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Determination of Some Physiological Parameters of *Acanthiophilus Helianthi* Rossi (Diptera: Tephritidae) Before and After Damage in Different Safflower (*Carthamus tinctorius* L.) Varieties

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ABSTRACT

One of the principal pests of safflower plants is Acanthiophilus helianthi, also known as the safflower fly. The safflower plant (Carthamus tinctorius), one of its hosts, is a significant energy plant whose cultivation has expanded recently in our nation. It is drought-resistant and highly adaptable. This study aims to investigate the effect of A. helianthi on some physiological (sugar, mineral substance, chlorophyll, total phenol, and antioxidant content) parameters in five different safflower cultivars, whose production has increased in the province of Van in recent years. The findings showed that under stress conditions brought on by the development of the pest, A. helianthi responded physiologically to the five different forms of safflower in a significant way. The mineral values of iron and potassium increased under stress conditions brought on by A. helianthi damage, but the mineral values of zinc, manganese, copper, phosphorus, and calcium decreased. According to the sugar content results, only the fructose amounts of Ayaz and Göktürk varieties differed before and after the damage. Before the damage, the antioxidant content of the cultivars Asol, Ayaz, Balcı, and Dinçer was found to be low, whereas the antioxidant content of the Göktürk cultivar was high, and the antioxidant content of the Göktürk cultivar significantly decreased after the damage. It was found that under stress, the chlorophyll content of the cultivars of safflower used were reduced. As a result, it was concluded that the safflower fly has different effects on safflower varieties before and after damage and that it can provide practical ideas to the producers who will produce safflower as a solution to the drought and energy problem.

Keywords: *Acanthiophilus helianthi, Safflower, Safflower fly, Physiological Parameters*

Acanthiophilus Helianthi Rossi (Diptera: Tephritidae)'nin Farklı Aspir (*Carthamus tinctorius* L.) Çeşitlerinde Zarar Öncesi ve Sonrası Bazı Fizyolojik Parametrelerinin Belirlenmesi

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ÖZ

Aspir bitkilerinin başlıca zararlılarından biri, aspir sineği olarak da bilinen Acanthiophilus helianthi'dir. Konukçularından biri olan aspir bitkisi (Carthamus tinctorius), ülkemizde yetiştiriciliği son yıllarda yaygınlaşan önemli bir enerji bitkisidir. Kuraklığa dayanıklı ve son derece uyumludur. Bu çalışma, Van ilinde son yıllarda üretimi artan beş farklı aspir çeşidinde A. helianthi'nin bazı fizyolojik (şeker, mineral madde, klorofil, toplam fenol ve antioksidan içerik) parametreler üzerine etkisini araştırmayı amaçlamaktadır. Bulgular, zararlının gelişiminin getirdiği stres koşullarında A. helianthi'nin beş farklı aspir formuna fizyolojik olarak önemli ölçüde tepki verdiğini göstermiştir. Acanthiophilus helianthi hasarının getirdiği stres koşullarında demir ve potasyum mineral değerleri artarken, çinko, manganez, bakır, fosfor ve kalsiyum mineral değerleri azalmıştır. Şeker içerikleri sonuçlarına göre sadece Ayaz ve Göktürk çeşitlerinin fruktoz miktarları zarar öncesi ve sonrası farklılık göstermiştir. Hasat öncesi Asol, Ayaz, Balcı ve Dinçer çeşitlerinin antioksidan içeriği düşük bulunurken, Göktürk çeşidinin antioksidan içeriğinin yüksek olduğu, zarardan sonra Göktürk çeşidinin antioksidan içeriğinin önemli ölçüde azaldığı tespit edilmiştir. Stres altında kullanılan aspir çeşitlerinin klorofil içeriklerinin azaldığı tespit edilmiştir. Sonuç olarak aspir sineğinin aspir çeşitleri üzerinde zarar öncesi ve sonrası farklı etkilerinin olduğu, kuraklık ve enerji sorununa çözüm olarak aspir üretimi yapacak üreticilere pratik fikirler sağlayabileceği kanısına varılmıştır.

Anahtar Kelimeler: *Acanthiophilus helianthi, Aspir, Aspir sineği, Fizyolojik Parametreler*

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Introduction

Safflower is one of the oldest crops known to man, with usage records dating back more than 2200 years in China. Safflower seeds were found in Egyptian tombs more than 4000 years ago (Gyulai, 1996). Native to the Middle East, the safflower plant is believed to have originated in Iran (Knowles, 1989; Weiss, 1983; McPherson et al., 2004; Zareie et al., 2013; Khalili et al., 2014). Safflower (Carthamus tinctorius L.) is a member of the Asteraceae family grown for its flowers, which are used for many purposes (edible oil, food source for birds, medicine and dye industry, biofuel) (Weiss, 1983). Safflower has a significant role in human nutrition. Flowers are drunk in China as herbal tea because they contain some vitamins (such as B1, B2, B12, C, and E), minerals, antioxidants, and amino acids. In some Middle Eastern and Asian countries, its flowers are used in rice, soup, sauce, bread, and pickles to create bright yellowish and orange colors (Dajue and Mündel, 1996; Singh and Nimbkar, 2006). Carotene, riboflavin, vitamins A and C, calcium, phosphorus, iron, and riboflavin are all abundant in safflower (Singh and Nimbkar, 2006).

Throughout their life, plants are generally exposed to a variety of similar factors, such as salinity, drought, pollution, diseases and pests, heat, and cold, which adversely influence their natural growth and development. Stress is defined as changes to these conditions in plants (Korkmaz and Durmaz, 2017). Reducing product losses due to stress has become very important in our world where food shortages may occur in the future due to increasing population density and decreasing arable land (Korkmaz and Durmaz, 2017).

Safflower is generally grown as a rain-fed product without the need for irrigation, this feature ensures that the incidence of diseases and pests is lower than in other agricultural products (Li and Mündel, 1996). However, it has been discovered via research that the safflower plant is susceptible to a few pests, including aphids, green worms, thrips, safflower flies, and mites, which negatively affect the quality and yield of the crop (Nimbkar, 2008). The safflower fly (Acanthiophilus helianthi Rossi), which belongs to the family Tephritidae from the order Diptera, is one of the main pests that cause significant damage to the safflower plant (Talpur et al., 1995). Acanthiophilus helianthi Rossi, head yellowish green, antennae yellow, wings hyaline, and they are gray spotted, 4-5 mm tall and 9–10 mm wide. The body is cylindrical and 4-5 mm long, the wing veins are yellow, and the larvae are initially white and eventually turn grayish-white as they age (Şengonca, 1983).

During the plant's reproductive period, A. helianthi is heavily infested, and considerable losses in seed quantity and quality have been documented as a result of larval feeding (Riaz and Sarwar, 2014; Khuhro et al., 2021).

It has been observed that researches on safflower are mostly seed and oil focused. It has been determined that there is no study on the total phenol, antioxidant, sugar, mineral substance, and chlorophyll content occurring in the leaves of the plant, especially before and after the safflower fly damage.

In this study, the safflower plant, which has the potential to gain an important place in sustainable agriculture methods used for both energy and consumption purposes in recent years, has been discussed. The degree of variation in the physiological parameters of the safflower plant—including sugar, mineral content, chlorophyll, total phenol, and antioxidant amount—before and after the safflower fly damage was evaluated.

Materials and Methods

Study area, location, and experimental design

Five safflower cultivars Asol, Ayaz, Balcı, Dinçer, and Göktürk were used to assess each cultivar's level of resistance to the safflower fly A.helianthi. Seeds of Asol and Göktürk varieties used for sowing were obtained from Van Yüzüncü Yıl University, Department of Field Crops, Ayaz variety from Bahri Bağdaş International Agricultural Research Institute, Balcı and Dinçer varieties from Eskişehir Geçit Kuşağı Agricultural Research Institute.

The research was prepared according to random plots and carried out with five replications in the experimental areas of the Faculty of Agriculture of Van Yüzüncü Yıl University in 2020. Five parcels of each category made up a total of 25 that made up the study area. The parcels were set up with a space of 2 metres between them and measurements of 5 m x 5 m. The rows are formed at intervals of 5 cm, with a row spacing of 25 cm. 12 rows separate each plot. The study area was plowed between 25 March and 15 April 2020 with the help of a plow and the clods formed in the soil were prepared by breaking up with a disc harrow.

The plots received 480 gr/da of nitrogen fertilizer and 240 gr/da of phosphorus (TSP) fertilizer just before planting. With the use of a marker, 12 rows were made in each plot following the fertilizer application, and 2 kg/da of seeds were planted. It is given time to grow after being covered with 1-2 cm of dirt. Safflower seeds planted on March 31, 2020, were released on April 20, 2020. In the early stages of development, weed control was carried out at regular intervals until the safflower plant reached a certain height.

Plants planted in the field were followed up with daily controls. Immediately after the plants started to form flower heads, attacks and observations were made at weekly intervals, and it was determined when the A. helianthi started to damage the plant. To determine the physiological changes in the mechanism of damage by A. helianthi to the safflower plant, plant samples were taken from a certain number of flower heads from each plot before and after the field was damaged and evaluated in terms of necessary parameters. Temperature, humidity, and precipitation values of the region to be planted are given in Table 2.1.

Table 2.1. *Van province climate values*

Months	1	2	3	4	5	6	7	8	9	10	11	12
Average temperature (C°)	-2.0	-1.5	4.6	7.9	13.9	18.6	22.2	21.3	20.3	14.2	7.3	2.1
Average relative humidity (%)	69.6	72.0	70.3	65.9	56.2	49.6	50.9	48.0	44.8	47.4	60.0	66.1
Total precipitation (mm/kg/m²)	50.3	79.9	44.3	51.8	27.8	13.7	17.6	10.0	5.6	1.8	12.8	27.7

Parameters and statistical analysis

Determination of total phenol content and antioxidant activity

The Folin-Ciocalteu kalorimetric technique was used to determine the total phenol content (Swain & Hillis, 1959). In brief, 1 g of the 4th compound leaf from the top of each fully developed plant was used for extraction. 400 µL of distilled water and 150 µL of Folin-Ciocalteu solution were added to 150 µL of the extract, followed by 300 µL of 20% sodium carbonate (Na2CO) (Merck 1.06392.1000, Germany) and let for 30 min in dark. A spectrophotometer (VarianBio 100, Australia) was used to measure the absorbance of the solutions at 725.0 and 700.0 nm. The antioxidant activity of the same extracts was evaluated using the FRAP (Ferric Reducing Antioxidant Power) technique (Benzie & Strain, 1996) for which 150 µL of the extract were combined with 2850 µL of the FRAP working solution and stored at 25°C for 30 min in the dark. For FRAP working solution, three preliminary solutions should be prepared. In the first one 1.55 g of acetate buffer was mixed with 0.25 L of distilled water followed by adding glacial acetic acid up to 0.5 L. For second solution, 100 mL of of diluted HCl (40 nM) was prepared followed by adding 50 mL TPTZ (2,4,6 Tri (2-prdidyl)-s-triazine). In the third solution, 0.270 g of ferric chloride (2 nM) was added in 50 mL of distilled water. In final working solution, 250 mL of the first solution, 25 mL of the second and third solutions were mixed and kept in a water bath at 37°C for 30 min. The total antioxidant activity was measured at 593.0 nm using a spectrophotometer (VarianBio 100, Australia).

Determining the amount of sugar

Safflower juice obtained from leaf samples taken from the field with the help of a homogenizer was centrifuged at 12000 rpm for 2 minutes and passed through a SEP-PAK C18 cartridge. The filtered samples were read using a refractive index detector and 85% acetonitrile liquid phase sugars using a µbondapak-NH2 column in the Food Control Laboratory HPLC device. The calculation of concentrations was made according to externally supplied standards.

Determination of mineral substance content (Ca, K, Mg, Cu, Fe, Mn) (mg/kg)

Mineral substance contents were prepared according to the dry burning method, and K, Ca, Mg, Fe, Mn, and Cu elements were determined with the help of an Atomic Absorption Spectrophotometer (Kacar, 1984).

Determination of leaf chlorophyll content

The chlorophyll amount was determined by measuring the leaves of the safflower plant from planting to the field with a SPAD device. To determine the amount of chlorophyll, measurements were made twice, before and after the safflower fly harmed it. To be able to measure, four plants were randomly separated from each plot, and each plant was divided into three parts from 4 plants and measured three times as upper, middle, and lower with a SPAD device.

Statistic analyses

The data obtained in the study were tested according to a one-way analysis of variance (one-way ANOVA, Tukey), and the differences between varieties were determined (SPSS, 2019).

Results

Five different safflower cultivars were observed to exhibit either a decrease in plant parameters or an increase in them in response to stress conditions brought on by Acanthiophilus helianthi damage.

Effect of Acanthiophilus helianthi on sugar content before and after damage in five different safflower cultivars.

The effect of Acanthiophilus helianthi on sugar content before and after damage in five different safflower cultivars is given in Table 1. According to this Table, the difference between sucrose, glucose, and fructose sugar amounts before and after the damage was found to be statistically significant ($p<0.05$). The highest amount of sucrose before damage was found in the Dinçer variety with 1.75 g, while the lowest value was observed in the Asol variety 1.21 (Table 1). 38% increase in the Ayaz variety and a 7% decline in the Asol variety were seen following the damage (Table 1).

The fructose quantity metric recorded extremely low values both before and after the damage. Asol 0.32 gr, Ayaz 0.22 gr, Balcı 0.31 Dinçer 0.25, and Göktürk 0.26 gr were the weights before the damage. Although the Ayaz cultivar (0.22 gr) had the lowest fructose value, the Asol cultivar had the greatest value (0.32 gr). All cultivars except Asol showed a rise in fructose content after harvest (Table 1).

The difference in glucose amount between the treatment groups both before and after damage was statistically insignificant ($p>0.05$). While the highest value before damage was 0.86 g in the Göktürk variety, the lowest value after the damage was 0.58 g in Asol and Ayaz varieties. A decrease of 33% was observed after damage in the Dinçer variety compared to pre-damage, and 37% in the Göktürk variety (Table 1). Ayaz and Göktürk cultivars only differed in fructose amount before and after damage, and no difference was found between other cultivars (Balcı, Dinçer and Asol), according to the sugar content results of the three cultivars (Sucrose, Fructose, Galactose) usually obtained in Table 1.

Table 1. *Sugar content before and after damage in five different safflower cultivars of Acanthiophilus helianthi (Mean±Standard deviation)*

	Sucrose		**Fructose**		**Glucose**	
Safflower varieties	Before damage x̄±S.D	After damage x̄±S.D	Before damage x̄±S.D	After damage x̄±S.D	Before damage x̄±S.D	After damage x̄±S.D
Asol	1.21 ± 0.22 Aa	1.12 ± 0.14 Aa	0.32 ± 0.09 Aa	0.32± 0.04 Aa	0.67 ± 0.08 Aa	0.58 ± 0.10 Aa
Ayaz	1.47 ± 0.30 Aa	2.04 ± 0.19 Ab	0.22 ± 0.02 Aa	0.47 ± 0.07 Ba	0.67 ± 0.08 Aab	0.58 ± 0.10 Aa
Balcı	1.32 ± 0.15 Aa	1.37 ± 0.28 Aab	0.31 ± 0.06 Aa	0.52 ± 0.05 Aa	0.44 ± 0.05 Aab	0.52 ± 0.09 Aa
Dinçer	1.75 ± 0.33 Aa	1.72 ± 0.39 Aab	0.25 ± 0.05 Aa	0.72 ± 0.11 Aa	0.72 ± 0.11 Aab	0.48 ± 0.13 Aa
Göktürk	1.24 ± 0.21 Aa	1.44 ± 0.11 Aab	0.26 ± 0.04 Aa	0.38 ± 0.16 Ba	0.86 ± 0.22 Aab	0.54 ± 0.37 Aa

*The difference between the same uppercase letters in each row and the same lowercase letters in each column in the table is statistically insignificant (p>0.05).

Table 2. *Total phenolic substance, and total antioxidant content before and after damage in five different safflower cultivars of Acanthiophilus helianthi (Mean±Standard deviation)*

Total phenolic substance (mg GAE / 100 g)	**Before damage**	**After damage**
Safflower varieties	x̄±S.D	x̄±S.D
Asol	116.88 ± 2.22 Ab	65.77 ± 10.59 Bb
Ayaz	270.22 ± 55.56 Ab	53.55 ± 5.55 Bb
Balcı	270.22 ± 40.06 Ab	103.55 ± 14.69 Bb
Dinçer	259.11± 30.93 Ab	70.22 ± 22.22 Bb
Göktürk	842.33± 131.46Aa	320.22 ± 130.64 Ba
Total antioxidant content (Trolox µmol TE /100g)		
Asol	78.18 ± 10.00 Ba	631.00 ± 56.72 Aa
Ayaz	133.75 ± 32.04 Ba	631.00 ± 56.70 Aa
Balcı	122.66 ± 17.34 Ba	219.87 ± 12.10 Aa
Dinçer	328.22 ± 32.74 Bb	367.11 ± 24.68 Aa
Göktürk	497.66 ± 80.07 Ac	219.84 ± 12.10 Bb

*The difference between the same uppercase letters in each row and the same lowercase letters in each column in the table is statistically insignificant (p>0.05).

Effect of Acanthiophilus helianthi on total phenolic substance, and total antioxidant content before and after damage in five different safflower cultivars.

The effect of Acanthiophilus helianthi on total phenolic substance, and total antioxidant content before and after damage in five different safflower cultivars is given in Table 2. When the total phenol content values were examined, it was determined that there were statistically significant differences between the pre-damage and post-damage varieties ($p<0.05$) (Table 2). Accordingly, a decrease was observed in all varieties after damage, depending on climate, stress, and environmental conditions. Before the damage, the lowest total phenol content was in the Asol variety. It is 116.88 mg before the injury and 65.77 mg after the injury, with a 43% difference between them (Table 2). The total amount of phenol before the highest damage was measured as 842.33 mg in the Göktürk cultivar. The difference between the total phenol content of Göktürk before and after the damage is 62% (Table 2). Although the total phenol level of the Ayaz and Balcı cultivars was 270.22 mg prior to damage, it was found that the Balcı cultivar's total phenol content after the damage decreased less than the Ayaz cultivar's total phenol content, falling to 103.55 mg. The lowest total phenol content after the damage was observed in Asol variety (Table 2).

In total antioxidant parameter, it was observed that all cultivars were statistically different before and after damage ($p<0.05$) (Table 2). While the Asol variety had the lowest antioxidant content with 78.18 µmol before damage, it had the highest value with 631.00 µmol after damage (Table 2). While the Göktürk variety had the highest antioxidant content with 497.66 µmol before damage, it had the lowest antioxidant content with 219.84 µmol after damage (Table 2). While the Göktürk variety had the highest antioxidant content with 497.66 µmol before the damage, it had the lowest antioxidant content with 219.84 µmol after the damage, with a difference of 55% between them (Table 2). The difference between antioxidant amounts before and after damage (12%) was observed at least in the Dinçer cultivar ($p<0.05$) (Table 2).

Effect of Acanthiophilus helianthi on Chlorophyll amount before and after damage in five different safflower cultivars.

The effect of Acanthiophilus helianthi on amount of chlorophyll before and after damage in five different safflower cultivars is given in Table 3. According to this table, the amount of chlorophyll decreased in all safflower varieties after damage. Göktürk variety, which had the highest chlorophyll content with 107.91 SPAD before the damage, decreased by 65% after the damage. Dinçer variety, which had the lowest chlorophyll content with 97.58 SPAD before the damage, had the highest chlorophyll content with 39.29 SPAD after the damage, and decreased by 60%. While it was measured as 100.31 SPAD before damage in Balcı variety, the lowest value was found as 37.94 SPAD after damage and decreased by 62%. Statistically significant differences were observed between the amounts of chlorophyll before and after damage in Asol, Ayaz, Balcı, Dinçer, and Göktürk cultivars ($p<0.05$) (Table 3).

Table 3. *Chlorophyll amount before and after damage in five different safflower cultivars of Acanthiophilus helianthi (Mean±Standard Deviation)*

Chlorophyll amount (SPAD)	Before damage	After damage
Safflower varieties	$\bar{x}$±S.D	$\bar{x}$±S.D
Asol	106.69 ± 2.39 ^{Aa}	38.53 ± 0.65 ^{Bab}
Ayaz	101.27 ± 2.59 ^{Aab}	39.04 ± 0.48 ^{Ba}
Balcı	100.31 ± 2.42 ^{Aab}	37.94 ± 0.30 ^{Bb}
Dinçer	97.58 ± 2.66 ^{Ab}	39.29 ± 0.33 ^{Ba}
Göktürk	107.91 ± 2.13 ^{Aa}	38.29 ± 0.28 ^{Bab}

*The difference between the same uppercase letters in each row and the same lowercase letters in each column in the table is statistically insignificant ($p>0.05$).

Effect of Acanthiophilus helianthi on the amount of mineral substance before and after damage in five different safflower cultivars.

The effect of Acanthiophilus helianthi on amount of mineral substance before and after damage in five different safflower cultivars is given in Table 4. When the five safflower varieties used in the study were evaluated together, it was observed that there were statistical differences between the phosphorus amounts before and after the damage (Table 4). According to this table, high decreases (between 93-97%) were observed in P values of all safflower cultivars after damage. The Göktürk variety had the lowest value before and after the damage, with a drop of 97%, as shown in Table 4. In line with the findings, the reductions in Phosphorus are related to the harm to the safflower fly.

All safflower cultivars' Ca values rose (between 26-51%) following damage compared to before damage. When the pre-damage and post-damage cultivars were examined, the difference was found to be statistically insignificant ($p>0.05$). The lowest pre-damage calcium value of 2.18% was obtained from Asol and Göktürk cultivars (Table 4). The highest value after the damage was found in the Balcı variety with 3.35% (Table 4).

The difference between the pre- and post-damage Cu contents of the cultivars was statistically significant ($p<0.05$). Cu values, on the other hand, did not show a parallel course. In Table 4, it showed an improvement between 18.74-25.78 mg/kg pre-damage, while it decreased between 40-70% after the damage and was determined as 5.61-10.74 mg/kg (Table 4). The lowest Cu amount was determined in Göktürk with 18.74 mg/kg before the damage and in Balcı with 5.61 mg/kg after the damage. The highest change in Cu amounts before and after the damage was in the Balcı variety with 79% (Table 4).

Considering the climatic conditions and soil structure of the province of Van, where the study was conducted, it generally has a high Fe content. Considering this situation, when the Fe values obtained in the safflower plant are examined, there is a value between 500-1200 mg/kg in all safflower varieties. (Table 4). The lowest pre-damage iron rate was 672.76 mg/kg and the highest was obtained from the Balcı variety with 909.92 mg/kg from the Ayaz variety. Statistical differences before and after damage in five cultivars were found only in Ayaz and Dinçer cultivars ($p<0.05$) (Table 4). The difference between Asol, Balcı, and Göktürk cultivars was statistically insignificant ($p>0.05$).

The K value (between 14 and 45%) after damage increased in all safflower cultivars. The pre-damage value was determined as 2.10% in the Asol variety, 2.42% in the Ayaz variety, 2.59% in the Balcı variety, 2.43% in the Dinçer variety and 2.23% in the Göktürk variety. After damage, Asol 2.63%, Ayaz 3.45% Balcı, 3.45% Dinçer, 2.79%, and Göktürk 2.78% values were obtained (Table 4).

One of the important structural elements of chlorophyll is Mg. Considering magnesium, which plays a role in the survival of the plant, it showed an increasing trend after the damage compared to before the damage, and this increased rate can be associated with the occurrence of the damage (Table 4). When the magnesium values before and after harvest were compared in general, it was seen that there was no statistical difference between the cultivars (except Asol and Balcı) ($P<0.05$). The biggest difference between before and after harvest is in the Balcı variety with an increase of 112%. The highest Mg value before damage is 0.50% in the Dinçer variety and 0.72% after damage in the Balcı variety (Table 4).

The difference between manganese values before and after damage among the cultivars (except Asol and Balcı cultivars) was statistically insignificant ($p>0.05$). After harvest, a 20-50% increase was observed in Asol, Ayaz, and Balcı cultivars, while decreases were observed in Dinçer and Göktürk cultivars (Table 4).

When Table 4 was scrutinized, it became clear that the sodium readings were quite high overall, with the highest values coming from the damage. Statistically significant differences were found in the pre-damage and post-damage data of the cultivars ($p<0.05$). The Balcı variety sustained the maximum damage (1950,61%), and the Göktürk variety sustained the lowest damage (1117,92%). Examining the post-damage data revealed a trajectory between 3000-5500%. When this course was examined, the Göktürk variety had the lowest score (3235.07%), while the Ayaz variety had the best score (5269.52) (Table 4).

When the Zn value was examined, there was no statistical difference between the cultivars (except for Balcı and Dinçer) (p>0.05). While Ayaz had the highest Zn value with 36.41% before the damage, it was the highest Zn value with 41.88% after damage, with an increase of 15% between them. The highest decrease in Zn value after the damage was seen in the Dinçer variety with 31%.

Table 4. *Mineral substances before and after damage in five different safflower cultivars of Acanthiophilus helianthi (Mean±Standard Deviation)*

		Before damage	**After damage**
Safflower varieties	Mineral substances	$\bar{x}$±S.D	$\bar{x}$±S.D
Asol	P %	0.62 ± 0.14 ^{Aa}	0.03 ± 0.00 ^{Bab}
	Ca %	2.18 ± 0.18 ^{Aa}	3.23 ± 0.19 ^{Aa}
	Cu mg/kg	25.78 ± 3.76 ^{Aa}	9.52 ± 1.70 ^{Bab}
	Fe mg/kg	760.90 ± 115.78 ^{Aa}	1018.74 ± 122.57 ^{Aa}
	K %	2.10 ± 0.08 ^{Aa}	2.63 ± 0.24 ^{Aa}
	Mg %	0.35 ± 0.03 ^{Ba}	0.69 ± 0.10 ^{Aa}
	Mn %	87.66 ± 8.80 ^{Ba}	108.07 ± 10.41 ^{Aa}
	Na %	1660.90 ± 239.93 ^{Ba}	4405.60 ± 1308.13 ^{Aa}
	Zn %	30.33 ± 4.02 ^{Aa}	28.13 ± 3.79 ^{Aab}
Ayaz	P %	0.66 ± 0.18 ^{Aa}	0.04 ± 0.00 ^{Bb}
	Ca %	2.50 ± 0.25 ^{Aa}	3.22 ± 0.27 ^{Aa}
	Cu mg/kg	21.28 ± 2.07 ^{Aa}	10.74 ± 1.73 ^{Bb}
	Fe mg/kg	909.92 ± 95.19 ^{Aa}	664.32 ± 198.02 ^{Ba}
	K %	2.42 ± 0.36 ^{Aa}	3.45 ± 0.53 ^{Aa}
	Mg %	0.45 ± 0.04 ^{Aab}	0.69 ± 0.10 ^{Aab}
	Mn %	113.65 ± 13.70 ^{Aa}	101.17 ± 25.62 ^{Aa}
	Na %	1699.90± 286.20 ^{Ba}	5269. 52 ± 1907.42 ^{Aa}
	Zn %	36.41 ± 8.35 ^{Aa}	41.88 ± 7.01 ^{Ab}
Balcı	P %	0.46 ± 0.08 ^{Aa}	0.03 ± 0.00 ^{Ba}
	Ca %	2.22 ± 0.34 ^{Aa}	3.35 ± 0.20 ^{Aa}
	Cu mg/kg	26.84 ± 7.07 ^{Aa}	5.61 ± 1.07 ^{Ba}
	Fe mg/kg	672.76 ± 82.28 ^{Aa}	978.40 ± 155.89 ^{Aa}
	K %	2.59 ± 0.30 ^{Aa}	3.45 ± 0.53 ^{Aa}
	Mg %	0.34 ± 0.04 ^{Ba}	0.72 ± 0.12 ^{Aa}
	Mn %	76.34 ± 9.64 ^{Aa}	113.83 ± 7.92 ^{Ba}
	Na %	1950.61 ± 309.85 ^{Ba}	3736.61 ± 1052. 58 ^{Aa}
	Zn %	28.88 ± 3.84 ^{Aa}	21.72 ± 4.44 ^{Ba}
Dinçer	P %	0.51 ± 0.10 ^{Aa}	0.02 ± 0.00 ^{Ba}
	Ca %	2.63 ± 0.29 ^{Aa}	3.32 ± 0.23 ^{Aa}
	Cu mg/kg	20.78 ± 1.22 ^{Aa}	6.05 ± 1.51 ^{Ba}
	Fe mg/kg	800.20 ± 158.83 ^{Aa}	1146.56 ± 209.67 ^{Ba}
	K %	2.43 ± 0.22 ^{Aa}	2.79 ± 0.35 ^{Aa}
	Mg %	0.50 ± 0.06 ^{Ab}	0.64 ± 0.07 ^{Aa}
	Mn %	98.33 ± 13.03 ^{Aa}	91.89 ± 13.76 ^{Aa}
	Na %	1737.97 ± 235.94 ^{Ba}	5263.51 ± 1212.13 ^{Aa}
	Zn %	30.85 ± 5.13 ^{Aa}	21.17 ± 3.50 ^{Aa}
Göktürk	P %	0.38 ± 0.05 ^{Aa}	0.01 ± 0.00 ^{Ba}
	Ca %	2.18 ± 0.17 ^{Aa}	3.25 ± 0.30 ^{Aa}
	Cu mg/kg	18.74 ± 2.98 ^{Aa}	6.38 ± 0.79 ^{Ba}
	Fe mg/kg	760.00 ± 115.75 ^{Aa}	468.82 ± 209.66 ^{Aa}
	K %	2.23 ± 0.10 ^{Aa}	2.78 ± 0.80 ^{Aa}
	Mg %	0.38 ± 0.02 ^{Aab}	0.71 ± 0.20 ^{Aa}
	Mn %	90.31 ± 16.94 ^{Aa}	94.79 ± 11.61 ^{Aa}
	Na %	1117.92 ± 300.76 ^{Ba}	3235.07 ± 1304.85 ^{Aa}
	Zn %	24.17 ± 2.60 ^{Aa}	25.80 ± 4.71 ^{Aa}

*The difference between the same uppercase letters in each row and the same lowercase letters in each column in the table is statistically insignificant (p>0.05).

Discussion and Result

This study showed that the effects of Acanthiophilus helianthi on chlorophyll, mineral substances, sugar amounts, total phenol, and total antioxidant parameters before and after damage were different in five different safflower cultivars. No study was found on the changing physiological parameters of the safflower fly, which is the main pest of the safflower plant, before and after the damage. Therefore, this study is the first report on the subject in the world. Studies are generally focused on the physiological changes of the plant in conditions such as drought, salt and temperature (Hasanshahi et al., 2012; Hasanshahi et al., 2013; Erdal et al., 2014; Gengmao et al., 2015; Hussain et al., 2016; Kumar et al., 2018; Özkan, 2019; Yeloojeh et al., 2020). Azizabadi et al. (2014), in their study to investigate the effect of potassium and drought stress on the number of plant nutrients in safflower, showed that drought stress reduces plant height and leaf area, decreases shoot dry weight and relative leaf moisture, but increases leaf chlorophyll. Drought stress also decreased zinc, manganese, copper, phosphorus, nitrogen, and calcium concentrations and increased iron and potassium concentrations in leaves. Compared to the results obtained in our study, it was observed that zinc, manganese, copper, phosphorus, and calcium values decreased, and iron and potassium values increased under stress conditions caused by A.helianthi damage.

The plant's defense mechanism is activated in response to environmental stress or like insect infestation as well as climatic conditions. It is expected that the number of antioxidants will increase with the effect of the defense mechanism or decrease with the use of existing antioxidants (Yavaş and İlker, 2020). In our study, while total phenol values decreased in all cultivars after damage, total antioxidant content increased in all safflower cultivars except Göktürk.

In our study, chlorophyll value decreased in all safflower varieties after damage. Some researchers have reported that when the plant is exposed to any stress condition, changes occur in its physiological structure. The amount of chlorophyll, which is one of them, is expected to both complete the maturation phase and reduce the amount of chlorophyll due to the stress conditions it is exposed to (Yavaş and İlker, 2020).

Manganese is present in many primary and secondary minerals. Its deficiency causes a deficiency of iron, magnesium, and calcium elements (Bolat and Kara 2017). As a result of our findings, it was determined that the manganese value increased in Asol and Biçer cultivars, and the nutritional values differed according to the cultivars.

One of the stress causes in plants is the change brought on by pest conditions. In the current world, where food shortages may emerge in the future due to increased population density and declining arable land, reducing product losses due to stress has become crucial. In this study, physiological parameter changes of safflower flies before and after damage were investigated in five different safflower cultivars. It was determined that all five cultivars gave important physiological responses under stress conditions due to the development of the pest. These findings are believed to be a very significant step in lowering product losses with more thorough biological research findings, and will also supply farmers who will grow safflower with useful ideas for how to deal with the drought and energy issues that will be faced in the future.

Authorship contribution statement

Esra KINA: Working method, experimental planning, interpretation of results, article writing. Hasret GÜNEŞ: Analysis processes, interpretation of results, article writing

Informed consent

The research involved no human participants and animals, so the statement on the welfare of animals is not required.

Declaration of competing interest

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

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