Turkish Journal of Agricultural and Natural Sciences 13 (1): 69–78, 2026

https://doi.org/10.30910/turkjans.1752386

TÜRK TARIM ve DOĞA BİLİMLERİ DERGİSİ

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TURKISH JOURNAL of AGRICULTURAL and NATURAL SCIENCES

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Original Article

Detection of Insect Pests in Stored Wheat Grains in Mardin Province, Türkiye

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ABSTRACT

The licensed warehousing is increasingly enlarging in Mardin Province, Türkiye. This study was carried out during 2022–2023 to determine insect species, their densities, and the extent of damage in stored wheat grains. Samples were collected using the probe method from both traditional warehouses and steel silos. Insects were examined in 500-gram samples prepared by compositing. A total of 9 insect species were identified in stored wheat, all of which belonged to the order Coleoptera. The most common species in stored wheat, known as a primary pest of cereals, was the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae). The number of live individuals collected was higher than dead ones (with live individuals comprising about 90% in traditional warehouse and 77% in steel silo). The rate of damaged grain caused by primary pests in grain wheat varied between 1-5% indicating that fumigations in the sampled warehouses and silos were found to be inadequate. It is recommended to ensure proper sealing and to monitor gas concentration levels using a detector during fumigation to maintain consistency.

Key words: Composition, damage, insects, *Rhyzopertha dominica*, storage, wheat grains

Mardin İlinde Depolanmış Buğday Danelerinde Zararlı Böceklerin Saptanması

ÖZ

Lisanslı depoculuğun giderek arttığı Mardin İli Kızıltepe, Nusaybin, Derik, Mazıdağı ve Artuklu İlçelerinde depolanmış dane buğday ve mısırlarda böcek türleri, yoğunlukları ve zarar durumları 2022-2023 yıllarında araştırılmıştır. Örnekler, gerek geleneksel ve gerekse çelik silo depolardan probe yöntemiyle alınmıştır. Paçal yapılarak elde edilen 500 gramlık örneklerde böcekler incelenmiştir. Depolanmış dane buğdaylarda 9 tür saptanmış olup, tamamının Coleoptera takımından oldukları belirlenmiştir. Depolanmış buğdaylarda en yaygın görülen ve tahılların primer zararlı olarak bilinen Ekin kambur biti, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) olmuştur. Toplanan canlı birey sayısının ölü bireylere göre daha yüksek olduğu (genel olarak adi depolarda canlı birey oranı %90, çelik silo depolarda %77) belirlenmiştir. Dane buğdaylarda primer zararlıların neden olduğu zarar görmüş dane oranı %1-5 arasında değişmiştir. Örneklenen buğday depo ve silolarında fümigasyonun yetersiz kaldığı görülmüş olup, sızdırmazlığın önlenmesi ve ayrıca fumigasyon süresince uygulanma alanlarında gaz yoğunluğunun detektörle ölçülerek sabit kalmasının sağlanması önerilir.

Anahtar kelimeler: Böcekler, dane buğday, depo, kompozisyon, *Rhyzopertha dominica*

INTRODUCTION

Cereals, which are among the world's most important agricultural crops, date back to around 8500 B.C. and were first domesticated in the region known as the Fertile Crescent, which includes southeastern Türkiye, playing a key role in the development of human history. Wheat is the first cereal crop to be domesticated in this region (Diamond, 2008). As a staple food source within agricultural production systems, cereals hold great importance because they are the most consumed foods in our diets and provide more than half of the calories

from all consumed food plants. The fact that wheat ranks first among all cereals produced globally and in Türkiye once again highlights its significance.

The global cereal cultivation area was 70.278.03 ha, producing 798.000.000 tonnes of cereals. Wheat and maize together, with a share of 58% of the total cultivated area and 64% of total production in 2024 (FAOSTAT, 2024). According to data from Türkiye in 2024, the total cereal cultivation area was 6.628.700 ha, and the production amounted to 19.750.000 tonnes of cereals (TUİK, 2024).

The economic losses caused by stored-product pests during cereal storage vary significantly depending on the type of crop, country, regional climate conditions, and storage duration, making them difficult to quantify. Moreover, a universally accepted method for such assessments has not yet been developed (Fox and Fimeche 2013). In general, it is estimated that insects cause annual global losses of about 10% in stored products. Abandoning traditional storage methods in favor of technologically equipped storage facilities significantly helps protect products from pests and diseases, while also preventing quality loss. In Southeastern Anatolia, the losses in cereal value vary depending on storage conditions. When storage conditions are good, losses are reported at approximately 1.8%, while under poor conditions, losses can rise to about 8.29% (Yücel, 1982). A study conducted in 1966 in the provinces of Mardin, Diyarbakır, and Şanlıurfa, Türkiye found that the khapra beetle (Coleoptera: Dermestidae) was widespread in the region, especially in the Kızıltepe district of Mardin (Ergül et al., 1972).

The species composition and distribution in stored wheat and barley in Ankara Province (Aydın and Soran, 1987), stored maize in Adana province (Mert, 2012), stored wheat and barley in Trakya region (Bağcı et al., 2014; Özder and Toğantimur, 2019), stored maize in the southern provinces (Adana, Mersin, Kahramanmaraş), Southeastern Anatolia (Şanlıurfa province), and Central Anatolia (Konya province) (Işıkber et al., 2016), stored wheat in Uşak province (Zengin, 2019), and wheat and maize in Mersin province (Yetkin and Atakan, 2022) have been reported. However, in different ecological regions, factors such as storage conditions (type and physical characteristics of the storage facility, temperature and humidity), storage duration, product circulation, and the characteristics of the stored product are among the variables that can affect the pest species composition and damage status in stored grains. In recent years, there have been no studies on pest species infesting stored wheat or other products, or on their economic importance in Mardin province. There is a fundamental need for research on pest species composition, infestation timing, and their distribution in traditional warehouses and steel silos. This study identifies the pest insect species, individual numbers, occurrence rates, and damage levels in stored wheat in Mardin, where licensed warehousing is increasingly common. The findings are expected to be useful for professionals working in this sector in terms of pest management.

MATERIALS AND METHODS

The main materials of the study were facilities in Mardin, where wheats are stored using various storage methods (traditional warehouses, reinforced concrete warehouses, steel silos, etc.) with high pest infestation potential. The study utilized tools and materials such as a grain probe sampler, sample bags, 2 mm sieves, calibrated sieves, storage containers of various sizes, preservation fluids (alcohol), a light source, and ethyl acetate with cotton for proper killing under suitable conditions (Figure 1).

Sampling Locations

Sampling was conducted in wheat storage facilities located in the districts of Kızıltepe, Nusaybin, Derik, Mazıdağı, and Artuklu in Mardin, where both cultivation and storage activities are intensive. Efforts were made to collect samples from as many different facilities as possible in order to identify pest species in stored wheat. The locations on the map where samples of stored grain wheat were collected in Mardin are shown (Figure 2). Sampling began on October 3, 2022, and ended on August 15, 2023. As much as possible, different types of storage facilities (traditional warehouses and steel silos.) were selected for sampling. In some of the sampled warehouses or silos, pesticide treatments, mostly fumigation with 57% aluminum phosphide, were applied beyond our control.



Figure 1. Sampling process using a probe device (a-b-c), 2-meter probe device and sieve used for sampling (d), light source, sable brush, ethyl acetate, and label paper used for sampling (e), calibrated sieve (f), steel silo from which the sample was taken (g), and ordinary warehouse from which the sample was taken (h)



Figure 2. Locations on the map of the samples taken from stored wheat grains in Mardin province

Sampling of Insects

Sampling activities were conducted in stored grain wheat within traditional warehouses and steel silo storages. Sampling began on October 3, 2022, for stored wheat. Samples were taken at intervals of at least 15–20 days throughout the storage period. A total of 16 traditional (conventional) wheat warehouses and steel silos were sampled. Based on the amount of product stored, 4 to 8 probes were conducted in both traditional and steel silo storages. From various points and depths within the wheat piles, 2–4 kg of grain samples was collected. After mixing the grain samples (to create a composite sample), 500 grams were placed into polyethylene bags, and labels were added to record data such as pest condition (alive or dead), sampling date, crop type, storage type, and date of storage.

Laboratory Procedures

The samples collected from stored wheat were brought to the laboratory to detect insect infestations. The samples were passed through 2 mm sieves, and insects remaining under the sieve were separated and identified by species level. The number of adult individuals of known species was counted and recorded.

Pre-adult stages (eggs, larvae, and pupae) found in the sieved samples were transferred into 500-gram glass jars to obtain adult specimens. These jars were sealed with tightly woven tulle. The jars were incubated in dark conditions with appropriate temperature (minimum 27°C) and relative humidity (60%) for larval

development. The developing individuals were regularly checked, and the emerging adults were prepared for identification and recorded.

Identification of Insect Species

The identification of insect specimens collected from stored wheat in Mardin was conducted at the species level by second author using the key identification's guides (Özgür, 1990; Rees, 2004).

Assessment of Damage

From different types of storage facilities, 2–4 kg of wheat grain samples was mixed into composite samples. Then, 100 grains were randomly selected from the 500 g subsample and examined individually. The grains were classified as healthy or damaged. Damaged grains included those hollowed out by primary pests, with emergence holes, resulting from larval feeding. The damage rate (%) was calculated accordingly.

Data Evaluation

Collected data were evaluated using Microsoft Excel and presented in tables. In these tables, the number of individuals for each identified pest species was listed according to storage type and sampling date. For warehouses where sampling was conducted regularly, the percentage of damaged grains was calculated following Karman (1971), and the results were presented in relevant tables. Since the sampled conventional warehouses and steel silos were located in the same area (Mardin province), and the storage and fumigation processes were similar, the data obtained from the 16 warehouses or silos were combined and presented together.

RESULTS AND DISCUSSION

Pest Species, Their total Numbers, Percentages in Traditional and Steel Silos Storages

Table 1 shows the pest species, their total numbers of individuals and their percentages in traditional wheat storages. During 2022-2023, nine insect species were identified in stored wheat grains in traditional warehouses in Mardin. The most prevalent species was *Rhyzopertha dominica* (F.), with 25 individuals and an occurrence rate of 37.31%. This insect was followed by *Tribolium castaneum* (Herbst), with 15 individuals (22.39%), and *Trogoderma granarium* Everts (khapra beetle), with 10 individuals and a 14.93% presence among adults.

Table 1. Insect species, their total numbers and percentage in total adults found in wheat grains stored in traditional warehouses in Mardin province, during 2022-2023

Order	Family	Insects	Total number	Percentage
Coleoptera	Bostrychidae	*Rhyzopertha dominica*	25	37.31
	Curculionidae	*Sitophilus granarius*	1	1.49
		Sitophilus oryzae	5	7.46
	Dermestidae	*Trogoderma granarium*	10	14.93
	Laemophloeidae	*Cryptolestes turcicus*	3	4.48
	Silvanidae	*Oryzaephilus surinamensis*	2	2.99
	Tenebrionidae	*Tribolium castaneum*	15	22.39
		Tribolium confusum	3	4.48
		Latheticus oryzae	3	4.48
		Total	67	100

Table 2 shows the pest species, their total numbers of individuals and their percentages in wheat steel silos storages. A total of eight pest insect species were identified in wheat stored in steel silos in Mardin during

2022-2023. These belonged to five different families within the order Coleoptera (Table 2). Similar to traditional storages, *R. dominica* was the most common species, with 37 individuals and a 45.12% occurrence rate. This was followed by *Tribolium confusum* Jacquelin du Val., with 24 individuals (29.27%), and *Sitophilus oryzae* (L.), a primary cereal pest, with 17 individuals (8.54%). Other species had low abundance and occurrence rates ranging from 1 to 5 individuals and 1% to 6% (Table 2).

Table 2. Insect species, their total numbers and percentage in total adults found in wheat grains stored in steel silos in Mardin province, during 2022-2023

Order	Family	Insects	Total number	Percentage
Coleoptera	Bostrychidae	*Rhyzopertha dominica*	37	45.12
	Curculionidae	*Sitophilus granarius*	5	6.10
		Sitophilus oryzae	7	8.54
	Laemophloeidae	*Cryptolestes turcicus*	2	2.44
	Silvanidae	*Oryzaephilus surinamensis*	1	1.22
	Tenebrionidae	*Tribolium castaneum*	24	29.27
		Tribolium confusum	3	3.66
		Latheticus oryzae	3	3.66
		Total	82	100

When the survey results from stored wheat in traditional warehouses and steel silos are evaluated together, the following conclusions can be summarized: The number of insect species in traditional and steel silo storages was found to be similar (9 and 8 species, respectively). The most common species in stored wheat were *R. dominica* and *T. castaneum*. Species of genus *Sitophilus* (grain and rice weevils), which are known as primary pests of stored grains, were recorded in very low numbers. All identified species belong to different families of the order Coleoptera, with slightly more species found in the families Curculionidae and Tenebrionidae. Studies from various geographical regions of Türkiye have reported different numbers of species: for example, 31 species in the Adana province (Ekecan and Özgür, 1990) and 13 species (Çankaya, 1998). In a study conducted in 2019 in Tarsus and Akdeniz districts of Mersin province, 9 species were found in traditional warehouses and 7 in silo-stored wheat, with *Sitophilus* species being the most common (Yetkin and Atakan, 2022). Differences in the number of species reported in studies from Adana and elsewhere may be due to variations in storage types, fumigation practices, storage conditions, temperature and relative humidity within the depots, crop types, and product turnover. For instance, Yetkin and Atakan (2022) suggested that *S. granarius* may have been transported to Mersin with wheat from the Central Anatolia Region of Türkiye as this species is primarily found in colder climates. Among the species identified in this current study, *R. dominica* is known to prefer higher temperatures, with optimal development occurring above 30°C (Rees, 2004). Summers in Mardin are known to be hot and dry, which may explain the widespread presence of *T. castaneum* in local storage facilities, as it also favors hot ecosystems (Rees, 2004). Furthermore, the relatively higher number of harmful insects during months of autumn or summer time may be related to rising temperatures.

Total Numbers of Pest Species According to Sampling Dates in Traditional and Steel Silos Storages

The distributions of insect species with total numbers per 500 g sample according to sampling dates in wheat traditional storages during 2022-2023 is shown in Table 3. *Rhyzopertha dominica* was collected most abundantly on December 5, 2022, and all individuals were alive (Table 3). Most species were recorded in the warmer months (June–July), with individual numbers ranging from 1 to 5. A total of 60 live and 7 dead insects were collected from traditional warehouses (Table 3).

The total numbers of individuals according to sampling dates in wheat steel silos storages during 2022-2023 are given in Table 4. *R. dominica* was collected on all sampling dates except one, with individual numbers ranging from 2 to 45. Most individuals were found to be alive. The highest number (10 individuals) was recorded on October 20. Similarly, *T. castaneum* was observed in several sampling dates in small numbers. *Sitophilus granarius* was found on October 20 and December 5, 2022. *Oryzaephilus surinamensis* was recorded only once

on October 20. Considering all sampling dates, the majority of collected individuals were alive (63 live and 19 dead; Table 4).

Table 3. According to sampling dates, total numbers of individuals of insect species found in wheat grains stored in traditional warehouses in Mardin province, during 2022- 2023

Dates	n	Sga	Sor	Tca	Tco	Rdo	Oss	Ctur	Tga	Lor	Dead	Alive
Sep 5, 2022	4	0	0	2	0	3	0	0	0	1	0	6
Sep 20, 2022	6	0	2	0	3	0	0	0	0	0	0	5
Nov 4, 2022	5	0	0	2	0	0	0	0	0	1	0	3
Nov 20,.2022	3	0	0	0	0	0	0	0	0	0	0	0
Dec 5, .2022	4	0	0	4	0	11	2	0	0	0	0	17
Jan 1, 2023	1	0	0	0	0	0	0	2	0	0	0	2
Jan 18,.2023	1	0	0	0	0	0	0	0	0	0	0	0
Feb 4, 2023	1	0	0	0	0	0	0	0	0	0	0	0
Feb 21, 2023	1	0	0	0	0	0	0	0	0	0	0	0
Mar 6, 2023	1	0	0	0	0	0	0	0	0	0	0	0
Mar 20, 2023	2	0	0	0	0	0	0	0	0	0	0	0
May 24, 2023	1	0	2	1	0	0	0	0	1	0	0	4
Jun 14, 2023	2	0	1	0	0	5	0	1	1	0	0	8
Jun 29, 2023	2	0	0	4	0	0	0	0	0	1	0	5
Jul 14, 2023	2	1	0	1	0	0	0	0	3	0	1	4
Jul 29,2023	1	0	0	1	0	4	0	0	2	0	4	3
Aug 15, 2023	1	0	0	0	0	2	0	0	3	0	2	3
Total	38	1	5	15	3	25	2	3	10	3	7	60

Sga: *Sitophilus granarius*, Sor: *Sitophilus oryzae*, Tca: *Tribolium castaneum*, Tco: *Tribolium confusum*, Rdo: *Rhyzopertha dominica*, Oss: *Oryzaephilus surinamensis*, Ctur: *Cryptolestes turcicus*, Tga: *Trogoderma granarium*, Lor: *Latheticus oryzae*

Table 4. According to sampling dates, total numbers of individuals of insect species found in wheat grains stored in steel silos in Mardin province, during 2022- 2023

Dates	n	Sga	Sor	Tca	Tco	Rdo	Os s	C tur	Tga	Lor	Dead	Alive
Sep 5, 2022	6	0	0	2	0	3	0	0	0	1	0	6
Sep 20, 2022	15	4	3	4	4	10	1	0	0	1	6	21
Nov 4, 2022	6	0	0	2	0	0	0	0	0	1	0	3
Nov 20, 2022	5	0	0	7	2	2	0	0	0	0	1	10
Dec 5, 2022	7	1	6	7	0	16	2	2	0	0	3	31
Jan 1, 2023	1	0	0	0	0	0	0	2	0	0	0	2
Jan 18,.2023	1	0	0	0	0	0	0	0	0	0	0	0
Feb 4, 2023	1	0	0	0	0	0	0	0	0	0	0	0
Feb 21, 2023	2	0	0	1	0	5	0	0	0	0	0	6
Mar 6, 2023	2	0	0	0	0	2	0	0	0	2	3	1
Mar 20, 2023	2	0	0	0	0	0	0	0	0	0	0	0
May 14, 2023	2	0	0	5	0	5	0	0	0	0	5	5
Jun 14, 2023	1	0	0	2	0	2	0	0	0	0	0	4
Jun 29, 2023	1	0	0	1	0	4	0	0	0	0	1	4
Jul 14, 2023	2	0	2	2	0	2	0	0	0	0	0	6
Jul 29,2023	2	0	1	0	0	5	0	1	1	0	0	8
Aug 15, 2023	2	0	0	4	0	0	0	0	0	1	0	5
Sep 5, 2022	2	2	0	1	0	0	0	0	3	0	1	5
Sep 20,.2022	1	0	0	1	0	4	0	0	2	0	4	3
Nov 4, 2022	1	0	0	0	0	2	0	0	3	0	2	3
Total	62	7	12	39	6	62	3	5	9	6	26	123

Sga: *Sitophilus granarius*, Sor: *Sitophilus oryzae*, Tca: *Tribolium castaneum*, Tco: *Tribolium confusum*, Rdo: *Rhyzopertha dominica*, Oss: *Oryzaephilus surinamensis*, Ctur: *Cryptolestes turcicus*, Tga: *Trogoderma granarium*, Lor: *Latheticus oryzae*

Damaged Grain Ratios (%) in Wheat Stored in Traditional Warehouses and Steel Silos

Table 5 presents the percentages of damaged wheat grains from traditional warehouses in Mardin during 2022-2023 by sampling date. Grain damage began to be noticeable at the end of May, with the highest damage rate of 5.26% recorded on May 24. Damage rates dropped to about 1% in June and July, then rose again in mid-July and August to 4.17%. Table 6 presents the damaged grain ratios (%) for wheat stored in steel silos by sampling date. No damage was detected in samples collected in November 2022. The highest damage rate in steel silos was recorded on April 28, 2023 at 3.09%.

Table 5. According to sampling dates, damaged wheat grains due to insects in traditional warehouses in Mardin province, during 2022-2023

Sampling date	Number of sample (n)	Total number of grain	Total number of undamaged grain	Total number of damaged grain	Percentage of damaged grain
Sep 5, 2022	4	400	399	1	0.25
Sep 20, 2022	6	600	600	0	0.00
Nov 4, 2022	5	500	500	0	0.00
Nov 20, 2022	3	300	300	0	0.00
Dec 5, 2022	4	400	395	5	1.27
Jan 1, 2023	1	100	100	0	0.00
Jan 18, 2023	1	100	100	0	0.00
Feb 4, 2023	1	100	100	0	0.00
Feb 21, 2023	1	100	100	0	0.00
Mar 6, 2023	1	100	100	0	0.00
Mar 20, 2023	2	200	200	0	0.00
May 24, 2023	1	100	95	5	5.26
Jun 14, 2023	2	200	196	4	2.04
Jun 29, 2023	2	200	198	2	1.01
Jul 14, 2023	2	200	197	3	1.52
Jul 29,2023	1	100	96	4	4.17
Aug 15, 2023	1	100	96	4	4.17
Total	38	3800	3772	28	0.74

Table 6. According to sampling dates, damaged wheat grains due to insects in steel silos storage in Mardin province during 2022-2023

Sampling Date	Number of sample (n)	Total number of grain	Total number of undamaged grain	Total number of damaged grain	Percentage of damaged grain
Sep 5, 2022	2	200	198	2	1.01
Oct 20, 2022	9	900	896	4	0.45
Nov 4, 2022	1	100	100	0	0.00
Nov 24, 2022	2	200	200	0	0.00
Dec 5, 2022	3	300	297	3	1.01
Feb 21, 2023	1	100	98	2	2.04
Marc 6, 2023	1	100	98	2	2.04
Apr 9, 2023	2	200	195	5	2.56
Apr 28, 2023	1	100	97	3	3.09
May 14, 2023	1	100	98	2	2.04
May 29, 2023	1	100	98	2	2.04
Total	24	2400	2375	25	1.05

Throughout the sampling period, most insects collected from both traditional and steel silo storages were found to be alive. Despite claims by warehouse and silo owners that fumigation was carried out, the proportion of live insects exceeding 70% may indicate that fumigation practices were not desirably effective. Maintaining a constant gas concentration during fumigation is critical (Emekci and Ferizli, 2000). This raises the possibility that gas may have leaked during the process, even if fumigation was performed. Therefore, optimal storage conditions and monitoring gas concentration using detectors during fumigation are essential. Another issue is dose regulation. Temperature and humidity inside the warehouse are important physical factors affecting the success of fumigations. The high number of live individuals could also be due to poor fumigation practices or, possibly, the development of resistance to phosphine gas among these species. Populations of *S. oryzae* collected from wheat and maize storages in Mersin and Konya provinces were found to be 83–88% resistant to phosphine (Doğanay, 2019). The same study also reported high levels of phosphine resistance among *Tribolium* species collected from stored cereals in southern provinces such as Adana, Hatay, Osmaniye, Kahramanmaraş, and Mersin (Işıkber et al., 2005 and 2016). However, no such study has yet been conducted in Mardin.

Due to lower insect densities in steel silos, damage levels were lower compared to traditional warehouses. The highest damage rate in wheat grains was recorded in May, when temperatures began to rise, reaching 5%. Damage in steel silos was lower, with a maximum of 3%. Overall, damage rates in wheat grains ranged from 1–5%. In another study conducted in Mersin, damage rates in wheat grains were reported to be between 1–2% (Yetkin and Atakan, 2022).

CONCLUSION

In Mardin (districts of Kızıltepe, Nusaybin, Derik, Mazıdağı, and Artuklu), pest populations in stored wheat were found to be higher during the autumn (September–October) and summer (May–August) periods. Fumigation and other pest control measures (e.g., empty warehouse treatment and pre-storage fumigation of infested products) were found to be insufficient, due to high numbers of the alive insects collected. A likely reason for ineffective fumigation is the fluctuation in gas concentration during the process, in other words, leakage from the storage facility. Therefore, it is recommended that gas concentration be measured with detectors throughout the fumigation process.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

Muhammed Mustafa SARUHAN: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; software; writing— original draft; writing—review and editing.

Ekrem ATAKAN: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; software; writing— original draft; writing—review and editing.

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Article History	
Submission received:	28.07.2025
Revised:	20.12.2025
Accepted:	23.12.2025

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