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Original article (Orijinal araştırma)

Pest status and population dynamics of the lucerne leaf beetle, *Gonioctena fornicata* (Brüggemann, 1873) (Coleoptera: Chrysomelidae), in a lucerne field in Adana Province, Turkey[1]

Adana İli (Türkiye)'nde bir yonca tarlasında Yonca yaprakböceği, *Gonioctena fornicata* (Brüggemann, 1873) (Coleoptera: Chrysomelidae)'nin zarar durumu ve popülasyon dinamiği

Ekrem ATAKAN[2*] **Yusuf DAĞ[2]**

Abstract

The lucerne leaf beetle, *Gonioctena fornicata* (Brüggemann, 1873) (Coleoptera: Chrysomelidae), is an important pest of lucerne in Europe and several parts of Turkey. Its damage and thus the loss of yield due to this pest insect is unknown. This study was conducted at Çukurova University, Faculty of Agriculture Research and Application Farm in Adana Province, Turkey in 2017 and 2018. It was found that the pest had one generation per year. Especially the larvae of *G. fornicata* was found to feed extensively on the leaves, shoots, flowers and seeds of lucerne, almost turning them into leafless. In the untreated plots, there was about 148% loss in both fresh weight and dry weight in 2017 caused by this pest species and up to 27% loss in 2018. *Gonioctena fornicata* negatively affected the fresh and dry weight yields. It is estimated that the yield losses were 3.48 t/ha. Although the yield difference between the treated and untreated plots was lower than expected, the cost of loss of yield was still high. Economic loss in the untreated plot was about 4250 TRY/ha (about 545 USD/ha as of December 2020).

Keywords: Adana, alfalfa, damage, *Gonioctena fornicata*, population dynamic

Öz

Yonca yaprakböceği, *Gonioctena fornicata* (Brüggemann, 1873) (Coleoptera: Chrysomelidae) Avrupa ve Türkiye'nin bazı yerlerinde yoncanın önemli bir zararlısıdır. Buna karşın, bu böcek neden olduğu zarar düzeyi ve verim kayıpları bilinmemektedir. Bu çalışma, Adana ilinde Çukurova Üniversitesi Ziraat Fakültesi Araştırma ve Uygulama Çiftliği'nde 2017 ve 2018 yıllarında yürütülmüştür. Zararlının bir döl verdiği bulunmuştur. Yonca yaprakböceği'nin özellikle larvalarının bitkilerin yaprak, sürgün, çiçek ve tohumlarında obur bir şekilde beslenerek bitkileri adeta yapraksız duruma getirdiği görülmüştür. İlaçsız parsellerde 2017 yılında yaş ağırlıkta %14.7, kuru ağırlıkta, %14.6 kayıp meydana gelmiştir. 2018 yılında ise yaş ağırlıkta %26.3, kuru ağırlıkta %27.4 kayıplar saptanmıştır. *Gonioctena fornicata*'nın yonca deneme alanında mart-mayıs döneminde ana zararlı duruma geldiği belirlenmiştir. *Gonioctena fornicata* kuru ve yaş ağırlığı olumsuz etkilemiştir. Bu böcek nedeniyle hektara verim kaybı 3480 kg'dır. İlaçlı ve ilaçlı parseller arasında verim kayıpları beklenenden daha düşük olmasına karşın, verim kaybının maliyeti yüksek olmuştur. İlaçlanmayan parselde ekonomik kaybın parasal değeri 4250 TL/ha olup, bunun Amerikan doları karşılığı, Aralık 2020 itibarıyla 545 US$/ha'dır.

Anahtar sözcükler: Adana, yonca, zarar, *Gonioctena fornicata*, popülasyon dinamiği

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[2] Çukurova University, Faculty of Agriculture, Department of Plant Protection, 01330, Adana, Turkey
* Corresponding author (Sorumlu yazar) e-mail: eatakan@mail.cu.edu.tr
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Introduction

A significant portion of Turkey's population gains a living in agriculture. Turkey is still an agricultural country with its geographical location, climate features and fertile soil suitable for agriculture. Despite this, it is an important problem today that the cultivated areas are gradually decreasing, and now the population reaching 80 million to be fed. In particular, forage crops have an important place in terms of providing sufficient animal protein, and more importance should be attached to the production of forage crops. In this context, lucerne, which is an important perennial legume forage plant, stands out as a quality and high-yielding forage plant (Sumberg et al., 1983; Abd El-Halim et al., 1992). However, lucerne production has been decreasing in Turkey recently. Total production in 2012, 2016, 2017 and 2018 were 676, 652, 659 and 635 kha, respectively (TUİK, 2018).

The most important feature of lucerne is its high nutritional content. Lucerne contains 15-22% crude protein and is an excellent source of minerals and vitamins. As a result of various narrowing and ill-considered destruction of agricultural areas, it has become essential to obtain the highest yield per unit area from lucerne, just as it is for most other crops. One of the biggest factors of low yield in lucerne is disease and pests. Due to these factors, there is a significant loss of production every year and a significant decrease in lucerne yield is observed due to these factors (Yıldırım et al., 1996).

One of the important pests of lucerne is lucerne leaf beetle [*Gonioctena fornicata* (Brüggemann, 1873)] (Coleoptera: Chrysomelidae). Adults and larvae of this pest feed on the leaves, flowers and shoots of lucerne. Kovancı (1982), in the study of the morphology and biology of *G. fornicata* in Ankara Province, reported that this pest occurred in Ayaş, Beypazarı, Nallıhan, Kızılcahamam, Çubuk and Polatlı Districts. Also, Yıldırım et al. (1996) found that *G. fornicata* is an important lucerne pest in Erzurum and Erzincan Provinces in its study on its definition, biology and damage. Aslan & Özbek (1999) also identified *G. fornicata* in their faunistic and systematic studies in Artvin, Erzincan and Erzurum Provinces, Turkey. Life table of the *G. fornicata* has been well studied (Ghavami et al., 1998; Efe & Özgökçe, 2014). It has been reported that *G. fornicata* larvae are sensitive to all *Beauveria bassiana* (Bals.-Criv.) Vuill. isolates used in dose-death studies (Baysal et al., 2019).

Previous research on this pest is available in the world literature but for Turkey information on damage and economic losses caused by this pest is limited. The time of emergence, larvae and adult development of lucerne leaf beetle in the lucerne fields, in other words, the population dynamics are unknown. In several studies conducted in Turkey, population development has been investigated by the sweep net sampling of *G. fornicata* (Anay, 2000; Coşkuncu & Gençer, 2006). In previous studies, damage and economic loss due to infestation of this pest have not been reported for Turkey. The damage and the economic loss caused by the pest in Adana therefore unknown. Population changes of pest species were investigated by plant sampling in this study. For this purpose, as well as the population dynamics in the insecticide-treated and untreated plots, the yield loss caused by it was also revealed. The data obtained can be used for the management of the *G. fornicata* in lucerne fields.

Materials and Methods

This study was conducted in 2017 and 2018 in the lucerne area of Adana Province, Çukurova University Faculty of Agriculture Research and Application Farm. The experimental was 0.1 ha divided into eight plots each of 100 m^2 in a split-plot design. Replicates were created by dividing main plots (with and without treatment). The study was conducted with four replicates, four plots (10 × 10 m) were insecticide free and four plots were treated with insecticides. Two m was left between plots and blocks, and these areas were left bare. Application of insecticides was done according to the program of Research and Application Farm, and when the damage reached 10-20% by counting damaged leaves within 1 m^2 area insecticides were applied by field sprayer (Holder) with 1 t capacity and operated with 4 bar pressure. The

insecticides had active ingredients of deltamethrin 20 g/l (EC) (300 ml/ha) in 2017 and chlorpyrifos ethyl 480 g/l (400 ml/ha) in 2018. Lucerne cultivar Nimet was used in the experiment. Two hundred kg/ha of 21% ammonium sulfate and 500 kg/ha of 42% triple super phosphate were applied to the soil before the sowing. Sprinkler irrigation system was operated every 15 d during the experiment.

Insect sampling

For this purpose, 1 × 1 m quadrat was arbitrarily thrown twice in each subplot and the plants within the quadrat examined. The adults and larvae of *G. fornicata* were counted in the field and recorded. In order not to prevent the development of the pest population, after the counts, the insects were returned to the plots after counting. Insect sampling was done in the morning between 08:00 and 10:00.

Lucerne yield

When flowering of the lucerne crop reached 80% (10 May in both the years), harvesting was done in accordance with the Research and Application Farm management program. Each plot was mowed separately using a disc-formatted machine. To determine the fresh weight, the cut lucerne obtained in the plots were individually bagged and weighed. The lucerne that was left to dry in the field were baled after it dried in the sun. The bales were made separately in each plot and their dry weights were determined with a hand scale. In addition, the economic damage of the lucerne due to the pest feeding was calculate using the market price per kg, the cost of spraying per ha and the loss of yield in the insecticide-free plot. In order to determine the crude protein, ADF (acid detergent cellulose) and NDF (neutral detergent cellulose) values of the dry lucerne hay, 500 g of samples were taken from each plot and numbered on the purse paper (Naidenova & Donschev, 1995). Analysis were done at the Department of Field Crops at the Faculty of Agriculture, Bozok University, Yozgat Province, Turkey.

Statistical analysis

Populations of larvae and adults were converted to means for treated and untreated plots recorded weekly. These means were compared by t-test to determine the effect of the treatment. For this purpose, iterative statistical analysis method (repeated measures ANOVA) was used. The effect of sampling date, insecticide treatment and sampling date by treatment interaction were analyzed. The t-test ($P < 0.05$) was again used in the calculation of the mean yield, crude protein, ADF and NDF values for the plots. Yield and crude protein losses (%) were calculated according to Karman (1971). The relationships between the mean number of insects (larvae and adults) and meteorological factors (temperature and RH) were examined by linear regression analysis at $P < 0.05$ significance level. All statistical analyzes were done in SPSS Package Program (Version 15) (SPSS, 2006).

Results

Population dynamics of *Gonioctena fornicata*

The sampling date, treatment and sampling date by treatment were significantly affected by the *G. fornicata* population (Table 1).

Population dynamics of adults and larvae of *G. fornicata* in 2017 in the lucerne field in the insecticide-treated and insecticide-free plots are given in Figure 1 and Table 2. The first adults (0.1±0.12 adults/m²) on insecticide-free plots were detected on 18 April. The highest adult density was recorded as 0.6±0.26 adults/m^2 on 9 May, when the mean temperature was 20.2ºC, RH was 81.1% and the mean rainfall was 1.62 mm (Figure 2). The first adults in the treated plots were recorded on 18 April, and the highest adult density as found on 9 May (0.9±0.39 adults/m^2). No significant differences were found between insecticide-treated and insecticide-free plots in adult population density ($P > 0.05$). This may be related to the low number of adults in both plots.

Table 1. Results of repeated measures ANOVA for *Gonioctena fornicata* in a lucerne field in Adana Province, Turkey during 2017

Variation source	Df	MS	F	P
Date (sampling)	6	2135	57.4	<0.0001
Date x Treatment	6	858	23.0	<0.0001
Error (date)	168	37		
Treatment	1	6227	83.6	<0.0001
Error	28	75		

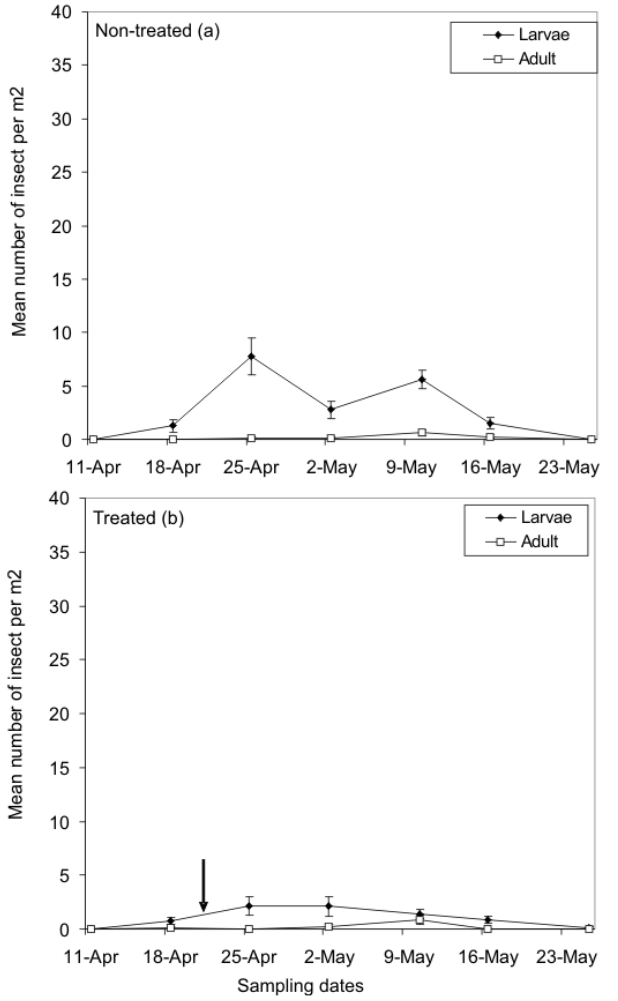

Figure 1. Mean number of *Gonioctena fornicata* per m^2 in the untreated (a) and treated plots (b) plots in 2017 by the sampling of lucerne in Balcalı, Adana Province, Turkey. The straight dark arrow sign indicates the date of application (21 April 2017).

Population dynamics of *G. fornicata* larvae in the lucerne field in 2017 on treated and untreated plots are shown in Figure 2 and Table 2. The first larvae were registered on the treated and untreated plots on 18 April. Larvae reached the highest population density in the untreated plot on 25 April (7.8±1.8 larvae/m^2). This short-term decrease mean numbers of larvae finished on 9 May (5.6±0.88 larvae/m^2). Similar to adults, larval density in untreated plots declined to zero on 23 May. The mean larval density in the treated plot was lower than the untreated plots. When the larval densities are compared in the untreated and treated plots; the difference was significant on 25 April ($F_{1,14}$ = 8.43, t = 2.89, P = 0.012) and 9 May ($F_{1,14}$ = 18.8, t = 4.34, P = 0.001), and the highest larval density was recorded in the untreated plots. No significant correlation was found between plant sampling, larval and adult population densities of pests and meteorological factors (P > 0.05).

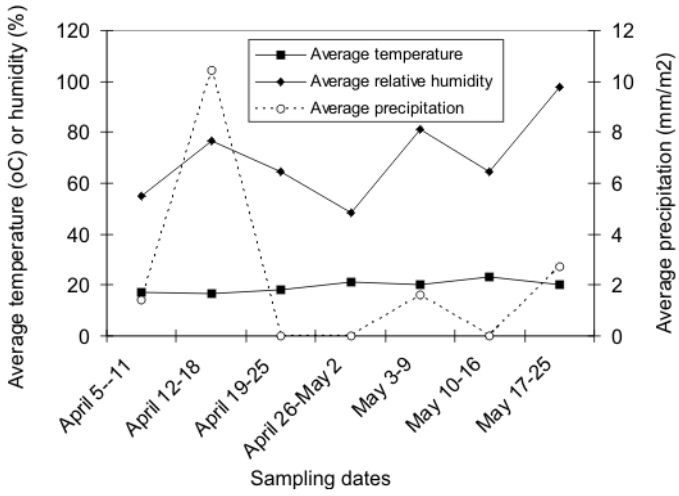

Figure 2. Meteorological data for Adana Province, Turkey in 2017.

Table 2. Mean number of larvae and adults of *Gonioctena fornicata* per m^2 in treated and untreated lucerne plot in Balcalı, Adana Province, Turkey during 2017

Plot type	11 April	18 April	25 April	2 May	9 May	16 May	23 May
				Adult			
Non-treated	0.00±0.00	0.00±0.00	0.12±012	0.12±0.12	0.62±0.26	0.25±0.60	0.00±0.00
Treated	0.00±0.00	0.12±0.12	0.00±0.00	0.25±0.16	0.87±0.39	0.00±0.00	0.00±0.00
				Larvae			
Non-treated	0.00±0.00	1.25±0.55	7.75±1.75*[a]	2.75±0.79	5.62±0.88*	1.50±0.56	0.00±0.00
Treated	0.00±0.00	0.75±0.31	2.12±0.85	2.12±0.91	1.37±0.41	0.87±0.35	0.12±0.12

* Means±SEM within columns followed by an asterisk are statistically different according to the t-test (P < 0.05).

In the statistical analysis for 2018 data, date (sampling) and date × treatment had a significant effect on the population of *G. fornicata* (Table 3). Also, treatment was also found to be significant (Table 3).

Population changes of adults and larvae in 2018 in the lucerne field in Balcalı are shown in Figure 3 and Table 4. Both the treated and untreated plots had higher adult densities than the previous experimental year. The adult density in the untreated plots increased rapidly after 10 April, when the mean temperature was 18.6ºC, RH was 56.1% and the mean rainfall was 11.5 mm. It reached its peak on 17 April (26.3±6.7 adults/m^2), when the mean temperature was 19.5ºC, RH was 67.1% and the mean rainfall was 10.1 mm (Figure 4). The insecticide applied at this date probably affected the adult density in the treated plots and reduced the adult population. As seen in Table 4, the adult density in untreated plot increased again on 1 May, when the mean temperature was 23.2ºC, RH was 58.6% and the mean rainfall was 0 mm/m^2 (14.25±1.16 adults/m^2). After this date, the mean population density decreased to the lowest level (0.12±0.12 adults/m^2) on 22 May. Significant differences were found for adult density (24 April, $F_{1,14} = 18.7$, t = 4.31, P = 0.01; 1 May, $F_{1,14} = 53.7$, t = 7.54, P < 0.0001 and 8 May, $F_{1,14} = 56.8$, t = 7.54, P < 0.0001).

Table 3. Results of repeated measures ANOVA for *Gonioctena fornicata* in a lucerne field in Adana Province, Turkey during 2018

Variation sources	df	MS	F	P
Date (sampling)	6	24084	96.4	<0.0001
Date × Treatment	6	1582	6.4	<0.0001
Error (date)	168	249		
Treatment	1	11861	73.6	<0.0001
Error	28	161		

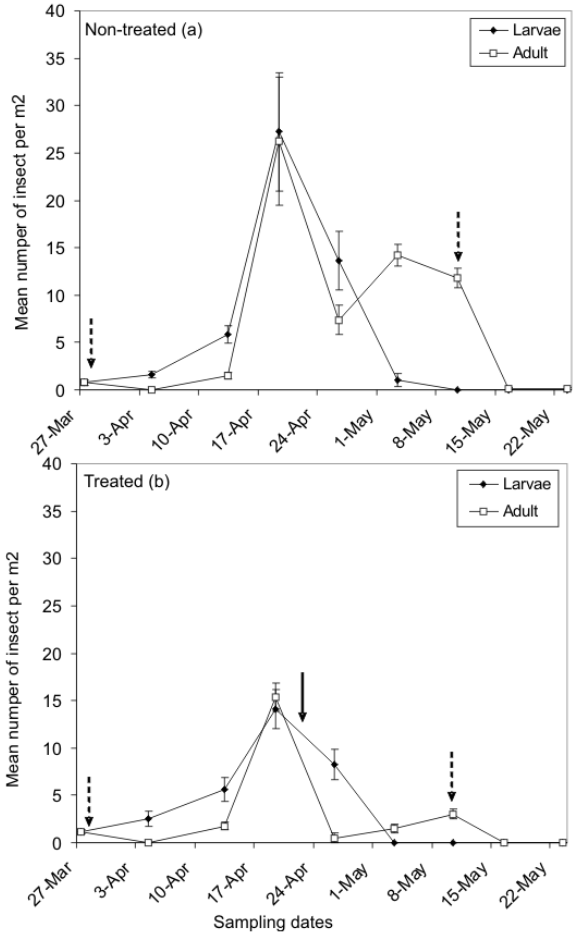

Figure 3. Mean number of *Gonioctena fornicata* per m^2 on the untreated (a) and treated (b) plots in 2018 in a lucerne field in Balcalı, Adana Province, Turkey. The straight dark arrow indicates the date of application against *G. fornicata*, (18 April 2018), the dashed arrow lucerne indicates mowing dates of lucerne (27 March 2018 and 10 May 2018).

Table 4. Mean number of larvae and adult of *Gonioctena fornicata* per m^2 in treated and untreated lucerne plots in Balcalı, Adana Province, Turkey during 2018

Treatment	27 March	3 April	10 April	17 April	24 April	1 May	8 May	15 May	22 May
					Adult				
Untreated	1.8±0.25	0.0±0.00	1.5±0.32	26.3±6.72	7.4±1.54*	14.3±1.16*	11.8±0.30*	0.1±0.12	0.1±0.12
Treated	1.1±0.22	0.0±0.00	1.8±0.41	15.4±1.49	0.5±0.37	1.5±0.50	3.0±0.53	0.0±0.00	0.0±0.00
					Larvae				
Untreated	0.8±0.25	1.6±0.37	5.9±0.93	27.3±6.24	13.6±3.1	1.0±0.68	0.0±0.00	0.0±0.00	0.0±0.00
Treated	0.1±0.22	2.5±0.80	5.6±1.23	14.1±2.09	8.3±1.58	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00

* Means±SEM within columns followed by an asterisk are statistically different according to the t-test ($P < 0.05$).

Population changes of larvae in untreated and treated plots in 2018 are given in Figure 3 and Table 4. With the effect of the first mowing on 27 March, the larval density remained low until 10 April. Larvae population reached the highest density on 17 April (27.3±6.2 larvae/m^2) in untreated plots. After this date, the larval density declined. After 8 May, larvae could not be found in the untreated plots. Similar to untreated plots, the larval density was highest on 17 April (14.1±2.1 larvae/m^2), and no larvae were found in the treated plots after 1 May. Although the larval density was about half of the untreated plots on 17 April, no

significant difference was found (Table 4). The difference between larval densities in the treated and untreated plots was determined on 24 April, and insecticide application significantly reduced the larval density ($F_{1,14}$ = 4.88, t = 2.21, P = 0.044, Table 4). No significant relationship was found between plant sampling, pest larvae and adult population densities and meteorological factors (P > 0.05).

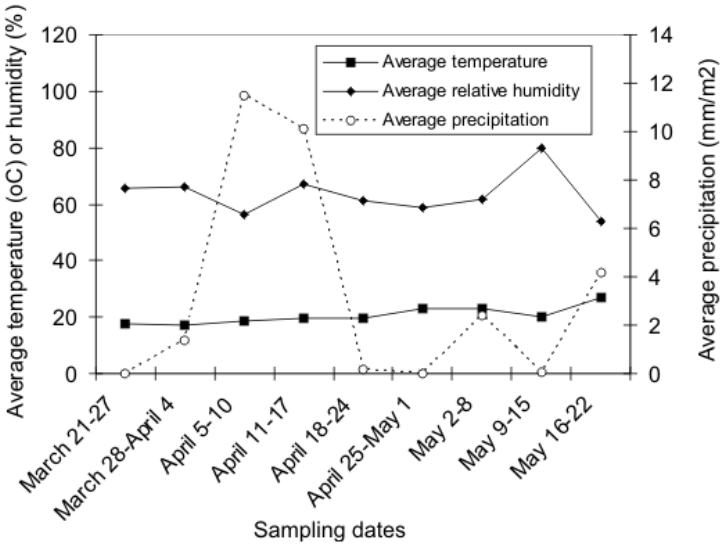

Figure 4. Meteorological data for Adana Province, Turkey in 2018.

Although the mean population density across all the sampling dates was 19.9±1.8 individuals/m^2 in the untreated plots in 2017 with plant sampling, 14.62±1.52 individuals/m^2 were found in the treated plots and the difference was found to be statistically significant ($F_{1,14}$ = 12.3, t = 3.50, P = 0.004) (Table 5).

Average population density across all the sampling dates in untreated plot was 98.8±11.1 individuals/m^2 in 2018 with plant sampling, whereas 50.6±4.0 individuals/m^2 were found in treated plot, the difference was statistically significant ($F_{1,14}$ = 16.7, t = 4.08, P = 0.001, Table 5).

Table 5. Total mean numbers of *Gonioctena fornicata* in treated and untreated plots of lucerne in Balcalı, Adana Province, Turkey during 2017 and 2018

Year	Treatment	Mean insects/m^2
2017	Untreated	19.9±1.79*
	Treated	14.6±1.52
2018	Untreated	98.8±11.08*
	Treated	50.6±4.02

* Means±SEM within columns followed by an asterisk are statistically different according to the t-test (P < 0.05).

Yield loss due to *Gonioctena fornicata* feeding

Different factors affected yield and yield components. Among these, the effect of other insects should be considered. However, in the period when this study was conducted (March-May), lucerne leaf beetle was main pest. The fresh and dry weight of the treated and untreated plots in the lucerne field in Balcalı are given in Table 6. Although the fresh weight in the untreated plot was 117±5.6 kg/100 m^2 in 2017, it was 138±1.7 kg/100 m^2 in the treated plot. The difference was found to be statistically significant ($F_{1,6}$ = 12.0, t = -3.47, P = 0.013). Although the fresh weight was 105±1.8 kg/100 m^2 in the untreated plot in 2018, it was 142±5.3 kg/100 m^2 in the treated plot. The difference was statistically significant ($F_{1,6}$ = 45.5, t = -6.75, P = 0.001).

Table 6. Mean fresh and dry weights (kg) of lucerne in treated and untreated plots of lucerne in Balcalı, Adana Province, Turkey during 2017 and 2018

Year	Treatment	Fresh weight	Dry weight
2017	Untreated	117±5.6	103±4.8
	Treated	138±1.7*	121±1.8*
2018	Untreated	105±1.8	92±0.4
	Treated	142±5.3*	127±5.8*

* Means±SEM within columns followed by an asterisk are statistically different according to the t-test ($P < 0.05$).

The dry weight in the untreated plot was 103±4.8 kg/100 m^2 in 2017, whereas the dry weight in treated plot was 121±1.8 kg/100 m^2 (Table 6). The difference was statistically significant ($F_{1,6} = 11.7$, $t = -3.42$, $P = 0.014$). The dry weight in the untreated plot was 92±0.4 kg/100 m^2 in 2018, whereas it was 127±5.8 kg/100 m^2 in the treated plot (Table 6). The difference was statistically significant ($F_{1,6} = 41.6$, $t = -6.45$, $P = 0.001$).

In 2017, the fresh weight decreased by 14.7% and dry weight by 14.6%. In 2018, fresh weight decreased by 26.3% and dry weight decreased by 27.4%.

For the economic evaluation of the damage of lucerne leaf beetle, the treated and untreated plots were compared and the costs of different applications (insecticide, equipment and workmanship) are shown in Table 7. The dry weight difference was used to find the loss of yield between the two plots. Using the calculation, loss of yield times market price of lucerne minus spraying expense, the financial loss in the untreated plot was determined (Table 7).

Table 7. Economic analysis due to damage of *Gonioctena fornicata* in Turkish Lira (TRY)

Issues of economic analyses	Cost, price or yield loss
Spraying cost (insecticide, equipment and workmanship)	96.5 TRY/ha
Market price of dry lucerne	1.25 TRY/kg
Average yield loss between treated and untreated plots	3480 kg/ha
Economic loss in the untreated plot	4250 TRY/ha

Loss of crude protein, acid detergent fiber and neutral detergent fiber in harvested lucerne

No statistically significant difference was found between ADF and NDF ($P > 0.05$, Table 8). Although crude protein was 25.6±0.91% in the treated plot, it was 22.70±0.81% in the non-treated plot. The crude protein value was slightly higher in the treated plots, and the difference between the treated and untreated plots was statistically significant ($F_{1,6} = 8.75$, $t = 2.96$, $P = 0.025$).

Table 8. Mean (±SEM) crude protein, ADF and NDF values of lucerne in Balcalı, Adana Province in 2018

Treatment	Crude protein (%)	ADF (acid detergent fiber) (%)	NDF (neutral detergent fiber) (%)
Untreated	22.0±0.81	24.2±1.35	38.1±1.81
Treated	25.6±0.91*	29.0±1.66	42.8±2.09

* Means±SEM within columns followed by an asterisk are statistically different according to the t-test ($P < 0.05$).

Discussion

Although the first adults were seen in the lucerne plots in early April in 2017, the larvae appeared in late April. In 2018, the pest infestation started earlier (March). The first adults and eggs were detected in mid-March before the plots were established in 2018. The differences in the appearance of the first adults and larvae by sampling years may be related to plant phenology. Given that of lucerne field was planted in 2017,

this may be related to the fact that lucerne establishment takes a long time and plant growth is not suitable for larvae and adults to feed. The first sampling in 2017 could only be made in the second week of April, since the plant growth was quite short. The higher density of pests in 2018 may attributable to meteorological factors (relatively high temperature) being more favorable for pest population development in 2017. Anay (2000) found the first adults in Balcalı (Adana Province) in late February and their larvae in mid-March. In our study, the first adults and larvae appeared in late-March, especially in 2018; this may be related to sampling starting later. However, Çoşkuncu & Gençer (2006) found the first adults in late-March to early-April under natural conditions. Kovancı (1982) reported that the first appearance of the overwintering adults was in late-March to early-April according to climatic conditions. In Plovdiv (Bulgaria), *G. fornicata* first adults appeared in April and their larvae later in May (Atanasova & Semerdjieva, 2009). These differences may be related to the fact that Adana, located in the Mediterranean climate zone, has a warmer and humid climate.

The larvae were actively feeding on leaves, shoots and flower organs of lucerne plants for 5 weeks in 2017 and for 6 weeks in 2018. It was observed that the larvae and adults of the pest were feeding in the cool time of the day, and they were withdrawing to the soil during the hot time of the day. Brovdii (1977) reported that larvae fed in the clover field in Ukraine for 19-27 d, the pupa period lasted 5-9 d, and young adults (new generation adults) appeared in the period between late-June and mid-July. The differences between these findings and the current study may be related to ecological factors.

Although the peak number of adults in the lucerne plots appeared 2 weeks after the first detection, the larvae reached the highest population density 1 week after their first detection (25 April). In 2018, larvae and adults were recorded at the highest densities in mid-April, about 3 weeks later after they were first detected. This may be related to plant phenology, as mentioned earlier. However, in general, it can be emphasized that adults and larvae reached their highest population density in mid- to late-April. After April, larval and adult densities declined. New generation adults were recorded in the first week of May. Adults and larvae were not found until after mid-May. Çoşkuncu & Gençer (2006) reported that populations of *G. fornicata* were the highest in late-May to early-June with a sweep net sampling performed lucerne field in Bursa Province, Turkey. The later emergence of adults and larvae in that study may be related to the colder conditions in Bursa than in Adana. Brovdii (1977) reported that *G. fornicata* is an important pest in Ukraine, overwintering as an adult 20 cm deep in the soil, and adults are seen in the Transcarpathian Region in mid-April to early-May. Lustun & Panu (1968) found that adults of *G. fornicata* overwinter 10-15 cm depth of the soil, and Kovancı (1982) found that *G. fornicata* adults overwintered in the soil at a depth of 1-20 cm in Ankara. Yıldırım et al. (1996) reported that *G. fornicata* overwintered 10-25 cm deep in a field of lucerne in Erzurum Province, and when the lucerne reached 10 cm in early April, they left the overwintering area and moved to the lucerne. It was found that this harmful pest species had one generation a year. Coşkuncu & Gençer (2006) also reported that *G. fornicata* had one generation per year under conditions of Bursa Province. Kovancı (1982) reported that *G. fornicata* had obligatory diapause and was a species that has only one generation per year, Keresi & Sekulic (2005) reported that *G. fornicata* overwintered as adult and had one generation per year. Bronskikh (1987) reported that *G. fornicata* has one generation per year, and for this pest in Kishinev (Russia), Moldavia and Ukraine, larvae and adult damage are important, primarily feeding on the tips of leaves, buds and young shoots.

Insecticide application decreased the pest population by 26.4% in 2017 and 48.7% in 2018. In 2017, insecticide deltamethrin 20 g/l was not sufficiently effective, and in 2018 a relatively higher effect was observed with chlorpyrifos ethyl 480 g/l, and it reduced the harmful population by only about 50%. Bronskikh (1987) reported that *G. fornicata* is an important pest in the lucerne fields in Kishinev, and endosulfan (2.5 kg/ha) was highly effective, reducing pest populations by 95, 98 and 85% after 4, 7 and 13 d from application, respectively. Atanasova & Andreev (2012) found that pyrethrum FSEC (pyrethrin, sesame oil and soft potassium soap), Neem Azal T/S (azadirachtin) were effective against *G. fornicata* adults and larvae. They also reported that the preparation of *Bacillus thuringiensis* subsp. *kurstaki* de Barjac &Lemille, 1970 gave highly positive results against adults and larvae of the pest.

Gonioctena fornicata negatively impact fresh and dry weight yields. It is estimated that the actual yield loss (greater than the measured 3.40 t/ha) will be higher because the insecticides used were not sufficiently effective. Although the yield difference between the treated and non-treated plots was lower than expected, the cost of the loss was still high (Table 7). The financial loss in the untreated plots was about 4,250 TRY/ha (about 545 USD/ha as of December 2020). Grigorov (1976) reported that fresh weight decreased by over 60% and seed yield decreased by around 100% as a result of the feeding of adult and larvae of *G. fornicata* in Central and Southwest Europe. Naidenova & Donschev (1995) reported that *Hypera postica* (Gyllenhal, 1813) and *G. fornicata* were important pests in lucerne in Pleven (Bulgaria), and that the dry weight loss varied between 48 and 67%, and the yield of the shoots decreased by 32-45%.

Lucerne leaf beetle did not affect ADF and NDF values. In contrast, the crude protein value was relatively lower in the insecticide-free plots (Table 8). In other words, this pest significantly affected crude protein. Naidenova & Donschev (1995) found that loss of crude protein due to leaf beetles feeding ranged from 49-70%.

This study reveals that the *G. fornicata* is the main pest and the needs insecticides application to minimize economic damage in large production areas. There are no registered insecticides to control *G. fornicata* in Turkey. The mowing done in March 2018 delayed larval population development of this pest by about 2 weeks, and the population density of larvae remained low. It is recommended as a precautionary measure to make the spring mowing earlier (e.g., early- to mid-March) to reduce the population of this pest. The economic threshold for the *G. fornicata* is unknown in lucerne in Turkey. Therefore, further study is needed to determine its economic threshold in lucerne in different ecological regions of Turkey. In Tokat Province, Turkey, the two-parasitoid species of *G. fornicata* in lucerne fields were identified as *Macquartia tenebricosa* (Meigen, 1824) and *Meigenia mutabilis* (Fallen, 1810) (Diptera: Tachinidae) (Atay, 2018). According to that study, larval parasitization rates varied between 0.5% and 3.7%. *Meigenia mutabilis* was found to be the more potent parasitoid of *G. fornicata*. In this present study, although the larvae were cultured, no parasitoid species could be detected in the larvae. More detailed studies are needed on this issue.

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