



Seasonal Population Trends and Environmental Influences on *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Soybean Fields of the Eastern Mediterranean Region of Türkiye

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ABSTRACT

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Seasonal monitoring of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) was conducted in soybean fields in the Eastern Mediterranean Region of Türkiye during the 2021 and 2022 growing seasons to assess adult population dynamics, larval infestation patterns, and environmental influences. In 2021, pheromone traps deployed in Osmaniye Province captured 2,399 adult moths between July 5 and October 4, exhibiting a bimodal pattern with peaks on July 19 and August 23 ($F = 10.69$; $P = 0.0001$). Larval densities peaked on August 16 (0.50 larvae per sampling unit), closely aligning with adult emergence. In 2022, 1,321 adults were caught in Adana Province from July 14 to October 6, showing a single major peak on September 15 ($F = 25.22$; $P = 0.0001$). Larval infestations were sporadic and low, reaching a maximum density of 0.33 larvae per unit. Environmental conditions included weekly average temperatures ranging from 22.2°C to 30.2°C and relative humidity between 31.8% and 78%. A significant positive correlation was recorded synchronisation of adult flight peaks, larval populations, and favourable environmental factors indicates overlapping generations of *H. armigera* during the soybean growing period. These highlighting the importance of pheromone traps for early pest detection and informed management decisions, ultimately leading to reduced crop damage and improved soybean production in the region.

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Introduction

Soybean (*Glycine max* (L.) Merrill) is among the most economically and nutritionally important leguminous crops worldwide, accounting for more than 50% of global oilseed production (Anonymous, 2021). Soybeans' high protein (36–45%) and oil (18–24%) content supports its broad use in food products, animal feed, and industrial applications, including biodiesel, adhesives, and biodegradable plastics (Hartman et al., 2011; Arıoğlu, 2014; Patel et al., 2014; Kim et al., 2021; Şahin & İşler, 2022). In 2021, global soybean production reached approximately 339 million tons, with Brazil, the United States, and Argentina collectively contributing over 80% of this total (Anonymous, 2021). In Turkey, soybean was cultivated on 326,840 decares in 2023, producing 137,500 tons (TÜİK, 2024). National production is highly localised, with approximately 99% concentrated in the Mediterranean (93%), Black Sea (5%), and Southeastern Anatolia (1%) regions (TÜİK, 2023). The provinces of

Adana (65.27%), Mersin (11.57%), Kahramanmaraş (10.45%), Osmaniye (5.24%), Samsun (2.65%), and Hatay (2.09%) together accounted for 97.3% of the total output.

Soybean (*G. max*) a crop of considerable global and regional importance, faces significant production challenges due to insect pest infestations. Globally, more than 380 insect species have been documented on soybean (Kalaisekar et al., 2017), while in India, approximately 275 species have been reported, with about a dozen considered economically significant (Agarwal & Kalode, 2004). According to Gaur & Mogalapu (2018), the crop harbours over 300 insect species, although only a limited number reach major pest status. Prominent among these pests, particularly during the critical reproductive stages of the crop, when they cause substantial yield and economic losses, are the Bihar hairy caterpillar, *Spilosoma obliqua* Walker (Lepidoptera: Erebidae); soybean aphid, *Aphis* spp. (Hemiptera: Aphididae); cotton bollworm or gram pod

borer, *H. armigera* Hübner (Lepidoptera: Noctuidae); jassids, *Apheliona maculosa* Pruthi (Hemiptera: Cicadellidae); tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae); girdle beetle, *Obereopsis brevis* Swederus (Coleoptera: Cerambycidae); thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae); stem fly (*Melanagromyza sojae* Zehntner, 1901) (Diptera: Agromyzidae); Stink bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae), and whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) (Agarwal & Kalode, 2004; Kalaisekar et al., 2017; Gaur & Mogalapu, 2018; Yardım & Ölmez Bayhan, 2019).

Among these, *H. armigera* Hübner is recognised as one of the most damaging pests in soybean cultivation (Hardwick, 1965; Fitt, 1989; Agarwal & Kalode, 2004; Naseri et al., 2009; Pogue, 2013; Kalaisekar et al., 2017; Singh & Sharma, 2017; Stacke et al., 2018). As a highly polyphagous insect, it feeds on more than 180 plant species spanning 47 families and is found across Asia, Africa, Australia, and the Americas (Zalucki et al., 1986; Fitt, 1989; Tay et al., 2013; Cunningham & Zalucki, 2014; Savaşır, 2022). This pest primarily targets the reproductive parts of soybean plants—such as flowers, pods, and seeds—leading to substantial economic losses (Hardwick, 1965; Naseri et al., 2009; Pogue, 2013; Stacke et al., 2018). Damage to flowers and pods during key growth stages, particularly flowering and pod setting, significantly reduces yield (Rogers & Brier, 2010; Singh & Sharma, 2017). Moreover, *H. armigera*'s ability to complete up to 11 generations per year in tropical regions, combined with its extensive resistance to many standard insecticides, significantly complicates pest management efforts (Barbosa et al., 2016; Yang et al., 2013). While chemical insecticides have long been favoured for their quick and effective control, their excessive and indiscriminate use has contributed to the development of resistance, environmental harm, and negative impacts on non-target species, including beneficial insects (Kranthi et al., 2002; Lal et al., 2010).

Pheromone traps are a crucial tool for the early detection and monitoring of *Helicoverpa armigera*, particularly during the spring emergence of adult moths (Tamhankar et al., 2000; Baker et al., 2011; Guerrero et al., 2014; CABI, 2022; Savaşır, 2022). This early warning system enables timely pest management interventions and accurate assessment of pest distribution (Reddy & Manjunatha, 2000; Baker et al., 2011; CABI, 2022). Among various trap designs, pheromone-baited bucket traps have proven to be the most effective for capturing *Helicoverpa* moths (Guerrero et al., 2014; Savaşır, 2022). These traps employ synthetic sex pheromones primarily (Z)-11-hexadecenal along with minor components such as (Z)-9-hexadecenal that mimic the signals of female moths to attract and capture male moths (Cork et al., 1992; Tamhankar et al., 2000). This approach reduces mating success, thereby suppressing larval populations (Ranga Rao et al., 1993). Funnel and bucket traps are preferred due to their high trapping efficiency and durability under field conditions (Guerrero et al., 2014; CABI, 2022). Deploying 10 to 15 traps per hectare has been shown to be an effective method for monitoring and managing pest populations (Srinivasan & Rajendran, 2001).

Trap efficacy is influenced by several environmental factors. Elevated temperatures accelerate pheromone

degradation, while cooler night temperatures can reduce moth activity (Reddy & Guerrero, 2000; Witzgall et al., 2010). Additional variables such as humidity, rainfall, wind patterns, and lunar phases also, impact pheromone plume dynamics and moth behavior (Cork et al., 1992; Tamhankar et al., 2000). Furthermore, as the soybean canopy develops, adjusting trap height is crucial to ensure optimal exposure and pheromone dispersal above the foliage. The ideal placement height for traps is between 0.5 and 1 meter above the crop canopy, especially during flowering and pod stages when the crop is most vulnerable (Higley & Boethel, 1994).

The objective of this study was to evaluate the seasonal population trends and environmental factors affecting *H. armigera* in soybean (*G. max*) fields in the Osmaniye and Adana provinces of Turkey during the 2021 and 2022 growing seasons. By monitoring adult moth captures using pheromone traps, assessing larval densities, and analysing environmental conditions, the study aimed to identify peak periods of pest activity and support the development of timely and effective pest management strategies for soybean cultivation.

Materials and Methods

The study was conducted during the 2021 and 2022 growing seasons in soybean (*G. max*) fields located in Aslanpınarı village (Toprakkale district, Osmaniye Province) and Dağıştan village (Ceyhan district, Adana Province), Türkiye. In both years, the soybean cultivar 'Lider' was cultivated. *H. armigera* populations were monitored 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, following the formulations 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), Zhou et al. (2000), and Savaşır (2022). The pheromone was impregnated into rubber septa and replaced every four weeks to maintain lure efficacy.

In 2021, six funnel traps were deployed in Osmaniye (Aslanpınarı village), and in 2022, six traps were installed in Adana (Dağıştan village), maintaining a trap density of one per 0.5 hectares. Trap construction followed the design specifications of Kant et al. (1999) and Guerrero et al. (2014), consisting of a white plastic bucket (12.5 cm height × 16 cm diameter) with a yellow funnel (3.2 cm opening) and a green circular cover (16 cm diameter). The pheromone lure was suspended inside a green plastic basket (5.3 cm length) positioned above the funnel. Each trap contained mixture of water and olive oil to immobilise and preserve the captured moths. Traps were suspended from metal poles, with the lure positioned approximately 1 meter above the ground, following the recommendations of Higley & Boethel (1994) for optimal trap height during the flowering and pod development stages.

Trap installation began on June 28, 2021, and July 7, 2022. Traps were inspected weekly, with adult moths counted and removed during each visit.

Monitoring concluded on 4 October 2021 and 6 October 2022. Concurrently, larval infestation was assessed weekly by counting larvae in six randomly selected 3-meter sections of

soybean rows per field. Environmental variables, including average temperature and relative humidity, were recorded throughout the sampling period to examine their relationship with pest dynamics. Data were analysed using analysis of variance (ANOVA) in SAS, and treatment means were separated using the Student–Newman–Keuls (SNK) test at the 5% significance level ($P < 0.05$) (SAS Institute, 1998).

Results and Discussion

*Seasonal Trends in Adult *H. armigera* Populations (2021)*

During the 2021 soybean growing season (5 July to 4 October), a total of 2,399 *H. armigera* adults were captured using six pheromone traps deployed in the Toprakkale district of Osmaniye Province ($F = 10.69$; $P = 0.0001$) (Figure 1). The temporal distribution of adult captures exhibited a significant bimodal pattern. Initial trap catches averaged 14.67 moths per trap on 5 July, followed by a slight decline to 11.00 on 12 July. A moderate increase was observed with a peak of 23.33 moths on 19 July, after which numbers dropped sharply, reaching a seasonal low of 1.83 moths per trap on 2 August. A marked resurgence in moth activity began in early August, with two pronounced peaks recorded: 51.67 moths per trap on August 16 and the seasonal maximum of 61.00 on August 23. Although captures declined thereafter, trap catches remained relatively high into early September, with 56.33 moths on 30 August and 41.33 on 6 September, before gradually decreasing to 5.33 by the final sampling date on 4 October. These capture patterns indicate the occurrence of at least two overlapping generations of *H. armigera* during the season, with peak adult emergence soybean reproductive stages and favourable climatic conditions.

Environmental Influences During 2021 Monitoring

Environmental data collected from July 5 to October 4, 2021 indicated high temperatures and moderate humidity levels throughout the soybean season (Figure 1). Weekly average temperatures ranged from 23.8°C to 30.2°C, peaking on 19 July. A gradual cooling trend was observed from mid-August onwards. Relative humidity ranged from 31.8% to 76.1%, peaking on 12 July. These climatic conditions are known to influence *H. armigera* development and are likely to have contributed to the observed temporal trends in adult moth activity and larval infestations.

Larval Infestation Patterns in 2021

A total of 18 *H. armigera* larvae were recorded through weekly sampling of six randomly selected 3-meter soybean row sections (Figure 2). Initial larval density was low (0.17 larvae/unit) on 5 July and remained steady through mid-July. A slight increase occurred on 19 July (0.33 larvae), followed by a peak density of 0.50 larvae on 16 August, corresponding to the first major adult population peak. Larval numbers then declined steadily, reaching zero by late September. The alignment of larval and adult peaks suggests a close generational link, indicating that adult monitoring can predict larval infestations and support timely interventions in pest management.

*Seasonal Trends in Adult *Helicoverpa armigera* Populations (2022)*

Between 14 July and 6 October 2022, 1,321 *H. armigera* adults were captured in six pheromone traps placed in a soybean field in Ceyhan district, Adana Province ($F = 25.22$; $P = 0.0001$) (Figure 3). Trap counts began relatively high (29.33 moths/trap on 14 July) but sharply declined to 11.17 on 21 July and 4.33 on 28 July. A moderate increase occurred on 4 August (14.50), with fluctuating values between 14.33 and 19.50 throughout late August. The population stabilised in early September, then peaked sharply at 42.00 moths/trap on 15 September. This was followed by a steep decline to 13.00 on 22 September, with low counts through October (6.67 on 29 September and 6.17 on 6 October). This temporal pattern indicates staggered adult emergence with a significant peak in mid-September, likely representing a subsequent generation.

Environmental Influences During 2022 Monitoring

Environmental conditions in the 2022 season were marked by moderate temperatures (22.2°C to 30.1°C) and variable humidity (37.6% to 78%) (Figure 3). The highest temperature was recorded on 4 August, and humidity levels remained above 60% for most of the season, except for a brief period dip in early September. The peak in adult moths on 15 September coincided with optimal conditions moderate temperatures and high humidity suggesting a strong environmental influence on adult emergence. Lower adult counts in late July and early October aligned with more extreme or fluctuating weather conditions.

Larval Infestation Patterns in 2022

Weekly larval sampling revealed sporadic and low *H. armigera* presence, with only seven larvae recorded during the entire season (Figure 4). The initial larval density was 0.33 per sampling unit on 14 July. No larvae were found from 21 July to 11 August. Minor larval presence resumed in late August and early September (0.17 larvae on 18 and 25 August; 0.17 on 8 September). The highest density (0.33 larvae) was noted on 15 September, coinciding with the adult peak. No larvae were detected after mid-September. Despite low infestation levels, the temporal association between larval occurrence and adult peaks suggests overlapping generations influenced by environmental conditions.

Seasonal monitoring of *H. armigera* populations in soybean fields across two consecutive years revealed marked interannual variability in adult moth activity and larval infest primarily by environmental conditions and crop phenology. Pheromone trap data from 2021 and 2022 underscore the importance of adult surveillance for understanding population dynamics and guiding timely pest management interventions (Pawar et al., 1988; Srinivasan & Rajendran, 2001; Cunningham & Zalucki, 2014; Haile et al., 2021).

In 2021, a clear bimodal adult emergence pattern was observed in Osmaniye Province, with peaks in mid-July and late August. The highest trap catches, 61.00 moths/trap on August 23, coincided with critical reproductive stages of the soybean, raising the risk of larval damage. Larval densities peaked at 0.50 larvae/unit on 16 August, approximately one week after the first major adult peak, reflecting a tight generational synchrony.

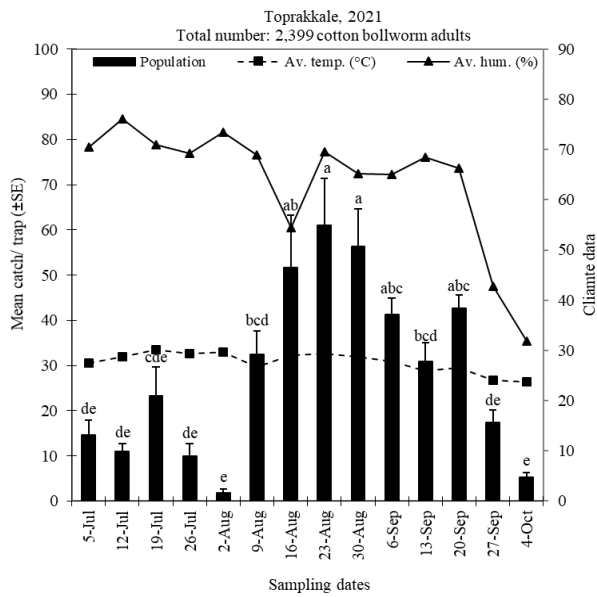


Figure 1. Mean (\pm SE) weekly catches of *Helicoverpa armigera* adult males in pheromone traps recorded from 5 July to 4 October 2021, in a soybean (*Glycine max* (L.) Merrill) field in the Toprakkale district of Osmaniye Province. Corresponding temperature and relative humidity data are also presented. Different letters above the bars indicated statistically significant differences based on the Student–Newman–Keuls (SNK) test at the 5% significance level ($P < 0.05$).

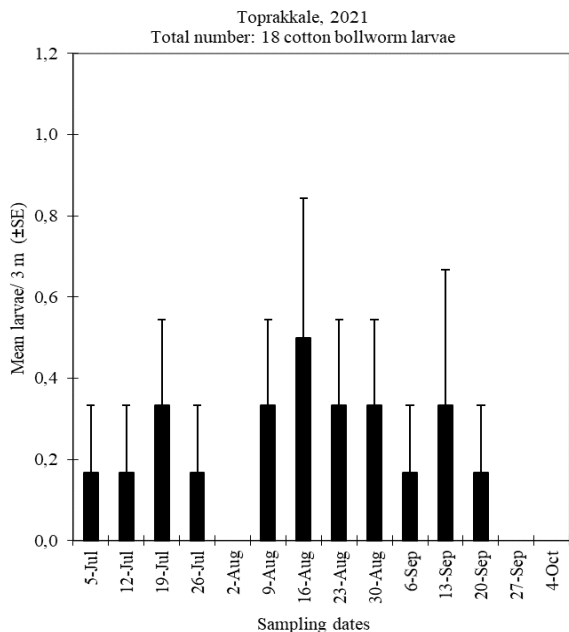


Figure 2. Mean (\pm SE) weekly counts of *Helicoverpa armigera* larvae per 3-meter row, recorded from 5 July to 4 October 2021, in a soybean (*Glycine max* (L.) Merrill) field in the Toprakkale district of Osmaniye Province.

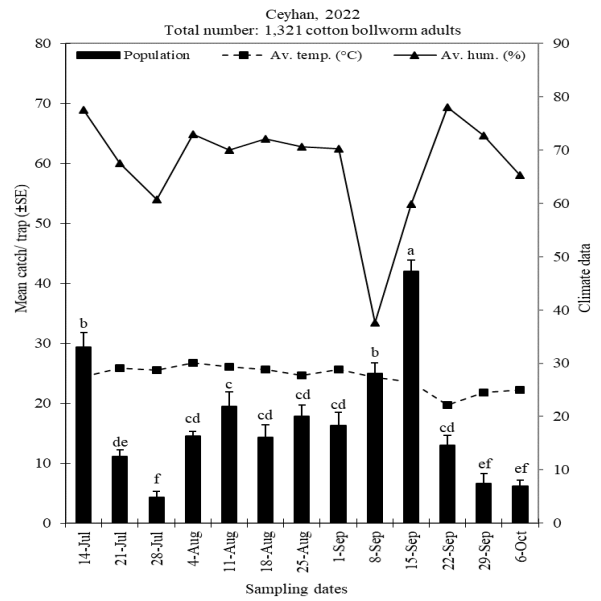


Figure 3. Mean (\pm SE) weekly catches of *Helicoverpa armigera* adult males in pheromone traps recorded from 14 July to 6 October 2022, in a soybean (*Glycine max* (L.) Merrill) field in the Ceyhan district of Adana Province. Corresponding temperature and relative humidity data are also presented. Different letters above the bars indicated statistically significant differences based on the Student–Newman–Keuls (SNK) test at the 5% significance level ($P < 0.05$).

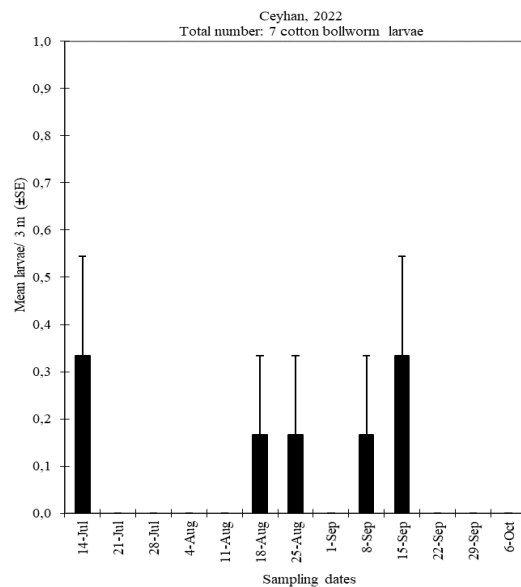


Figure 4. Mean (\pm SE) weekly counts of *Helicoverpa armigera* larvae per 3-meter row, recorded from 14 July to 6 October 2022, in a soybean (*Glycine max* (L.) Merrill) field in the Ceyhan district of Adana Province.

This alignment supports findings from previous studies that emphasise the close temporal relationship between adult moth activity and larval emergence (Fitt, 1989; Liu et al., 2004; Haile et al., 2021; Tuan et al., 2017).

Contrastingly, in 2022, data from Adana Province revealed a different pattern: initial high adult captures in mid-July declined sharply, followed by a delayed single peak in mid-September. This staggered emergence may reflect local climatic variability. While temperatures remained conducive to development, high relative humidity in early September appeared to promote adult activity. These conditions, known to enhance fecundity and larval survival (Hackett & Gatehouse, 1982; Mironidis & Savopoulou-Soultani, 2008; CABI, 2022), likely contributed to the observed peak. Despite this, larval densities in 2022 were notably low, with only seven larvae recorded across the entire season. The highest density (0.33 larvae/unit) occurred on 15 September, aligning with the adult population peak and confirming generational overlap. However, the suppressed larval establishment may have resulted from biotic pressures such as predation and parasitism or suboptimal conditions during oviposition and early development (Guerrero et al., 2014; Gregg et al., 2018).

Environmental parameters—particularly temperature and humidity—clearly influenced *H. armigera* population dynamics. Moderate to high temperatures and relative humidity were positively associated with adult activity, consistent with previous research indicating these factors accelerate development and enhance survival (Zalucki et al., 1986; Mironidis & Savopoulou-Soultani, 2008). Importantly, extreme heat stress (>35°C), known to impair reproduction and larval viability (Hackett & Gatehouse, 1982), was not recorded in either year, likely supporting continued population development.

Globally, *H. armigera* is recognized as a polyphagous, multivoltine pest capable of damaging a wide array of crops, including soybean (CABI, 2022). Its sensitivity to climatic factors and capacity for multiple generations underscore the need for regionally adapted monitoring. The uni- and bimodal flight patterns observed in this study are consistent with broader literature and further emphasize the climate-dependent phenology of this pest (Ibrahim et al., 1974; Jyothi et al., 2021).

This study further validates pheromone traps as strategic tools for pest forecasting. Adult peaks predicted larval presence 7–10 days later, reflecting the species' egg-to-larva development period (Hardwick, 1965; Kant et al., 1999). The accuracy of trap data relies on deployment methods, environmental factors, and species behavior (Cork et al., 1992; Baker et al., 2011). The consistent adult-larva alignment here underscores pheromone traps' ongoing relevance for soybean pest surveillance.

Although larval infestations remained below economic thresholds during the study period, the combination of trap data with environmental variables proved effective for forecasting and could facilitate timely, targeted interventions. This approach minimizes unnecessary insecticide applications and supports sustainable management (Matthews & Tunstall, 1968; King, 1994; Yadav et al., 2016).

Conclusion

In conclusion, monitoring of *H. armigera* in soybean fields during the 2021 and 2022 seasons in Osmaniye and Adana provinces revealed clear seasonal patterns in adult moth activity, larval infestations, and environmental influences. In 2021, two distinct adult peaks were observed in mid-July and late August, followed by increases in larval density, indicating at least two overlapping generations. In 2022, adult emergence was more staggered, with a major peak in mid-September and overall lower captures; however, larval presence still corresponded with adult activity. Temperature and humidity strongly influenced pest dynamics in both years. These findings highlight the close relationship between adult monitoring, larval outbreaks, crop development, and climatic conditions. Pheromone traps effectively detected adult surges and can serve as an early warning tool within integrated pest management programs.

Declarations

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Ethical Approval Certificate

Ethical committee approval and informed consent is not required for this study.

Author Contribution Statement

N.D.: Supervision, analysis of the collected data with SAS, writing and editing

M.G.A.: Establishment of the experiment and data collection

Conflict of Interest

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

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