessed the number of actively respiring bacteria in comparison with the total number of bacteria after a contact time of applying the tested bacteria to both antimicrobial-treated (test) and untreated (control) footwear samples.

In this test, 5-Cyano-2,3-ditolyltetrazolium chloride (CTC) was used as the indicator of bacteria (living bacteria) with active electron transport systems (ETS). This staining was followed by 4′,6-diamidino-2-phenylindole (DAPI) staining, which was used to indicate the total number of cells present by staining the DNA of all cells present. Samples were then filtered using black polycarbonate membranes and observed under an epifluorescence microscope (Sanli Yurudu & Kimiran, 2015).

Bacterial percentage reduction was measured using the following equation:

$$\text{Percentage Reduction (\%)} = \frac{\text{Live Cell Count of the Control Sample} - \text{Live Cell Count of the Experiment Sample}}{\text{Live Cell Count of the Control Sample}} \text{x100}$$

Results

Results of qualitative antibacterial activity tests are presented in Tables 2 and 3.

AATCC 147 standard demonstrates bacteriostatic activity via the diffusion of an antibacterial agent through agar. According to this test method, the antibacterial compound-treated material should be compared with the untreated corresponding material, and for acceptable antibacterial activity, there must be no bacterial growth under the treated material. Antimic®-treated shoe insole samples exhibit acceptable antibacterial effects against *S. aureus* ATCC 6538, *K. pneumoniae* ATCC 4352, and *E. coli* ATCC 11229 bacteria (Table 2).

Table 2. Antibacterial efficiency of Antimic®-treated shoe insole foam according to AATCC 147-2019 standard test method.

Samples	*S. aureus* ATCC 6538	*K. pneumoniae* ATCC 4352	*E. coli* ATCC 11229
Antimic®-treated shoe insole	0 mm and No growth below sample[b]	0 mm and No growth below sample[b]	0 mm and No growth below sample[b]
Untreated insole (Control)	No zone, Intense growth[b]	No zone, Intense growth[b]	No zone, Intense growth[b]

[a] Acceptable antibacterial effect, [b] No Antibacterial effect

Similar results were obtained using the semi-quantitative EN ISO 20645:2004 standard test method for shoe insoles (Table 3). According to this method, the insoles exhibited good antibacterial activity against representative bacteria.

Table 3. Antibacterial efficiency of Antimic®-treated shoe insole foam according to EN ISO 20645:2004 standard test method.

Samples	*S. aureus* ATCC 6538	*K. pneumoniae* ATCC 4352	*E. coli* ATCC 11229
Antimic®-treated shoe insole	0 mm and No growth below sample[1]	0 mm and No growth below sample[1]	0 mm and No growth below sample[1]
Untreated insole (Control)	0 mm and Intense growth[0]	0 mm and Intense growth[0]	0 mm and Intense growth[0]

[1] Good effect, [0] No effect

Quantitative and semi-quantitative tests indicated that the compound diffused poorly in the agar medium. However, it was determined that there was intense growth below the samples of the control group, whereas it was observed that the lower part of the treated insole samples inhibited bacterial growth by creating a barrier effect.

Results of quantitative antibacterial activity tests performed against Gram-positive and Gram-negative representative bacteria are presented in Table 4. Under static conditions, the bactericidal rates of the antibacterial shoe insole samples against *S. aureus*, *K. pneumoniae*, and *E. coli* after 24-hour contact times were 96.59%, 95.77%, and 92.87, respectively (Table 4).

Table 5 presents the results of the antibacterial activity of the insole samples according to fluorescence staining. This method, which is used to detect dead and viable microorganisms when evaluated simultaneously with colony counting, also allows the detection of live but non-culturable forms (VBNC) that bacteria use as a survival strategy. As shown in Figure 1 (a-f), which includes representative fluorescence microscopy images, live cells are shown in red; dead cells are shown in blue. Antimic® (3-(trimethoxysilyl)-propyl, cocodimethylammonium chloride) compound-incorporated shoe insoles reduced live bacteria by 94.97%, 92.00%, and 91.15% for *S. aureus*, *K. pneumoniae*, and *E. coli* after 24-hour contact times, respectively (Table 5). When evaluated together with the quantitative culture method, it was determined that the Antimic® shoe insole did not trigger the VBNC status of the tested bacteria (Table 5, Fig. 1).

Table 5. Antibacterial activity results of the Antimic®-treated shoe insole foams after 1- and 24-hour contact time according to fluorescence staining test.

Samples	Bacteria	Contact Time (h)	Total Cell Count	Live Cell Count	Percent Reduction (%)
Antimic® Treated Foam	*S. aureus*	**1**	4.09×10^5	1.89×10^5	**50.13**
		24	3.26×10^7	1.18×10^6	**94.97**
	K. pneumoniae	**1**	3.61×10^5	1.90×10^5	**43.95**
		24	4.09×10^7	2.28×10^6	**92.00**
	E. coli	**1**	3.08×10^5	1.75×10^5	**39.02**
		24	3.74×10^7	2.76×10^6	**91.15**
Control (untreated) Foam	*S. aureus*	**1**	3.81×10^5	3.79×10^5	-
		24	2.44×10^7	2.35×10^7	-
	K. pneumoniae	**1**	3.47×10^5	3.39×10^5	-
		24	3.01×10^7	2.85×10^7	-
	E. coli	**1**	2.98×10^5	2.87×10^5	-
		24	3.28×10^7	3.12×10^7	-

Discussion

This study demonstrated the distinctive action of antimicrobial-incorporated footwear components (insoles) in decreasing the bacterial load on the test substances. The qualitative test (EN ISO 20645:2004) revealed the considerate action of Antimic®-treated shoe insole samples against the tested bacteria, with the inhibition of bacterial growth below the tested samples and

Table 4. Antibacterial activity results of the Antimic®-treated shoe insole foams after 1- and 24-hour contact time, according to the ISO 16187:2013 standard test method.

Samples	*S. aureus* ATCC 6538		*K. pneumoniae* ATCC 4352		*E. coli* ATCC 11229	
Contact times (h)	**1**	**24**	**1**	**24**	**1**	**24**
Control	3.77×10^5	2.23×10^7	3.23×10^5	2.65×10^7	2.79×10^5	3.06×10^7
Antimic® Treated Insole	1.78×10^5	7.6×10^5	1.73×10^5	1.12×10^6	1.65×10^5	2.18×10^6
Percent Reduction (%)	52.78	96.59	46.43	95.77	40.86	92.87

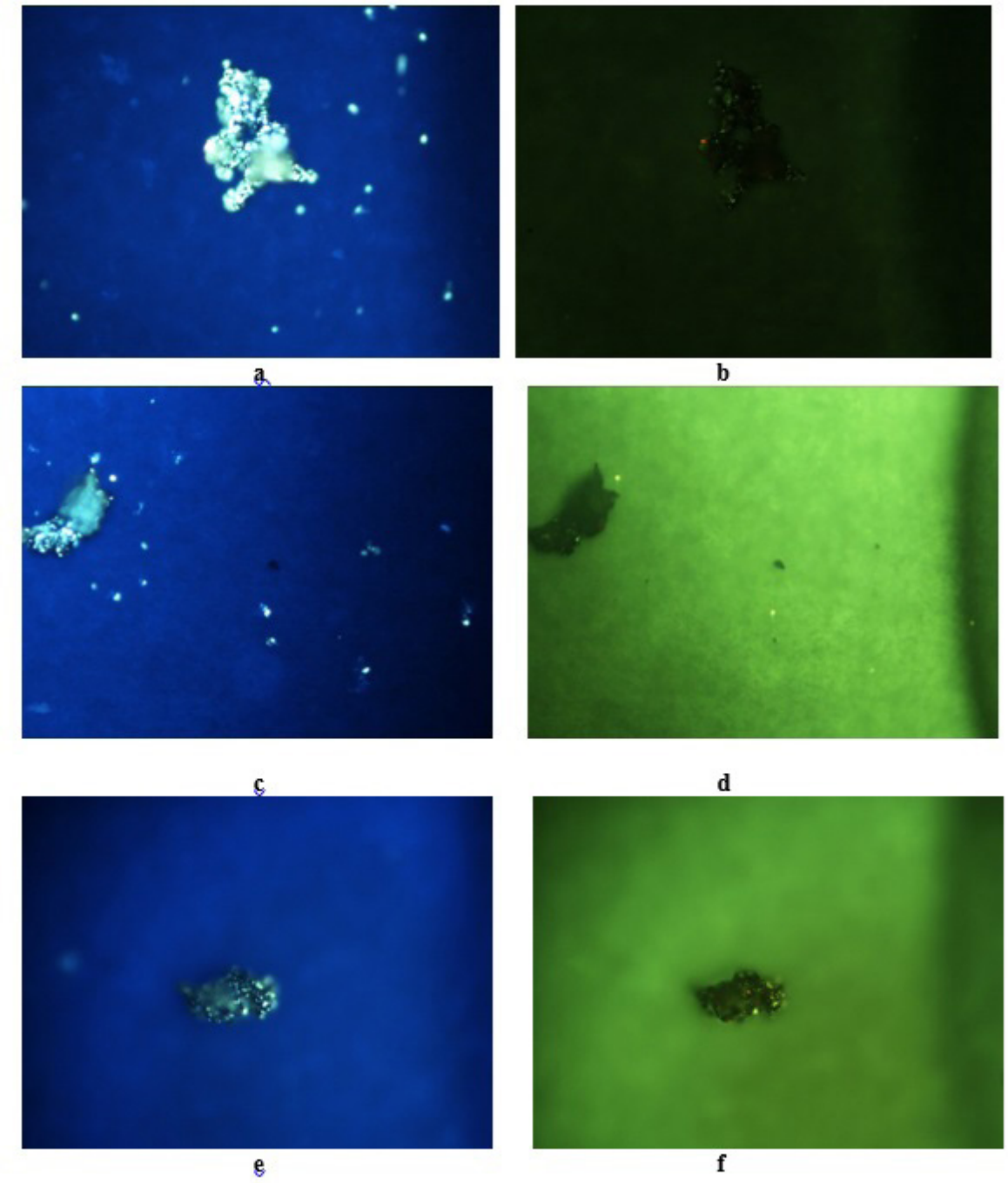

Figure 1. Representative photographs obtained in the evaluation of the antibacterial activity of insole samples according to the fluorescent staining method. a. *S. aureus* DAPI staining, b. *S. aureus* CTC staining; c. *K. pneumoniae* DAPI staining, d. *K. pneumoniae* CTC staining; e. *E. coli* DAPI staining, f. *E. coli* CTC staining.

no significant zone was observed. However, the quantitative test (ISO 16187:2013) revealed high percentage reductions in the bacterial loads of *S. aureus*, *K. pneumonia*, *and E. coli in* treated insole samples by 96.59%, 95.77%, and 92.87%, respectively after a 24-hour contact time.

Fluorescent staining (DAPI-CTC) of treated foam samples showed a significant decrease in the viable cell counts of *K. pneumonia*, *E. coli,* and *S. aureus* by 92.00%, 91.15%, and 94.97% respectively after a 24-hour contact time.

Modern footwear materials should have properties like the ability to withstand abrasion, wear, humidity, and temperature variations. Novel antimicrobial footwear technologies, including nanotechnologies and microencapsulation processes, can change the challenges met by wearing various types of footwear and the different

materials used to manufacture them. A previous study indicated that casual shoes provide the most conducive bacterial growth conditions, followed by running and perforated shoes (Miao *et al*., 2021). This would have been due to aeration leading to the ability of the shoe to maintain or get rid of excess moisture and temperature, which facilitate bacteria growth. A different study observed that leather shoes harbored microorganisms, including fungi, whereas shoe dampness increased the risk of microbial growth. However, regular dehydration and the use of antimicrobials can mitigate foot infections (Kenneth *et al*., 2017). The applications of this study would therefore be of importance if used in various footwear like insole materials like leather whose nature would otherwise encourage microbial growth and colonization. A study by Vo *et al*., (2020) investigated shoe insoles coated with copper oxide-zinc oxide (CuO-ZnO) nanocomposites and demonstrated their antibacterial effects against *E. coli*, *Bacillus cereus*, *S. aureus*, *Salmonella* spp., and *Pseudomonas aeruginosa*. This was in accordance with our study in which a different antimicrobial was used. However, in their study, the antibacterial activity of the shoe insole samples was remarkably reduced when they were soaked and washed with a rubbing action (Vo *et al*., 2020). This demonstrates the limitations involved in the use of antimicrobial-treated insole products, including the wearing of materials due to the continuous rubbing of the feet during movement (Vo *et al*., 2020). Moreover, the continuous washing of footwear with water and soap would reduce the efficacy of some insole-incorporated antimicrobial products (Vo *et al*., 2020). Therefore, it is important to replace insole footwear after a specific period or to perform repeated treatment of the same insole material with antimicrobial products to achieve the required antimicrobial effect against shoe insole-related microorganisms.

In a similar study by Lu *et al*., (2018), using the antimicrobial nanotechnology compound Bio-Kil, treated socks showed significant reductions in the *S. aureus* and *E. coli* bacterial counts after a 0-, 8-, and 48-hour contact time compared with untreated samples. It was observed that the Bio-Kil-treated socks from diabetic patients and healthy individuals showed significant reductions in bacterial counts compared with untreated samples after a 40-hour contact time (Lu *et al*., 2018). Our study, in accordance with Lu *et al*., (2018), recognized the possibility of the use of insole-incorporated antimicrobial components and other footwear components to prevent microbial colonization of insole footwear. Additionally, they can help eliminate microorganisms in diabetic and other foot wounds, including post-surgical foot or ankle wounds (Lu *et al*., 2018). Leather shoes have good water-absorbing properties, contrary to most athletic shoes made from synthetic materials. The poor water absorption of shoes encourages the accumulation of moisture from the perspiring feet, thereby creating favorable growth environments for microorganisms that lead to the pathogenic invasion of the foot skin (Gnanasundaram *et al*., 2013). Therefore, modified antimicrobial insole materials are a desirable choice for mitigating foot microbial infections (Gnanasundaram *et al*., 2013). The continuous antimicrobial activity of the treated shoe insoles can help eliminate bad shoe odors caused by the activities of certain bacteria (Messina *et al*., 2015).

On the other hand, our study focused only on some bacteria and did not examine the effect of our shoes with antimicrobial insoles against fungi. Therefore, this study provides insight for further studies on the antifungal activities of shoe insoles and foam.

Similar to our study, Sanchez-Navarro *et al.* (2013) found silver nanoparticles (AgNPs) and silver (AgNPs) @silica nanocomposites treated insole leather materials to have significant antimicrobial effects against Gram-positive (*S. aureus* and *B. subtilis*) and Gram-negative (*E. coli* and *K. pneumoniae*) bacteria using the agar diffusion method (Sanchez-Navarro *et al*. 2013).

Similar to Sanchez-Navarro *et al*. (2013), TiN-Ag antimicrobial coating of leather by Marques *et al.* (2022) showed great antimicrobial activity with >2 log reductions according to the Japanese Industrial Standard Z 2801:2000 (JIS Z 2801:2000) when tested against *Candida parapsilosis*, *Trichophyton mentagrophytes*, *S. aureus*, and *E. coli*. This was in accordance with our study in which the antibacterial activity of the Antimic®-treated shoe insole foams showed higher percentage reductions of tested bacteria (96.59%, 95.77%, and 92.87% for *S. aureus*, *K. pneumonia*, *E. coli* respectively) using the ISO 16187:2013 test method.

Based on the results of the study, using the Antimic®-treated shoe insole foams can prevent cross-contamination and foot microbial infections by acting as a suggestive alternative with strong antibacterial properties. The compounds used in this study have a quaternary ammonium structure and contain silane groups. The quaternary region of the compound neutralizes microorganisms by affecting the cell membrane, whereas the silane groups ensure that the chemical is retained on the surface. The compound (Antimic®) used in our study has important advantages by its nature: i) as being easily applied uniformly to a variety of materials like fabrics, plastics, and synthetic fibers; ii)

not creating any toxicity risks in long-term exposure since it does not release particles that are toxic to the environment and humans, iii) the immobilization and regeneration of the compound on applied material. These properties may be highly desirable for possible applications in materials science and healthcare, where the compound's ability to pass through biological membranes and other barriers is needed.

Conclusion

Antimic® compound-incorporated shoe insole products in this study exhibited significant antibacterial activity against the selected bacteria, with acceptable percentage reductions in the bacterial loads on test surfaces. This approach represents a significant advancement in the prevention and management of foot microbial infections, providing a continuous, effective, and convenient method for maintaining good foot health.

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