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Maize Pests and Their Natural Enemies in the North-West of Türkiye

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ABSTRACT

Maize is one of the most significant cereal crops in the world, and insect pests cause the highest economic loss. The objective of this study was to assess the level of insect pests and their natural enemies during 2020 and 2022 in the maize fields of Düzce and Sakarya, Türkiye. We performed weekly surveys from the vegetative growth stage of maize to harvest from April through November. A hundred plants were selected with regular and irregular samplings from each field. In addition, light traps and pheromone traps were placed in regularly sampled fields. To detect overwintering larvae, the stalks left in the field after the harvest were cut just above the soil. In the maize fields, a total of 13 pest species from six families in four orders, along with 19 natural enemies from eight families in five orders, were identified. *Ostrinia nubilalis* Hbn. (Lepidoptera: Crambidae) Was found as the primary pest, followed by *Helicoverpa armigera* Hbn. and *Mythimna unipuncta* Haw. (Lepidoptera: Noctuidae). *Meteorus pendulus* Müller (Hymenoptera: Braconidae) was a new record for the East Marmara and Western Black Sea regions and a new host record in Türkiye. Larval parasitoids of *M. unipuncta, Nemoraea pellucida* Meigen, and *Pales pavida* Meigen (Diptera: Tachinidae) represent new host records for Türkiye. Among the predators, *Orius minutus* L. (Hemiptera: Anthocoridae) and coccinellids showed an especially notable common in the maize fields of both provinces.

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ÖZET

Mısır, dünyada tarımı yapılan en önemli tahıllardan birisidir ve zararlı böcek türleri yüksek ekonomik kayıplara neden olmaktadır. Bu çalışma 2020 ve 2022 yılları arasında Düzce ve Sakarya mısır alanlarında bulunan zararlı böcek türleri ve doğal düşmanlarını belirlemek amacıyla yürütülmüştür. Örneklemeler Nisan ayı ile Kasım ayı arasında mısırın vejetatif büyüme evresinden hasata kadar haftalık olarak gerçekleştirilmiştir. Örneklemelerin yapıldığı her bir tarladan toplam 100 bitki incelenmiştir. Ayrıca örnekleme yapılan tarlalara ışık tuzakları ve feromon tuzakları yerleştirilmiştir. Kışlayan larvaları tespit etmek için hasattan sonra tarlada kalan saplar laboratuvara getirilerek incelenmiştir. Bu çalışmada, mısır alanlarında dört takıma bağlı altı familyadan 13 zararlı böcek tür, beş takımdan sekiz familyaya bağlı 19 doğal düşman türü belirlenmiştir. *Ostrinia nubilalis* Hbn. (Lepideoptera: Crambidae), *Helicoverpa armigera* Hbn. ve *Mythimna unipuncta* Haw. (Lepidoptera: Noctuidae) sırasıyla başlıca zararlılar olarak tespit edilmiştir. *Meteorus pendulus* Müller (Hymenoptera: Braconidae), Doğu Marmara ve Batı Karadeniz Bölgeleri için yeni kayıt olmasının yanı sıra Türkiye için yeni konukçu kaydı niteliğindedir. *Mythimna unipuncta*'nın larva parazitoitleri olan *Nemoraea pellucida* Meigen ve *Pales pavida* Meigen (Diptera: Tachinidae), Türkiye için yeni konukçu kaydı niteliğindedir. Predatör türlerden *Orius minutus* L. (Hemiptera: Anthocoridae) ve coccinellid türleri her iki ilde örnekleme yapılan mısır alanlarının birçoğunda yaygın olarak tespit edilmiştir.

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INTRODUCTION

Maize (*Zea mays* L.) is the most widely produced crop, with 1 billion tons worldwide. It has a high genetic diversity and can be grown in various climates, up to 3.800 meters above sea level and from the equator to around 50° north and 42° south latitudes (Ortega, 1987). In Türkiye, maize is the most widely grown crop after wheat and barley and is either sown as the main or the second crop by most farmers, with an approximate annual production of 6.750.000 tons (TUIK, 2021). Düzce and Sakarya provinces produce 332.000 tons of maize, representing 20% of the total production of Türkiye (TUIK, 2021). First-crop maize planting usually occurs between April and May, second-crop maize is in June and July, and harvesting is held from September to October in Düzce and Sakarya provinces. At the global level, maize is used 65-70% in animal feed, while around 20% is utilized in the production of sugar, starch, and oil, and the remaining is in the food industry (Özcan, 2009).

Animal pests, weeds, and pathogens threaten maize yield and quality (Oerke, 2006). Insect pests, especially lepidopteran species are the most critical factors limiting maize production. These pests attack any part of the plant, like foliage, tassel, ear, stem, or grain, and can infest at any stage of maize growth and storage, often causing severe damage (Ortega, 1987). Insect pests, particularly lepidopteran stem borers, severely reduce maize yields (Tonğa & Bayram, 2021). Currently, the most significant pests of maize in Türkiye are the European corn borer, *Ostrinia nubilalis* Hbn. (Lepidoptera: Crambidae) and the Mediterranean corn borer, *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae), which are the primary pests (Sertkaya et al., 2014). These corn borers cause economic loss from 2 to 4 million hectares of maize in Europe (Brookes, 2009). In Türkiye, other lepidopteran pests from the Noctuidae family include cotton leafworm (*Spodoptera littoralis* Boisd.), cutworms (*Agrotis* spp.), corn earworm (*Helicoverpa armigera* Hbn.), beet armyworm (*Spodoptera exigua* Hbn.), armyworms (*Mythimna* spp.), and the family Crambidae include spotted stem borer (*Chilo partellus* Swinhoe), which are significant cause of crop loss (Sertkaya et al., 2014; Akmeşe et al., 2017). Other pests of regional importance include wireworms such as *Agriotes* spp., *Cardiophorus cyanipennis* Mulsant & Wachanru, and *Melanotus fuscipes* Gyll. (Coleoptera: Elateridae), *Gryllotalpa gryllotalpa* (Orthoptera: Gryllotalpidae), *Tanymecus dilaticollis* Gyll. (Coleoptera: Curculionidae), spider mites (*Tetranychus* spp.), aphids (*Rhopalosiphum* spp., Hemiptera: Aphididae), thrips (Thysanoptera), leafhoppers (Hemiptera: Cicadellidae), and planthoppers (Hemiptera: Delphacidae, Cixidae) (Mutlu et al., 2008; Yılmaz et al., 2009; Sertkaya et al., 2010; Akmeşe et al., 2017).

Globalization has facilitated the increase in trade, transportation, travel, and tourism, eliminating natural barriers between specific regions, countries, and even continents and allowing many insect species to enter new habitats (Lowe et al., 2000). Additionally, in recent years, the impact of climate change has led to the emergence of some new insect pests as a frequent problem in various regions of the world.

Agricultural production has expanded considerably in the last 50 years because of the availability of synthetic fertilizers and high-yielding cultivars. In addition, the widespread use of pesticides, which provided farmers with better pest control, significantly contributed to the so-called green revolution (Newsom, 1980; Eichers, 1981; Kogan, 1998; Meissle et al., 2010). However, the rising use of chemicals in agriculture negatively affects the health of humans and animals, pollutes water and soil, and has side effects on beneficial insects such as natural enemies, decomposers, and pollinators (Metcalf, 1986; Pimentel, 2005). Insect pests substantially reduce maize yields, but an approach other than chemical control is lacking (Van Huis, 1981). The principle of knowing insect pests has a significant outcome, which can recognize the natural enemies that prey on or parasitize them. The capacity to correctly identify pests and beneficial insects is equally as critical as recognizing damaging ones because it can be used to improve pest management success (Ortega, 1987).

The primary purpose of the current study is to report the presence of pests and their natural enemies in maize fields of Düzce and Sakarya provinces. This study attempts to establish the basis for developing an integrated pest management program by identifying the pests and natural enemies in maize fields.

MATERIAL and METHOD

The study was performed in the first and second-crop maize fields in Merkez, Çilimli, Gümüşova districts of Düzce, and Hendek, Akyazı, Erenler districts of Sakarya between 2020 and 2022 (Figure 1). Regular samplings were made in 12 maize fields in Düzce and Sakarya provinces in 2021 and 2022. In addition, insect species were collected through irregular samplings from 54 different fields between 2020 and 2022. Field surveys were done from April to October each year, and samplings were carried out from the

vegetative growth stage to harvest. A hundred maize plants were checked in each field, with 20 randomly selected plants on 5 sampling spots. Each plant was carefully inspected, from the aerial root to the tassel. Additionally, solar-powered light traps and *O. nubilalis* pheromone traps (Z-11-Tetradecenyl acetate, E-11-Tetradecenyl acetate, Trece Incorporated, USA) were placed in regularly sampled fields. After the harvest, stalks remaining in the field were cut just above the soil, with 50 samples collected for each field and brought to the laboratory for detection of overwintering larvae in the stalks. Insect specimens were put into a plastic container (10 × 10 cm), falcon tubes, and Petri dishes, labeled, and protected via an ice box until transferred to the laboratory. The collected insect samples were incubated in a plant growth chamber (25±1 °C, 60±10 RH, 14 L:10 D photoperiod) with their natural (fresh maize leaves, stems, and cobs) and artificial diets, including toasted soybean flour, stabilized wheat germ, sugar, vitamins, and mineral salts (Southland Products Inc, USA). Samples were checked daily until adult pests or any possible natural enemies such as parasitoids or predators emerged. After the first adults emerged, the samples were sent to the expert taxonomist for identification.

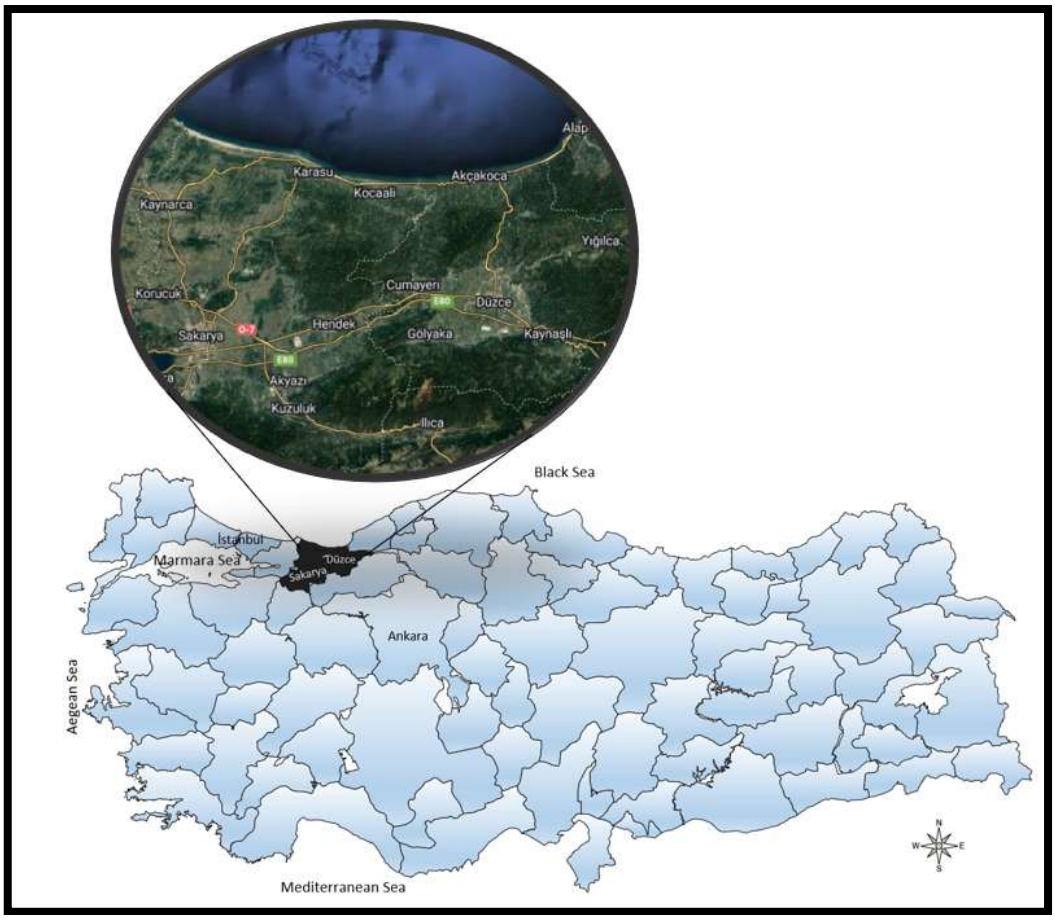

Figure 1. Map showing the location of Düzce and Sakarya provinces in Türkiye
Şekil 1. Çalışmaların yürütüldüğü Düzce ve Sakarya illerinin haritası

The molecular method based on DNA sequencing of ribosomal internal transcribed spacer (ITS) region was employed for the species identification of *Trichogramma* Westwood (Hymenoptera: Trichogrammatidae) specimens from *O. nubilalis* eggs. The extraction nucleic acids of samples, preserved in 95% ethyl alcohol, were isolated utilizing the DNeasy Blood and Tissue Kit (Qiagen, Valencia, CA, USA) following the instructions provided by the manufacturer. The PCR amplification to yield their ITS2 was conducted with the universal primer pair (forward 5'-TGTGAACTGCAGGACACATG-3' and reverse 5'-GTCTTGCCTGCTCTGAG-3') according to Stouthamer et al. (1999). The amplified fragments were sequenced by a commercial company (Macrogen Inc., Seoul, South Korea) with the same primers. The obtained DNA sequences were subjected to alignment using ClustalW, a method for multiple-sequence alignment (Thompson et al., 1994), and analyzed using the Basic Local Alignment Search Tool (BLASTn: http://blast.ncbi.nlm.nih.gov/Blast) at NCBI (National Center for Biotechnology Information:

https://www.ncbi.nlm.nih.gov/) against the GenBank nucleotide database to identify the closest presented reference sequences.

RESULTS and DISCUSSION

We detected 13 different insect pests from the orders Lepidoptera, Hemiptera, Coleoptera, and Orthoptera, and 19 different natural enemies from the orders Diptera, Hymenoptera, Hemiptera, Coleoptera, and Neuroptera in the maize fields of Düzce and Sakarya.

Maize Pests in Düzce and Sakarya Provinces and Their Status in Türkiye

The most common and high-density species were *O. nubilalis*, *H. armigera*, and *M. unipuncta*. *Loxostege sticticalis* L. (Lepidoptera: Crambidae) has also the highest density, although its occurrence was restricted to 2022. The other species were found in various locations in Düzce and Sakarya, and their population densities remained low (Table 1).

Table 1. Pest species identified in maize fields of Düzce and Sakarya
Tablo 1. Düzce ve Sakarya ili mısır alanlarında tespit edilen zararlı türler

Order	Family	Species
Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hübner, 1808)
	Noctuidae	*Mythimna unipuntca* (Haworth, 1809)
	Noctuidae	*Mythimna loreyi* (Duponchel, 1827)
	Noctuidae	*Mythimna congrua* (Hübner, 1817)
	Noctuidae	*Agrotis ipsilon* (Hufnagel, 1766)
	Noctuidae	*Autographa gamma* (Linnaeus, 1758)
	Crambidae	*Ostrinia nubilalis* (Hübner, 1796)
	Crambidae	*Loxostege sticticalis* (Linnaeus, 1761)
	Erebidae	*Hyphantria cunea* (Drury, 1773)
Hemiptera	Aphididae	*Rhopalosiphum padi* (Linnaeus, 1758)
	Aphididae	*Anoecia corni* (Fabricius, 1775)
Coleoptera	Curculionidae	*Tanymecus dilaticollis* (Gyllenhal, 1834)
Orthoptera	Gryllotalpidae	*Gryllotalpa gryllotalpa* (Linnaeus, 1758)

The European corn borer, *O. nubilalis* is the most common species in first and second-crop maize in Düzce and Sakarya provinces. It was detected in almost all the survey and sampled fields. Larvae of *O. nubilalis* were found on leaves, cobs, and stalks of maize and adults in pheromone and light traps. The pest was determined from the end of May until the harvest. In addition, overwintering the last stage larvae were found in the remaining corn stalks in the field after harvest. Pupae emerge as moths in May and June during the spring season. Previous investigations into the biological behavior of *O. nubilalis*, conducted in the field and laboratory, revealed the presence of first-generation larvae, typically from June to July, in the maize whorls. The pest overwinters as mature larvae in corn stalks and other plant refuse, including weed stems. (Özdemir, 1981). The second-generation larvae emerge from late July to August, causing severe damage (Özdemir, 1981; Melan et al., 1996). In the Cukurova region, the first generation is effective in late May and early June. 2nd, 3rd, and 4th generations were observed in July, August, and September, respectively (Kornoşor & Kayapınar, 1988a). The young larvae feed on the top tassels and leaves on the fresh shoots. Then, the larvae enter the cob and stem to transform into the pupal stage, causing the cob shedding and stalk tunnels, as well as restrictions on the cob and grains development (Hudon et al., 1989; Kaçar et al., 2023a). It causes considerable yield losses in Central and South Europe and North America (Dicke and Guthrie, 1988; Krattiger, 1997; Velasco et al., 2007). Similarly, *O. nubilalis* is recognized as one of the most severe pests of maize in various parts of Türkiye, such as the Black Sea, Aegean, Mediterranean, and Central Anatolia regions (Özdemir, 1981; Derin, 1992; Sade, 2003; Öztemiz et al., 2008). *Ostrinia nubilalis* is the primary pest of maize crops along with *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae), causing a 30% yield loss in second-crop maize (Özdemir, 1981; Cerit et al., 2006). However, in the study areas, *S. nonagrioides* was not detected in pheromone traps or light traps.

The corn earworm, *Helicoverpa armigera* is one of the most common pests after *O. nubilalis* in the maize fields of Düzce and Sakarya provinces. The pest was observed at a very low density in the first-crop maize during the 2020 and 2021 seasons. However, the pest was notably population density in the first-crop maize of 2022 and second-crop maize of all years. They have been frequently seen on second-crop maize from the end of August to the beginning of October while on first-crop maize from the second half of July to mid-August. According to earlier studies, *H. amigera* was generally a high population of second-crop maize, while the low density was in first-crop maize (Gözüaçık & Mart, 2005; Gözüaçık, 2016). *Helicoverpa armigera* larvae were found on leaves, silks, cobs, and tassels of maize, and adults in light traps. The larvae principally

damage the corn ear, which begins to feed on the silk of the cob soon. In addition to entering the cob and causing direct injury to the kernels, they also open access for infection by pathogens. Besides, the larvae may occasionally feed on leaf whorls or tassels when silks and cobs have not yet developed. *Helicoverpa armigera* is a globally distributed and devastating pest of agricultural and horticultural areas, containing over 181 plant species from 45 families. (Srivastava et al., 2005). The pest is a problem in a variety of crops in Africa, Middle East, Asia (Russia, China, Pakistan, India, Thailand), Europe (Portugal, Spain, Italy, Greece, Türkiye), Australia, New Zealand (Hardwick, 1965; Mohyuddin, 1985; Zalucki et al., 1986; Fitt, 1989; Karim, 2000, Scott et al., 2006; Fefelova & Frolov, 2008; Gözüaçık, 2020; Burgio et al., 2020). Also, *H. armigera* is regarded as one of the most significant pests of maize in some parts of Türkiye, including Black Sea, Central Anatolia, East Anatolia, Southeast Anatolia, Mediterranean, and Aegean (Özdemir & Uzunali, 1981; Şimşek & Sezer, 1983; Ünlü et al., 1995; Gözüaçık, 2004; Tiftikci and Kornoşor, 2015; Barış et al., 2020; Gözüaçık, 2020; Koca & Kaçar, 2021a). Management of *H. armigera* is complicated due to its high mobility, ability to adapt to adversities and complete many generations in a year, and capability to create pesticide resistance (Ali et al., 2009).

The study identified three armyworm species in the maize fields of Düzce and Sakarya provinces, namely *M. unipuncta, M. loreyi*, and *M. congrua*. Among these, *M. unipuncta* exhibited the highest population density, while *M. congrua* and *M. loreyi* were found in lower numbers. *Mythimna congrua* is a new record for the North-west of Türkiye, including East Marmara, and Western Black Sea Region. *M. congrua* has previously only been found in Izmir (Tanyeri et al., 2010), and Hatay (Can et al., 2018) provinces of Türkiye. *M. unipuncta* was found at low density in the first and second-crop maize in 2020. However, it was particularly population density in the second-crop maize of 2021 and the first and second-crop maize of the 2022 season. The pest was rarely found in the second half of July but frequently determined throughout August in the first-crop maize. In the second crop, it was intensely observed from the end of August until mid-October. *Mythimna* spp. consume the leaf tissue of maize plants. Feeding is usually confined to leaf margins, but larvae may occasionally strip the plants of leaf tissue. Additionally, it has been determined that they also feed on the silk of the cob as the leaves begin to harden or dry at the end of the vegetation period of the second-crop maize. In Çukurova, the first adults of *M. loreyi* were identified in late May using Robinson light traps in maize plants (İkincisoy, 1993). Similarly, the first adults of *M. unipuncta* were observed in early April, and adult emergence continued until May (Kara, 1994). Armyworms generally prefer to lay eggs and feed upon plants in the family Gramineae, including weedy grasses. Although the larva feeds primarily on grasses (oats, wheat, fall rye, maize, barley, and forage grasses), it can be a pest of some vegetables such as beans, cabbages, carrots, onions, peas, peppers, radishes, sweet potatoes, alfalfas, lettuces, celeries, onions, cucumbers, sugar beets, and watermelons (Cook et al., 2004; Capinera, 2018). Armyworms occur in many areas of the world, including North, Central, and South America, Southern Europe, Central Africa, and Western Asia (E1-Sherif et al., 1972; Singh et al., 1987; Cabello, 1989; Capinera, 2018). They have been subjected to intensive investigations due to their damage to maize plants in several areas of Türkiye, such as the Black Sea, Mediterranean, East Anatolia, Southeast Anatolia, and Mediterranean regions (Kornoşor, 1999; Sertkaya & Bayram, 2005; Gözüaçık et al., 2009; Ölmez et al., 2010; Tiftikci & Kornoşor, 2015; Gözüaçık, 2020; Kaçar & Koca, 2021a).

The silver Y moth, *A. gamma* was determined in Düzce and Sakarya provinces for all years. However, its population was at very low densities in the first and second-crop maize. It was found between July and September in all maize fields, regularly sampled. The adults were captured in light traps, and the larvae were found on the cob. The larvae cause damage to the corn ear and the cob silk. The silver Y moth is an economically significant polyphagous pest of vegetables and field crops throughout the Palearctic region, including Europe, Asia, and North Africa (Balachowsky, 1972). *A. gamma* is mainly found in open habitats such as grasslands and forest edges. Females lay their eggs primarily on low-growing herbaceous plants, and they can frequently be seen feeding while taking nectar from flowering plants during the day or early evening. Larvae of *A. gamma* can cause significant economic damage due to their wide range of various crops and vegetables, including peas, soybeans, sugar beets, cabbage, tomatoes, and industrial crops (Chumakov & Kuznetsova, 2021; Nagy et al., 2022).

Agrotis spp. is a polyphagous species on numerous cultivated and herbaceous plants. Adults of the pest were captured in light traps in Düzce province (Alacamescit and Matı/Central) in May 2021 and 2022. The adults were also captured in Aktarla (Akyazı) and Hasanbey (Erenler) in Sakarya in 2021 and 2022, respectively. On the one hand, larvae were first detected in a field in Sakarya province (Fatih/Akyazı) in the half of June 2021. Larvae of *A. ipsilon* were found in 4-8 leaves of the first-crop maize. The larvae cut through the ground stem of maize, causing the plant to wilt and die. Black cutworm, *A. ipsilon* is known to attack at least 49 cultivated plants and cause considerable economic losses in various crops, particularly industrial plants and vegetables, in

Türkiye and around the world (Odiyo, 1975; Potter, 1998; Hong & Williamson, 2004; Liu et al., 2015). According to Lodos (1980), *Agrotis* spp. is one of the six primary pests of maize in Türkiye. Moreover, young larvae consume fresh leaves or growing plants until they reach the fourth instar during their early stages. Mature larvae can cut many plants in a single night, resulting in extensive damage (Santos & Shields, 1998; Capinera, 2001). While young larvae exhibit activity throughout the day, mature larvae are predominantly active during the night, with peak activity observed between midnight and one hour before sunrise (Williamson & Potter, 1997).

The meadow moth, *L. sticticalis* was detected in Düzce and Sakarya provinces only in 2022. Furthermore, it has been reported that this pest has become an outbreak in many regions of Türkiye, including Kocaeli, İstanbul, Bolu, Düzce, and Sakarya (Kaçar et al., 2023b). The larvae of *L. sticticalis* did not cause any damage to the maize plant. Adults of *L. sticticalis* were caught in numbers ranging from 10 to 50 per light trap in different locations in each province. The first-generation adults flight from the last week of June to the first half of July and the second generation was seen from the beginning to mid-August. The females of *L. sticticalis* lay their eggs on the underside of the host leaves. The larvae feed on the leaves, shoots, buds, and flower leaves of the plants, which can completely consume the plants during the outbreak years (Anonymous, 2008; Kuznetsova & Chumakov, 2008; Kaçar et al., 2023b). *Loxostege sticticalis* is one of the most destructive migratory pests in Europe, Asia, and North America, causing significant economic damage nearly yearly (Qu et al., 1999). This species is a dangerous polyphagous pest that is capable of feeding on 200 species from 35 plant families, including cereals, vegetables, fiber crops, beans, and oilseeds, but has a special preference for certain host plants (Qu et al., 1999; Yin et al., 2004; 2005; Zhang et al., 2010). They are highly adaptable, capable of reproduction, and harmful. It can populate large areas by flying great distances within two to three days. (Shurovenkov & Alekhin, 1984; Frolov et al., 2000; Smirnova, 2000).

The fall webworm, *H. cunea*, was only found in the second-crop maize of Düzce and Sakarya. This pest was previously detected in Düzce and Sakarya provinces on hazelnuts, mulberries, and some forest trees, and it was reported that the pest produced two generations per year. (Kaçar et al., 2019; Kaçar et al., 2022). As the host of *H. cunea*, maize is not an apparent preference. At the end of the season, it prefers to feed on maize leaves and cob tassels, which are relatively fresher than the leaves of trees such as mulberry and hazelnut. The larval stages of the second generation of *H. cunea*, which were close to overwintering, passed to the overwintering areas after feeding on the maize plant. *Hyphantria cunea* is a polyphagous quarantined and serious invasive defoliator pest which causes significant damage and economic losses due to its great fecundity and extensive host range (Yang et al., 2006; Zhang et al., 2016). *H. cunea* defoliates 175 different plant species from 108 genera within 49 plant families, including ornamental, fruit, and forest trees as well as crops like maize, cotton, cabbage, and others (Qu, 1987; Wang, 1995; Yang et al., 2006). *H. cunea* was first detected in Turkey in 1975 and has spread to the Marmara, Black Sea, and North Aegean regions of Türkiye. It causes significant damage, especially in hazelnut orchards of the central Black Sea region (İren, 1977; Anonymous, 2011; Sullivan, 2011; Kaçar et al., 2019; Kaçar et al., 2022).

The maize leaf weevil, *T. dilaticollis*, was determined in Alacamescit (Cilimli) of Düzce province in May 2020, as well as Aktarla and Catalköprü (Akyazı) Sakarya province. They were detected in the 2-4 leaf period of maize and consume the leaf margins like a crescent shape. Barbulescu et al. (2001) reported that *T. dilaticollis* adults are more dangerous during the early vegetation stages of maize, while damage to its larvae is not important. So, adults consume leaves and destroy apical meristems. Besides that, *T. dilaticollis* has one generation per year and overwinters as an adult in the soil (Paulian, 1972). *Tanymecus dilaticollis* is a significant pest of maize and damage in the seedling period in Europe, Anatolia, Iran, Russia, South-western Asia, and the Caucasus (Draganova et al., 2012; Alonso-Zarazaga et al., 2017; Davidian, 2019). This species is a common pest in maize fields in many regions of Türkiye (Gözüaçık, 2019). Lodos (1980) reported that *T. dilaticollis* is one of the six main pests of maize fields of Türkiye. Although *T. dilaticollis* is considered a polyphagous species, it prefers maize for optimal development for the larvae and is the most preferred food by adults (Bărbulescu & Voinescu, 1998).

The mole cricket, *G. gryllotalpa* was only determined in a maize field in Seyfeler/Akyazı (Sakarya province) in 2021. The nymph and adult of the pest cut through the ground stem of maize, causing the plant to die. *Gryllotalpa gryllotalpa* is a significant pest of many crops in various parts of the world, causing damage to seedlings, roots, and tubers. They are distributed throughout temperate and tropical regions such as Europe, Russia, Turkey, Central Asia, Iran, Afghanistan, Central and Southern Asia, North Africa, America, and Southern Ukraine (Klechkovskii, 1967). The pest damages many crops such as soybean, cowpea, maize, turf, vegetable, tobacco, sunflower, cotton, fruits, and some tree seedlings (Frank & Parkman, 1999; Bhamrah, 2007; Akmeşe et al., 2017; Javadzadeh et al., 2017). *Gryllotalpa gryllotalpa* feeding on the roots of plants causes plant stress and even death (Thompson, 2003). In addition, plant

pathogenic fungi and bacteria can enter a plant through damage caused by feeding the pest (Thompson & Brandenburg, 2005).

Aphids are frequently found on maize leaves and tassels in large and dense colonies. Aphid infestation results in deformed and chlorotic showing leaves. If severely damaged, the tassel can become infertile and negatively affect the production of seeds (Bosque-Perez, 1995). Aphids, also produce honeydew on which the molds grow. It may limit the pollination process of maize when tassels and silks become covered in honeydew. Also, if aphids feed more inside the whorl before tassel emergence, it may affect kernel growth or result in sterile ears (Stray et al., 1994). Besides, *R. padi* transmits maize dwarf mosaic virus (Ferro et al., 1980). Maize aphids were detected in the Hendek and Akyazı districts of Sakarya and Merkez, Çilimli, and Gümüşova districts of Düzce. These species were primarily found in the first-crop maize, which varies from year to year but usually appears between mid-June and the end of August. Also, maize aphids were rarely detected in the second crop at the end of August.

Natural Enemies Detected in Maize Fields in Düzce and Sakarya Provinces

The study has revealed 19 beneficial species belonging to eight families from five different orders from the maize fields of Düzce and Sakarya. Nine parasitoid species were identified, including eight larval and egg parasitoids (Table 2).

Table 2. Parasitoids identified in maize fields of Düzce and Sakarya
Tablo 2. Düzce ve Sakarya ili mısır alanlarında tespit edilen parazitoitler

Family	Species	Host	Location
	Diptera		
Tachinidae	*Voria ruralis* (Fallén, 1810)	*H. armigera* *A. gamma*	Merkez (Düzce) Matı (Sakarya) Hendek (Sakarya)
Tachinidae	*Lydella thompsoni* (Herting, 1959)	*O. nubilalis*	Merkez (Düzce) Çilimli (Düzce) Akyazı (Sakarya) Erenler (Sakarya) Hendek (Sakarya)
Tachinidae	*Peleteria iavana* (Wiedemann, 1819)	Unknown	Merkez (Düzce)
Tachinidae	*Nemoraea pellucida* (Meigen, 1824)	*M. unipuncta*	Merkez (Düzce) Hendek (Sakarya)
Tachinidae	*Pales pavida* (Meigen, 1824)	*M. unipuncta*	Merkez (Düzce)
Tachinidae	*Peribaea tibialis* (Robineau-Desvoidy, 1851)	*M. unipuncta*	Merkez (Düzce)
	Hymenoptera		
Braconidae	*Meteorus pendulus* (Müller, 1776)	*M. unipuncta*	Merkez (Düzce) Erenler (Sakarya)
Ichneumonidae	*Hyposoter didymator* (Thunberg, 1822)	*H. armigera*	Merkez (Düzce)
Trichogrammatidae	*Trichogramma brassicae* (Bezdenko, 1968)	*O. nubilalis*	Merkez (Düzce) Çilimli (Düzce) Akyazı (Sakarya) Erenler (Sakarya) Hendek (Sakarya)

The larval parasitoids, *Meteorus pendulus* (Müller, 1776) from the Braconidae (Hymenoptera), were collected in the Alacamescit (Düzce) and Hasanbey (Sakarya) locations on *Mythimna unipuncta* Haw. (Lepidoptera: Noctuidae) larvae. It has been noted as a new record for the East Marmara and Western Black Sea regions and a new host record in Türkiye. *Meteorus pendulus* was only recorded in Adana province, in the Mediterranean region of Türkiye (Yılmaz et al., 2010). It is a solitary endoparasitoid that emerges from the larval stage of various Lepidopteran families, including Noctuidae, Tortricidae, Geometridae, Lycaenidae, Lasiocampidae, and Lymantriidae (Yu et al., 2012). Another larval parasitoid *H. didymator*, obtained from *H. armigera* larvae, is a solitary koinobiont endoparasitoid (Medina et al., 2007). This species is widely distributed in many regions, including Europe, Asia, the Middle East, North Africa, and Australia (Schneider et al., 2003). *Hyposoter didymator*, highlighted as an important parasitoid of *H. armigera*, has been documented to be an effective parasitoid under natural conditions on *Helicoverpa* and *Spodoptera* species, as well as economically significant harmful noctuids (Sertkaya et al., 2004; Mironidis & Savopoulou-Soultani, 2009).

The species *N. pellucida* and *P. pavida*, larval parasitoids of *M. unipuncta*, represent new host records for both species in Türkiye. *Peribaea tibialis*, a

solitary parasitoid species collected from *M. unipuncta larvae*, was previously discovered in the Bartın province of Turkey (Atay, 2017). In general, Tachinidae species are generally known to parasitize the Macrolepidoptera and Microlepidoptera larvae and to be polyphagous (Tschorsnig & Herting, 1994). The parasitoid *L. thompsoni*, obtained from *O. nubilalis* larvae, was previously reported in the Western Blacksea region of Türkiye (Melan & Kara, 2004), and it was widely documented in many countries worldwide (Cagáncaron et al., 1999). Gözüaçık (2020) obtained this parasitoid from *O. nubilalis* larvae in maize fields in the Iğdır province, reporting a parasitism rate ranging from 21.2% to 39.7%. Another tachinid species identified in our study, *V. ruralis*, was obtained from *H. armigera* larvae. This species was previously reported on *H. armigera* and *A. gamma* larvae in Türkiye (Kara & Özdemir, 2000). *Voria ruralis* is generally known as a parasitoid commonly found in the Noctuidae larvae (Tschorsnig & Herting, 1994). Among the Tachinidae species, *L. thompsoni* is the most frequent in both provinces, and following *V. ruralis* and *N. pellucida* were listed as common tachinids.

Among the identified parasitoid species, only an egg parasitoid has been detected. The identification of *Trichogramma* species was carried out by assessing the size of their ITS2 PCR product. BLASTn queries based on the ITS2 products of *Trichogramma* specimens in the maize fields of Sakarya and Düzce provinces showed that the sequences of isolates were 99–100% identical to those of *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) isolates in the GenBank database. The resultant sequences were deposited in GenBank under the accession numbers OP597676 to OP597679. In previous studies conducted in the region, the same species has been identified (Koca et al., 2018; Gülser & Öztemiz, 2020). Egg parasitoids of the *Trichogramma* genus have been commonly used in inundative biological control against a variety of agricultural pests, including Lepidoptera, Diptera, Coleoptera, Hemiptera, Hymenoptera, and Neuroptera (Smith, 1996). In Türkiye, *Trichogramma* species are mass-reared, and these parasitoids are released, particularly in maize fields (Öztemiz et al., 2008). These parasitoids play a significant role in maintaining the ecosystem in some areas by controlling the population of lepidopteran pests without pesticides (Thomson et al., 2003). Earlier studies in the Black Sea region of Türkiye have shown that the natural occurrence of the egg parasitoids, *T. evanescens* and *T. brassicae*, can effectively suppress the populations of *O. nubilalis* (Özdemir, 1981; Melan et al., 1996; Kutuk, 2017). In addition, *T. evanescens* is released against *H. armigera*, reducing up to 80% of *H. armigera* larvae (Öztemiz et al., 2009). Therefore, *Trichogramma* species are a significant mortality or reducing factor in *O. nubilalis* and *H. armigera* populations and may play a crucial role in their (Öztemiz et al., 2009; Koca & Kaçar, 2021b).

Table 3. Predators identified in maize fields of Düzce and Sakarya
Tablo 3. Düzce ve Sakarya ili mısır alanlarında tespit edilen predatörler

Family	Species	Location
	Hemiptera	
Miridae	*Stenodema virens* (Linneaus, 1767)	Çilimli (Düzce)
Anthocoridae	*Orius minutus* (Linneaus, 1758)	Merkez, Çilimli (Düzce) Akyazı, Erenler, Hendek (Sakarya)
	Coleoptera	
Coccinellidae	*Adalia decempunctata* (Linnaeus, 1758)	Çilimli, Merkez (Düzce) Erenler (Sakarya)
Coccinellidae	*Propylea quatuordecimpunctata* (Linnaeus, 1758)	Merkez (Düzce) Akyazı, Erenler (Sakarya)
Coccinellidae	*Harmonia axyridis* (Pallas, 1773)	Çilimli (Düzce) Erenler, Hendek (Sakarya)
Coccinellidae	*Coccinula quatuordecimpustulata* (Dobzhansky, 1925)	Merkez, Çilimli (Düzce) Akyazı, Hendek (Sakarya)
Coccinellidae	*Scymnus rubromaculatus* (Goeze, 1778)	Merkez, Çilimli (Düzce) Akyazı (Sakarya)
Coccinellidae	*Subcoccinella vigintiquatuorpunctata* (Linnaeus, 1758)	Merkez, Çilimli (Düzce) Akyazı, Erenler (Sakarya)
Coccinellidae	*Coccinella septempunctata* (Linnaeus, 1758)	Merkez, Çilimli (Düzce) Akyazı, Erenler, Hendek (Sakarya)
	Neuroptera	
Chrysopidae	*Chrysoperla carnea* (Stephens, 1836)	Merkez, Çilimli (Düzce) Akyazı (Sakarya)

In addition, 10 predators were detected, with seven belonging to the Coccinellidae family and one each from the Miridae, Anthocoridae, and Chrysopidae families (Table 3). Six coccinellids were predators, and one species (*Subcoccinella vigintiquatuorpunctata*) was phytophagous. Coccinellids play a crucial role in sustainable plant protection strategies, serving as fundamental members of biological control and famous predators in agroecosystems (Khan et al., 2007; Kaçar & Koca, 2020).

Among these taxa, *O. minutus* showed an especially notable presence in the maize fields of Düzce and Sakarya, practically ubiquitous across virtually all areas subject to sampling efforts. Similarly, coccinellids were also widely distributed in both provinces. *Stenodema virens* was detected only in the Matı localion in the first year of the study in Düzce province, whereas *C. carnea* emerged in relatively low population densities in different locations.

CONCLUSION

The study revealed nine Lepidopteran pests, two Hemipteran pests, and one Orthopteran and Coleopteran pest. Furthermore, the study has identified six parasitoid species belonging to the Tachinidae family, as well as one species from the Braconidae, Ichneumonidae, and Trichogrammatidae families. Besides, this research has also revealed six species from the Coccinellidae family and one species each from the Miridae, Anthocoridae, and Chrysopidae families as predator species. The primary pest was identified as the European corn borer, *O. nubilalis*, damaging maize cultivation in Düzce and Sakarya, followed by the species *H. armigera* and *M. unipuncta.* Over the past five years, problems with Lepidopteran pests, such as *O. nubilalis*, *H. armigera*, and *Mythimna* spp., have experienced a notable increase. This rise could be attributed to the expanding populations of pests, potentially influenced by warmer climatic conditions or the excessive application of pesticides.

Naturally occurring parasitoids and predators, which play an important role in biological control in the field, are frequently harmed by broad-spectrum insecticide applications. In recent years, there has been a rise in the prevalence of *H. cunea*, reaching epidemic levels in hazelnut orchards in Düzce. To manage the *H. cunea* population in these areas, a combination of registered and unregistered pesticides is frequently employed. Due to the interweaving of maize fields within hazelnut orchards, the regular application of pesticides against *H. cunea* could harm natural enemies and disrupt the biocontrol of *O. nubilalis* by *Trichogramma* species. Therefore, the chemicals used in the control of pests should be eco-friendly and not harm on natural enemies. In addition, a decrease in insecticide usage will contribute to enhanced biological control. Parasitoids and predators can also be promoted with specific measures, including diverse crop patterns, and managing field margins such as flower strips and hedges to provide food and overwintering sites. Besides seasonal population fluctuations, natural enemies of pest species should be followed to develop integrated pest management programs as an alternative against chemical control. In addition, it would be beneficial to research to determine the effectiveness of natural enemies.

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Author Contributions

The authors declare that they have contributed equally to the article.

Conflicts of Interest

The authors declare no conflict of interest.

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