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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Seasonal population dynamics and environmental influences on *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in peanut fields of Çukurova Region of Türkiye

Çukurova bölgesi yer fıstığı tarlalarında *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae)'nın mevsimsel popülasyon dinamiği ve çevresel etmenlerin etkisi

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ABSTRACT

This study investigated the seasonal population dynamics and environmental influences on *Helicoverpa armigera* in peanut (*Arachis hypogaea* L.) fields during 2021 and 2022 growing seasons in the Osmaniye and Adana provinces of Türkiye. A total of 2,931 and 2,099 adult moths were captured using five pheromone traps in 2021 and 2022, respectively, showing significant temporal variation (F = 12.05; P = 0.0001; F = 29.49; P = 0.0001). In 2021, a major population peak occurred on 16th August (145.2 moths/trap), while in 2022, two distinct peaks were observed, with the highest on 1st September (80.2 moths/trap). Larval counts reflected adult activity, with the highest numbers recorded on 16th August (2021) and 4th August (2022). Environmental monitoring revealed that temperatures ranged from 22.2°C to 30.2°C, while relative humidity varied between 31.8% and 78.0%. Both parameters exhibited a notable decline from mid-August to October.These fluctuations likely influenced moth emergence and larval development. Larval infestations were sporadic, underscoring variability in pest pressure. The results identify mid-August to early September as a critical period for implementing pest control strategies. The close alignment between environmental conditions, adult activity, and larval presence highlights the importance of integrated monitoring for effective *H. armigera* management in peanut cultivation.

ÖZET

Bu çalışma, 2021 ve 2022 yetiştirme dönemlerinde Türkiye'nin Osmaniye ve Adana illerinde yer fıstığı (*Arachis hypogaea* L.) tarlalarında *Helicoverpa armigera*'nın mevsimsel popülasyon dinamikleri ve çevresel faktörlerin etkilerini incelemiştir. İki sezon boyunca beş feromon tuzağı kullanılarak sırasıyla 2.931 ve 2.099 ergin birey yakalanmış olup, zamana bağlı olarak anlamlı farklılıklar tespit edilmiştir (F = 12,05; P = 0,0001; F = 29,49; P = 0,0001). 2021 yılında popülasyonun en yüksek seviyesi 16 Ağustos tarihinde (145,2 birey/tuzak) gözlenirken, 2022 sezonunda iki belirgin zirve oluşmuş ve en yüksek yoğunluk 1 Eylül tarihinde (80,2 birey/tuzak) kaydedilmiştir. Larva yoğunlukları, ergin aktivitesi ile paralellik göstererek 2021'de 16 Ağustos, 2022'de ise 4 Ağustos tarihlerinde en yüksek değerlere ulaşmıştır. Çevresel izlemeler neticesinde sıcaklıkların 22,2°C ile 30,2°C arasında, bağıl nem oranlarının ise %31,8 ile %78,0 arasında değiştiği; her iki parametrede de Ağustos ortasından Ekim ayına kadar belirgin azalma eğilimi olduğu belirlenmiştir. Bu çevresel değişimler, kelebek çıkışları ve larval gelişim süreçleri üzerinde etkili olmuş olabilir. Larva bulaşmaları düzensiz seyretmiş olup, zararlı baskısının değişkenliğini ortaya koymaktadır. Elde edilen bulgular, zararlı yönetimi açısından Ağustos ortası ile Eylül başı arasındaki dönemin kritik bir zaman dilimi olduğunu göstermektedir. Ayrıca, çevresel koşullar ile ergin ve larva popülasyonları arasındaki yakın ilişki, yer fıstığı üretiminde *Helicoverpa armigera*'nın etkin kontrolü için entegre izleme programlarının önemini vurgulamaktadır.

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INTRODUCTION

Peanut (*Arachis hypogaea* L.), commonly known as groundnut, is a leguminous crop of significant global importance, widely cultivated across Asia, Africa, and the Americas (Yayock et al., 1998; Sharma & Mathur, 2006; Bertioli et al., 2011; Jordan et al., 2017; FAO, 2023). It is primarily grown for its edible seeds, which are rich in oil (47–53%) and protein (25–36%), along with essential minerals, vitamins, and antioxidants, making it a vital food and oilseed crop (Savage & Keenan, 1994; Janila et al., 2013; Fletcher & Shi, 2016; Jordan et al., 2017). Peanut oil is widely used in cooking, while its high protein content supports both human nutrition and livestock feed (Nigam, 2000). Additionally, peanut has various industrial applications, including the production of soaps, cosmetics, lubricants, and biodiesel, underscoring its economic versatility (Dwivedi et al., 2007). Its adaptability to semi-arid regions and nitrogen-fixing ability further enhance its role in sustainable agriculture (Janila et al., 2013; Stalker & Wilson, 2016).

According to FAOSTAT data from 2020, the leading global producers of peanuts were China (33.5%), India (18.6%), Nigeria (8.4%), the United States (5.2%) and Sudan (5.2%), followed by Senegal (3.4%), Myanmar (3.1%), Argentina (2.4%), and Guinea (2%). Türkiye contributed approximately 0.4% to global production. In Türkiye, peanut cultivation is regionally concentrated, approximately 99.74% of national production originating from the Mediterranean (79.72%), Southeastern Anatolia (18.86%), and Aegean (1.16%) regions (TÜİK, 2024). In 2024, peanuts were cultivated on 576,418 decares in Türkiye, yielding a total of 246,796 tons. The provinces of Adana (47.20%), Osmaniye (23.07%), Şırnak (14.82%), Antalya (3.03%), Kahramanmaraş (2.6%), Hatay (2.8%), Gaziantep (2.6%), Şanlıurfa (1.3%) and Mersin (1.2%) accounted for 98.62% of total national production.

Peanut crops are susceptible to infestation by more than 360 insect species (Smith & Barfield, 1982). The major pests are *Tetranychus urticae*, *Aphis craccivora*, *Aphis gossypii*, *Empoasca kerri*, *Scirtothrips dorsalis*, *Thrips tabaci*, *Aproaerema modicella*, *Stegasta bosqueella*, *Spodoptera litura*, *S. littoralis*, *S. frugiperda*, *S. exigua*, *Spilosoma obliqua*, *Amsacta albistriga*, *A. moorei*, *Helicoverpa armigera*, *Duponchelia fovealis*, *Sphenoptera perotetti*, *Holotrichia serrata*, *H. consanguinea*, *Agrotis ipsilon*, *Gryllotalpa gryllotalpa*, and *Odontotermes obesus* (Nandgopal, 1992; Wightman & Ranga Rao, 1994; Subrahmanyam et al., 2001; Atwal & Dhaliwal, 2008; Tojo et al., 2008; Sharma et al., 2010; Boiça Junior et al., 2011; Anonymous, 2012; Muniappan et al., 2012; Baskaran et al., 2013; Tuan et al., 2017; Nigude et al., 2018; Pinto et al., 2020; Bademci & Sertkaya, 2021; Latha et al., 2022).

Among these pests, *Helicoverpa armigera* (Hübner), commonly known as the cotton bollworm or pod borer, is one of the most destructive, particularly in Asia, Africa, and parts of South America (Karim, 2000). This polyphagous pest targets more than 180 plant species across 40 families (Zalucki et al., 1986; Fitt, 1989; Patankar et al., 2001; Liu et al., 2004; Talekar et al., 2006; Tay et al., 2013; Cunningham & Zalucki, 2014; Pratissoli et al., 2015; Rahman et al., 2016; Gulzar et al., 2017; Bektaş Karapınar & Sertkaya, 2020; Demirel & Akgül, 2025). In peanuts, it attacks flowers and developing pods (War et al., 2012), causing yield losses exceeding 30% in the absence of control measures (Sharma et al., 2010; Muniappan et al., 2012), with damage surpassing 50% in some regions (Wightman et al., 1990; Srinivasan et al., 1996; Wu et al., 2008; Rogers & Brier, 2010; Singh & Sharma, 2017).

Chemical insecticides have traditionally been used for pest control due to their rapid action. However, indiscriminate use has led to pesticide resistance, environmental degradation, and adverse effects on non-target organisms, including beneficial insects (Kranthi et al., 2002; Lal et al., 2010).

Pheromone traps are a valuable tool for early detection and monitoring of *Helicoverpa armigera*, particularly during the spring emergence of adult moths. This early warning system enables timely implementation of control measures and facilitates effective assessment of pest distribution (Reddy & Manjunatha, 2000; Baker et al., 2011). Among various designs, pheromone-baited bucket traps have been identified as the most effective for capturing *Helicoverpa* moths (Guerrero et al., 2014). These traps are baited with synthetic sex pheromones—primarily (Z)-11-hexadecenal and minor components such as (Z)-9-hexadecenal—which mimic female attractants to lure and

capture male moths (Cork et al., 1992; Tamhankar et al., 2000). This reduces mating success and suppresses larval populations (Ranga Rao et al., 1993). Funnel and bucket traps are preferred for their efficiency and field durability (Guerrero et al., 2014; CABI, 2022). Deploying 10–15 traps per hectare has proven effective for monitoring and managing pest populations (Srinivasan & Rajendran, 2001). The optimal trap height is 0.5 to 1 meter above the crop canopy, particularly during the flowering and pegging stages when the crop is most vulnerable (ICRISAT, 2008).
The purpose of this study was to investigate the seasonal population dynamics and environmental influences on *Helicoverpa armigera* in peanut (*Arachis hypogaea* L.) fields across the Osmaniye and Adana provinces of Turkey during the 2021 and 2022 growing seasons. By monitoring adult moth catches with pheromone traps, recording larval densities, and analyzing environmental conditions, the study aimed to identify peak periods of pest activity and support the development of timely and effective pest management strategies in peanut cultivation.

MATERIALS and METHODS

The study was conducted in peanut (*Arachis hypogaea* L.) fields in Aslanpınarı village (Toprakkale district, Osmaniye Province) in the 2021 and Burhanlı village (Ceyhan district, Adana Province) in the 2022 growing seasons, Türkiye. In both years, the peanut variety 'Masal' was cultivated. Monitoring of *Helicoverpa armigera* populations was carried out using pheromone traps baited with lures containing a synthetic blend of (Z)-11-hexadecenal (major component) and (Z)-9-hexadecenal (minor component) in a 97:3 ratio, as described by Pawar et al. (1988), Cork et al. (1992), Loganathan & Uthamasamy (1998), Loganathan et al. (1999), Tamhankar et al. (2000), Visalakshmi et al. (2000), and Zhou et al. (2000). The pheromones were impregnated into rubber septa and replaced every four weeks to maintain efficacy. In 2021, five funnel traps were deployed in Osmaniye (Aslanpınarı), and in 2022, five traps were installed in Adana (Burhanlı), with a trap density of one per 0.5 hectares. Trap design followed the specifications of Kant et al. (1999) and Guerrero et al. (2014), using a white plastic bucket (12.5 cm height × 16 cm diameter) fitted with a yellow funnel (3.2 cm opening) and a green circular cover (16 cm diameter). A pheromone lure was suspended inside a green plastic basket (5.3 cm length) above the funnel. A mixture of water and olive oil was added to each trap to immobilize and preserve captured moths. Traps were suspended from metal poles, with lures positioned approximately 1 meter above the ground, in accordance with ICRISAT (2008) recommendations for optimal trap height during the critical flowering and pegging stages. Trap installation began on 28th June 2021 and 7th July 2022. Traps were inspected weekly, and during each visit, captured adult moths were counted and removed. Traps were removed from fields on 13th September 2021 and 6th October 2022. Simultaneously, larval infestation was monitored weekly by counting larvae along five randomly selected 3-meter sections of peanut rows per field. Environmental parameters, including average temperature and relative humidity, were recorded throughout the sampling period to assess their correlation with pest dynamics. Data were analyzed using analysis of variance (ANOVA) with the SAS statistical software package, and means were separated using the Least Significant Difference (LSD) test at the 5% significance level ($P < 0.05$) (SAS Institute, 1998).

RESULTS and DISCUSSIONS

Adult moth population dynamics in 2021

A total of 2,931 adult cotton bollworms (*Helicoverpa armigera*) were captured using five pheromone traps over the study period from 5th July to 13th September in 2021 ($F = 12.05$; $P = 0.0001$) (Figure 1). The population dynamics of *H. armigera* showed marked temporal variation during this period. Trap catches remained moderately high throughout July, with mean captures ranging from 39.6 to 53.2 moths per trap. A sharp decline was observed on 2nd August, with the lowest catch recorded at 7.6 moths per trap. This was followed by a rapid increase, peaking at 145.2 moths per trap on 16th August. Additional notable peaks occurred on 9th August, 5th July, and 29th

September. Following the mid-August peak, adult moth captures gradually declined, reaching 39.8 moths per trap by 13th September. These results highlight a distinct population surge in mid-August, identifying this period as a potential critical window for the implementation of control measures.

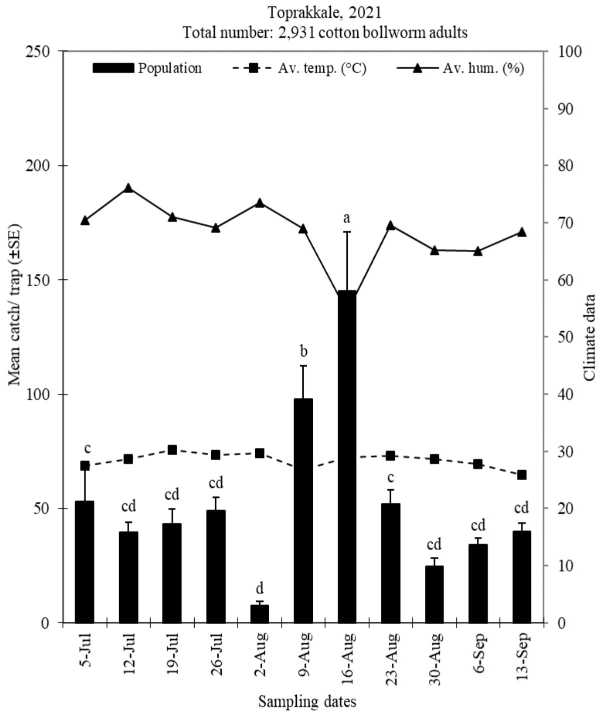

Figure 1. Mean (±SE) weekly catches of *Helicoverpa armigera* adult males in pheromone traps recorded from 5th July to 13th September 2021, in a peanut (*Arachis hypogaea* L.) field in the Toprakkale district of Osmaniye Province. Corresponding temperature and relative humidity data are also presented. Different letters above the bars indicated statistically significant differences based on the Least Significant Difference (LSD) test at *P* < 0.05

Şekil 1. 5 Temmuz – 13 Eylül 2021 tarihleri arasında, Osmaniye ili Toprakkale ilçesindeki bir yer fıstığı (Arachis hypogaea L.) tarlasında feromon tuzaklarıyla yakalanan Helicoverpa armigera ergin erkeklerinin ortalama (±SH) haftalık yakalanma sayıları kaydedilmiştir. İlgili sıcaklık ve bağıl nem verileri de sunulmuştur. Sütunlar üzerindeki farklı harfler, %5 önem düzeyinde LSD testine göre istatistiksel olarak anlamlı farkları göstermektedir

Environmental conditions in 2021

Environmental parameters, including weekly average temperature and relative humidity, were monitored in the peanut (*Arachis hypogaea* L.) field located in the Toprakkale district of Osmaniye Province from 5th July to 4th October 2021. Average temperatures ranged from a maximum of 30.2°C on 19th July to a minimum of 23.8°C on 4th October (Figure 1). The highest tempereture conditions were recorded in mid-July, followed by a gradual cooling trend into early October. Relative humidity revealed greater variability than temperature across the study period. The highest average humidity (76.1%) was observed on 12th July, while the lowest (31.8%) occurred on 4th October. A noticeable decline in humidity were observed in mid-September, with the driest weeks coincided with the latter part of the monitoring period. These fluctuations in temperature and humidity may have influenced the population trends of *H. armigera*, both adult trap catches and larval activity.

Larval infestation in 2021

Larval infestation was assessed weekly by counting *H. armigera* larvae on five randomly selected 3-meter sections of peanut rows. Between July 5th and September 13th, 2021, a total of 26 larvae were recorded (Figure 2). The highest mean larval count was observed on August 16th, with other notable infestations on July 12th and July 19th. In contrast, no larvae were detected on August 2nd and August 23rd, indicating intermittent larval presence and underscoring the temporal variability of infestation levels in the crop.

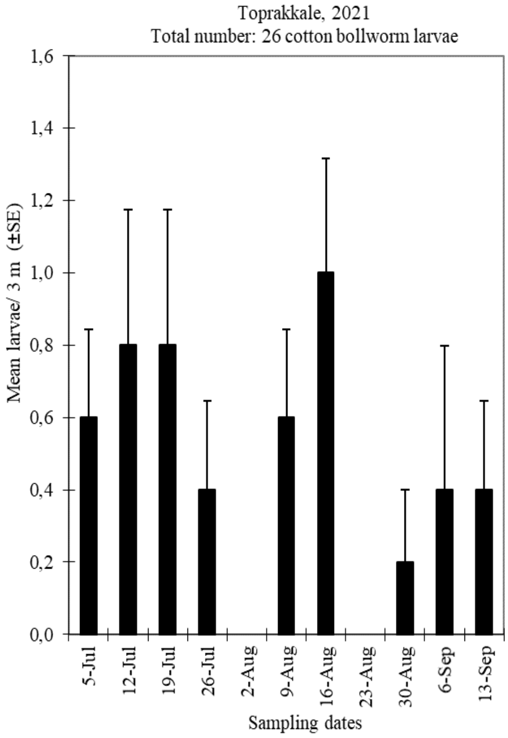

Figure 2. Mean (±SE) weekly counts of *Helicoverpa armigera* larvae per 3-meter row, recorded from 5th July to 13rd September 2021, in a peanut (*Arachis hypogaea* L.) field located in the Toprakkale district of Osmaniye Province

Şekil 2. 5 Temmuz – 13 Eylül 2021 tarihleri arasında, Osmaniye ili Toprakkale ilçesindeki bir yer fıstığı (Arachis hypogaea L.) tarlasında, 3 metrelik sıra başına düşen Helicoverpa armigera larvalarının ortalama (±SH) haftalık sayımları kaydedilmiştir

Adult moth population dynamics in 2022

A total of 2,099 adult cotton bollworms (*Helicoverpa armigera*) were captured using five pheromone traps during the monitoring period from 14th July to 6th October 2022, indicating significant temporal variation in trap catches (F = 29.49; P = 0.0001) (Figure 3). Weekly observations revealed two distinct peaks in adult moth activity. Initial trap counts gradually increased from 26.6 moths per trap on July 14th to 31.8 on July 21th and 36.2 on July 28th. A notable increase was recorded on August 4th, reaching 63.0 moths per trap. This early peak was followed by a sharp decline, with catches dropping to 16.4 on 11th August and reaching a seasonal low of 7.2 moths on 18th August. A second and more pronounced surge in population was observed thereafter, with captures rising to 77.2 moths per trap on 25th August and peaking at 80.2 on 1st September —the highest count of the season. Post-peak, trap catches steadily declined to 28.4 on 8th September, followed by continued decreases to 13.4, 16.8, 11.6, and finally 11.0 moths per trap by 6th October. These patterns underscore two key periods of adult emergence and flight activity, particularly from late August to early September, representing a critical window for implementing targeted pest control measures.

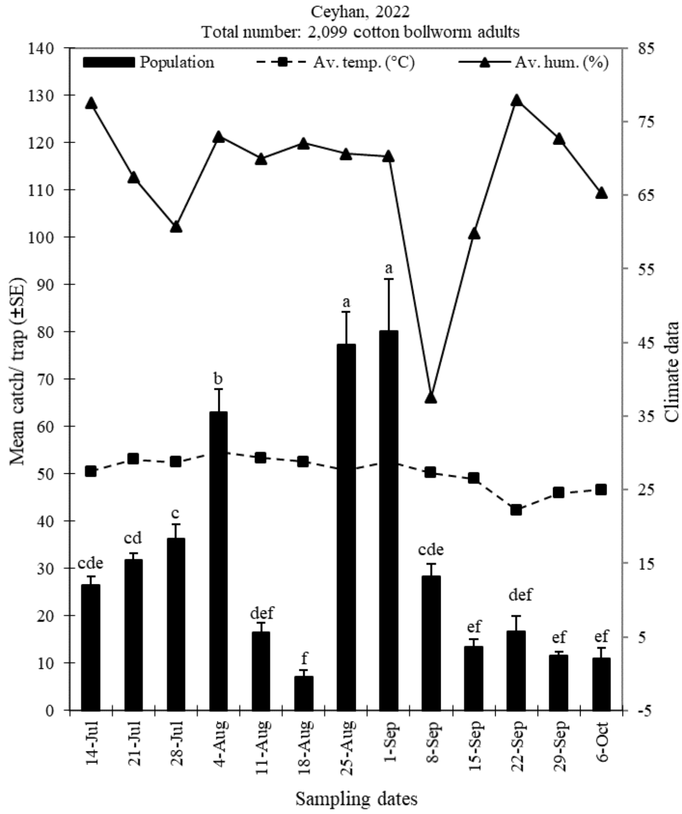

Figure 3. Mean (±SE) weekly catches of *Helicoverpa armigera* adult males in pheromone traps recorded from 14th July to 6th October 2022, in a peanut (*Arachis hypogaea* L.) field in the Ceyhan district of Adana Province. Corresponding temperature and relative humidity data are also presented. Different letters above the bars indicated statistically significant differences based on the Least Significant Difference (LSD) test at $P < 0.05$

Şekil 3. 14 Temmuz – 6 Ekim 2022 tarihleri arasında, Adana ili Ceyhan ilçesindeki bir yer fıstığı (Arachis hypogaea L.) tarlasında feromon tuzaklarıyla yakalanan Helicoverpa armigera ergin erkeklerinin ortalama (±SH) haftalık yakalanma sayıları kaydedilmiştir. İlgili sıcaklık ve bağıl nem verileri de sunulmuştur. Sütunlar üzerindeki farklı harfler, %5 önem düzeyinde LSD testine göre istatistiksel olarak anlamlı farkları göstermektedir

Environmental conditions in 2022

Environmental parameters, including weekly average temperature and relative humidity, were recorded in the peanut (*Arachis hypogaea* L.) field located in the Ceyhan district of Adana province from 14th July to 6th October 2022. Average temperatures during this period ranged from 22.2°C to 30.1°C, with the highest temperature (30.1°C) coinciding with the early adult flight peak on 4th August (Figure 3). A general cooling trend followed mid-August, reaching the lowest average of 22.2°C on 22nd September. Relative humidity showed substantial variation, ranging from a minimum of 37.6% on 8th September to a peak of 78.0% on 22nd September. These fluctuations in environmental conditions likely influenced the seasonal abundance and behavioral patterns of both adult and larval stages of *Helicoverpa armigera*.

Larval infestation in 2022

Larval infestation was assessed weekly by counting *H. armigera* larvae on five randomly selected 3-meter sections of peanut rows. Throughout the study, a total of seven larvae were recorded (Figure 4). The highest larval count occurred on 4th August, coinciding with the initial adult peak. Additional larval activity was observed on 14th July , 28th July, 25th August, and 1st and 22nd September. No larvae were detected on 21st July, 11th and 18th August, and during the final weeks (8th, 15th, and 29th September, and 6th October), indicating a sporadic presence and highlighting the temporal variability in larval infestations. These findings suggest a close relationship between environmental conditions, adult moth activity, and larval development patterns.

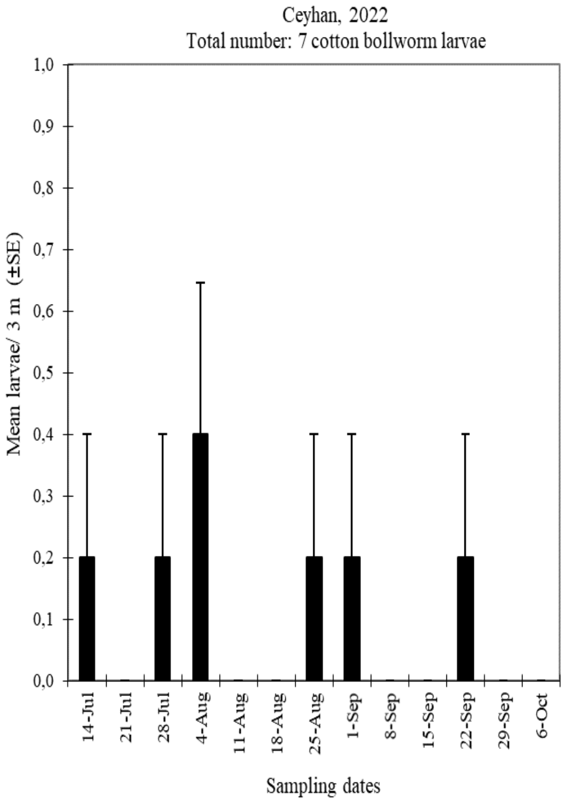

Figure 4. Mean (±SE) weekly counts of *Helicoverpa armigera* larvae per 3-meter row, recorded from 14th July to 6th October 2022, in a peanut (*Arachis hypogaea* L.) field located in the Ceyhan district of Adana Province

Şekil 4. 14 Temmuz – 6 Ekim 2022 tarihleri arasında, Adana ili Ceyhan ilçesindeki bir yer fıstığı (Arachis hypogaea L.) tarlasında, 3 metrelik sıra başına düşen Helicoverpa armigera larvalarının ortalama (±SH) haftalık sayımları kaydedilmiştir

This study provides critical insights into the seasonal population dynamics of *Helicoverpa armigera* in peanut (*Arachis hypogaea* L.) fields in southern Türkiye during the 2021 and 2022 growing seasons. Our findings reinforce the importance of sustained monitoring for informed pest management decisions, particularly through the use of pheromone traps-a tool that continues to prove effective for early detection and timely intervention (Pawar et al., 1988; Srinivasan & Rajendran, 2001).

Helicoverpa armigera is known for its wide host range and polyphagous nature, complicating management across diverse cropping systems (Cunningham & Zalucki, 2014; Patankar et al., 2001). Its damaging presence in peanut aligns with previous reports from India and other regions where significant yield losses occur (Baskaran et al., 2013; Sharma & Mathur, 2006). Our results indicate that population peaks occur during mid to late season-coinciding with flowering and pod development stages-suggesting that these phenological phases are particularly vulnerable to infestation and require precisely timed control measures (Liu et al., 2004; Tuan et al., 2017).

Pheromone trap catches in this study provided valuable early-warning data, confirming their continued relevance for pest surveillance (Cork et al., 1992; Kant et al., 1999). The efficacy of trapping systems is known to depend on trap type, placement height, and environmental factors (Baker et al., 2011; Guerrero et al., 2014). Consistent with these findings, our monitoring efforts revealed that peak adult flights were predictive of larval appearance approximately 7–10 days later-observed most clearly on 16th August 2021 and 4th August 2022. This lag reflects the typical egg-to-larva development period under favorable summer temperatures (Hardwick, 1965; Jayaraj, 1982) and highlights the strategic value of adult monitoring for timing interventions before economic thresholds are exceeded.

Although adult moth captures were high, larval populations remained below economic thresholds in both years. This disconnect may be attributed to natural control factors, such as predation or parasitism, as well as unfavorable microclimatic conditions during oviposition or larval establishment (Gregg et al., 2018; Dourado et al., 2021). Additionally, adult migration to adjacent crops like cotton or maize may have reduced larval pressure in peanuts. Similar patterns were observed in earlier regional data, where Bademci & Sertkaya (2021) noted threshold exceedance in 2017 but subdued populations in 2018.

Environmental variables played a decisive role in shaping pest dynamics. Our findings confirm that moderate mean temperatures (29.8–30.2°C) and relative humidity levels above 60% corresponded with peak adult activity-conditions consistent with optimal reproductive success and larval development (Mironidis and Savopoulou-Soultani, 2008; CABI, 2022). Conversely, higher temperature extremes (above 35°C), known to suppress *H. armigera* fecundity and survival, were not reached during the study period. The observed humidity range (31.8% to 78.0%) may have further influenced population levels by impacting egg desiccation or hatchability (Hackett & Gatehouse, 1982; Mironidis & Savopoulou-Soultani, 2008).

Flight activity exhibited uni- or bimodal patterns across both years, reflecting the multivoltine nature of *H. armigera*, which can complete multiple generations per season depending on climatic suitability (Ibrahim et al., 1974; Jyothi et al., 2021). The 2022 bimodal peaks -early and late August- likely reflect generation overlap, a phenomenon commonly observed under stable environmental conditions (Fitt, 1989). These patterns suggest that monitoring should begin by mid-July and extend through September, a period during which climatic conditions facilitate population expansion.

Collectively, our findings emphasize the value of integrating pest and environmental monitoring into IPM frameworks. Despite no threshold-level larval damage were observed in this study, the predictive utility of trap catches and their correlation with environmental trends support the use of trap-based strategies for more precise pest management (Matthews & Tunstall, 1968). In major peanut-producing provinces such as Adana and Osmaniye -regions of national economic importance- such proactive approaches could minimize insecticide use and promote sustainability (Bademci & Sertkaya, 2021).

Looking ahead, efforts should prioritize the incorporation of real-time weather data, pest phenology models, and biological control assessments into predictive systems. These integrated tools can enhance decision support, refine economic thresholds, and buffer against climate-induced variability (King, 1994; Yadav et al., 2016). As climate conditions continue to shift, adaptive IPM strategies that align with ecological and environmental indicators will become increasingly crucial for the sustainable management of *H. armigera* in peanut and other vulnerable crops.

In conclusion, this two-year study demonstrated clear seasonal patterns in *Helicoverpa armigera* populations in peanut fields, with peak moth activity from late July to early September. In 2021, a single mid-August peak was observed, while in 2022, two peaks occurred in early August and early September. Temperature and humidity strongly influenced adult emergence and larval development. Larval infestations mirrored adult trends but varied weekly. These findings highlight the importance of pheromone-based monitoring and environmental data to guide timely and effective IPM strategies.

To improve the management of *Helicoverpa armigera* in peanut fields, regular pheromone trap monitoring is recommended for timely detection of adult peaks. Environmental factors such as temperature and humidity should be included in monitoring programs to better predict pest development. Control measures should be applied during peak moth activity, especially from late July to early September. Weekly field scouting is advised to assess larval density and inform control decisions. Developing region-specific forecasting models and training farmers on monitoring and IPM practices will support more effective and timely interventions.

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STATEMENT OF CONFLICT OF INTEREST

The author(s) declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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