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# The effect of hoeing time for weed management on yield and yield criteria of sunflowers (*Helianthus annuus* L.)

Ayçiçeğinde (*Helianthus annuus* L.) yabancı ot mücadelesinde çapalama süresinin verim ve verim kriterlerine olan etkisi

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ABSTRACT

Hoeing time is important in weed management and is effective to reduce weed populations in sunflower cultivation. The study was conducted between 2018-2019 to determine the hoeing times for mechanical weed control in sunflower in Adana province of Turkey. To determine weed control time in experimental fields, weeds were allowed to germinate in natural conditions at intervals between 15 days for mechanical hoeing at the emergence of sunflower to the harvest time. The interactions between weeds and sunflower yield criteria were observed by periodic hoeing treatments. At the end of the experiments, the criteria for sunflower yield, seed yield, oil content, oil quality, head diameter, plant height, weed biomass, and coverages of hoeing time effects were determined. Combining the two-year data, it was observed that the sunflower yield and seed yield were the highest in plots of 75 and 90 days weed-free, while the lowest yield and seed yield were observed in 60, 75, and 90 days weedy. It was determined that the sunflower oil yield was higher in plots of long hoeing period time, but the oil quality did not change. It was found that sunflower height were statistically similar for each year in different hoeing period times, moreover, sunflower head diameter was not affected. In weedy plots with shorter hoeing times, higher weed biomass due to increased weed coverage was noted. As a result, it was determined that long-term hoeing in sunflower weed management increases the yield, and hoeing time is significant in sunflower weed management.

## INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the significant crops used for oil production in Turkey similar to the world. It has an important place in terms of human health due to its ingredients such as protein, fat, and carbohydrates, and a large part of Turkey's vegetable oil production is provided from sunflower (Arıoğlu 2007, Gül et al. 2016). Moreover, as a good alternation crop, it leaves a clean and ventilated soil for the next rotation crop (Arıoğlu 2007).

According to FAO data for 2018, Turkey was listed among the top 10 countries in the world in terms of sunflower harvest areas, with 2.67% of the total cultivation area (734.190 ha),

and 1.86% (26549 kg ha$^{-1}$) of the world production (FAO 2018). The Marmara region had the highest production in Turkey in 2019 by providing 51.30% (381.881 ha) of sunflower cultivation. This was followed by Central Anatolia 20.05% (149.287 ha) and Mediterranean regions13.93% (103.695 ha), respectively (TUIK 2019).

There are various pests that reduce sunflower yield and quality, and the most important of them are weeds, which cause major yield losses. Weeds compete with crops, increasing the production costs as well as decreasing the yield and quality of the crops (Oerke et al. 1994, Tepe 2014). It was reported that yield losses in sunflower, without weed management, varied between 25-75% (D'Alessandro et al. 1992, Dharam et al. 1993, Fleck et al. 1991, Heidarian et al. 2012, Kaya et al. 2020, Onofri and Tei 1994). As in the world, some important weed species in sunflower were found in Turkey such as *Acroptilon repens* (L.) DC., *Amaranthus retroflexus* L., *Chenopodium album* L., *C. vulvaria* L., *Convolvulus arvensis* L., *Cuscuta campestris* Yuncker, *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Daucus carota* L., *Datura stramonium* L., *Echinochloa colonum* (L.) Link., *Euphorbia prostrata Aiton*, *Heliotropium europaeum* L., *Orobanche* spp., *Polygonum aviculare* L., *Portulaca oleracea* L., *Prosopis farcta* (Banks & Sol.) *Macbride*, *Sinapis arvensis* L. *Solanum nigrum* L., *Tribulus terrestris* L. and *Xanthium strumarium* L. (Asav and Serim 2019, Başaran et al. 2017, Erol 2010, Karabacak and Uygur 2017, Özkil et al. 2019, Tepe 2014, Tursun et al. 2017, Yay 2015 ).

In order to minimize the weed damage on crops, there is an increase in labor and other aspects of input in controlling the weeds, and therefore, serious economic losses are experienced. In this respect, it is necessary to determine the weed control time correctly and to integrate the appropriate weed control methods in integrated weed management concept (Swanton and Weise 1991). As a matter of fact, it has been reported that weed control is required to reduce weed density in the early growing period of sunflower and inclusion of different treatment methods in integrated weed management systems to reduce herbicide use (D'Alessandro et al. 1992). In the case of high weed density in sunflowers, and without managing it, significant yield losses occur on sunflowers (Hossein et al. 2010, Kaya 2016).

Today, weed control is mostly provided by herbicides. Intensive use of herbicides may cause resistance to weeds and leads to environmental pollution. Hence, excessive use of herbicides and failure of the integrated weed management control strategies also causes economic losses. This study was aimed to determine the effects of selected hoeing treatments and different hoeing periods for weed control on sunflower yield and yield criteria.

## MATERIALS AND METHODS

This study was conducted in 2018 and 2019 (37.10°N, 35.41°E) in a sunflower field in Ceyhan (Sağkaya) district of Adana, Turkey. In the first year of the experiment, the field trial was started on March 10, 2018 and finished on July 10, 2018. In the second year, the experiment was established on May 02, 2019 and finished on August 15, 2019. The climatic data obtained in the experiment are given in Figure 1, and soil characteristics are given in Table 1.

**Table 1.** Soil characteristics of the experiment field (0–30 cm soil depth)

| Soil characteristics | |
|---|---|
| Values | 2018-2019 |
| Saturation (%) | 65.78 |
| $P_2O_5$ (mg kg$^{-1}$) | 3.37 |
| Organic matter (%) | 2.15 |
| $K_2O$ (mg kg$^{-1}$) | 126.00 |
| Total soluble salt (%) | 0.025 |
| Iron-Fe (mg kg$^{-1}$) | 5.20 |
| Manganese-Mn (mg kg$^{-1}$) | 0.45 |
| Lime-$CaCO_3$ (mg kg$^{-1}$) | 6960.00 |
| Magnesium (mg kg) | 1333.20 |
| pH (1 : 2.5) | 7.83 |

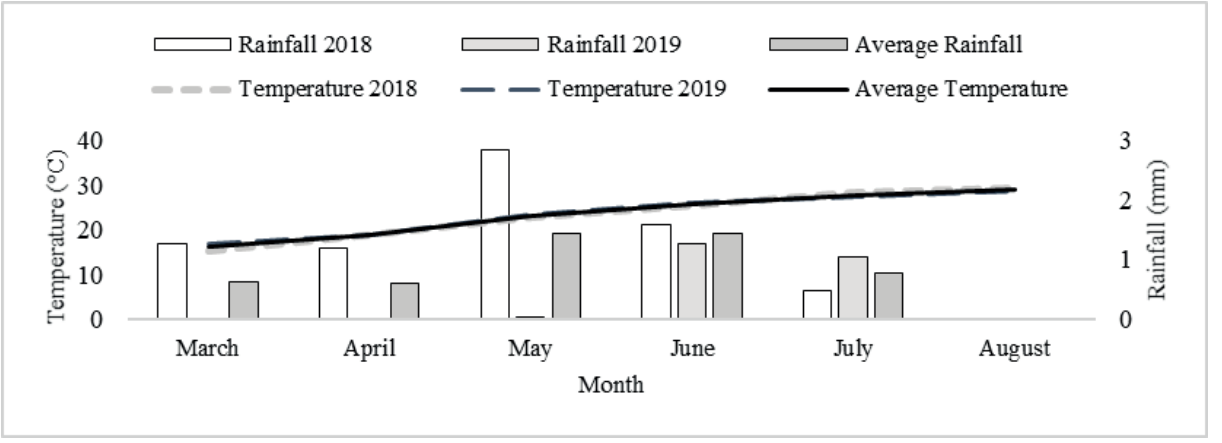


**Figure 1.** Climatic conditions for experiment area in 2018 and 2019

**Table 2.** Determined hoeing treatments for sunflower

| Weed-free treatments | Weedy treatments |
|---|---|
| 1) 15 days weed-free after emergence | 8) 15 days weedy after emergence |
| 2) 30 days weed-free after emergence | 9) 30 days weedy after emergence |
| 3) 45 days weed-free after emergence | 10) 45 days weedy after emergence |
| 4) 60 days weed-free after emergence | 11) 60 days weedy after emergence |
| 5) 75 days weed-free after emergence | 12) 75 days weedy after emergence |
| 6) 90 days weed-free after emergence | 13) 90 days weedy after emergence |
| 7) Weed-free | 14) Weedy |

Sunflower seeds were sown with a seed drill set for 70 cm inter-row and 30 cm intra-row spacing. The experiment design was established with 3 replications according to the randomized complete block design with a plot size of 8.40 $m^2$ (2.80 m x 3.00 m). In experimental area, safety strips between the blocks (1.0 m) and the plots (0.5 m) were left. There were four sunflower rows in each plot, and the weeds in the plots were removed by hand hoe or pulling. Weeds' removal was started after sunflowers emerged. Hoeing was carried out every 15 days on the experimental plots. In the study, 14 different hoeing times were implemented (Table 2).

*Determination of weed species, weed coverages, and fresh weed biomass*

In the experimental field, 3 points of 1 $m^2$ were fixed in each plot and periodic observations of weed species and densities were regularly observed. Accordingly, weed coverages (%) of hoeing treatments were determined, then weeds in these points were cut from the soil surface and the fresh weed biomasses (g $m^{-2}$) were weighed on an assay balance (Odum 1971, Uygur et al. 1984). Then, the effects of hoeing time treatments were evaluated.

*Data collection of sunflower yield and yield criteria*

In the study, weeds were removed from the plots by hand hoeing or pulling, depending on the hoeing times in the experiment. The yield (kg $ha^{-1}$) was calculated by harvesting the middle two sunflower rows for each plot out of four sunflower rows (Erol 2010, Kaya et al. 2020). At the end of the experiment, the yield was obtained from the plots where the treatments were carried out and were compared with the yield data from weed-free and weedy plots during the season. Sunflower seeds were counted and kernel weight (g) was calculated by taking four sunflower heads from rows of each plot. Moreover, 10 random sunflower heads (cm) and sunflower heights (m) from the soil surface were measured before harvesting. In each treatment plot, 10 sunflower plant samples were harvested in the middle of 2 sunflower rows.

At the last, sunflower oil was obtained from the seed samples taken from the plots by using the Soxhlet Device with petroleum ether or hexane solvents, as in the extraction method. The values were calculated as a percentage (%), thus, the seed yield values per hectare determined for each plot were multiplied by the oil ratio values (%) determined for the plots (TS EN ISO 659, 2009).

*Statistical analysis*

SPSS package software was used to analyze the comparison of obtained data. In the Multiple Comparison Tests, the data between selected characters depending on the hoeing times were grouped at 0.05 significant levels statically using the Duncan test (SPSS, 2015).

## RESULTS AND DISCUSSION

*Treatment observation dates, weed species and density of the experimental area*

In Adana, a total of 17 weed species belonging to 11 families were identified in the experimental area in 2018 and 2019. Major weed species such as *C. album*, *C. vulvaria*, *H. europaeum*, *C. arvensis*, *C. rotundus* and *P. farcta* have been observed. Poaceae family was significant, with 4 weed species, followed by 2 weed species each belonging to Amaranthaceae, Euphorbiaceae, and Polygonaceae families, respectively. In previous studies conducted in Turkey, 52 weed species belonging to 23 families in Çukurova region (Adana, Mersin, and Osmaniye provinces) (Karabacak and Uygur 2017), 67 weed species belonging to 30 families in Adana province (Özkil et al. 2019) were identified in the sunflower surveys. Accordingly, in Çukurova region, it has been noted that the highest weed densities were *A. retroflexus*, *C. album*, *C. arvensis*, *C. vulvaria*, *C. rotundus* and *H. europaeum* (Karabacak and Uygur 2017, Özkil et al. 2019). Between 2014 and 2015, 58 weed species belonging to 24 families (Asav and Serim 2019) in Ankara province, 36 weed species belonging to 17 families in Edirne in 2013 (Yay 2015) were also detected. In all these studies, the most prominent weed species were of Poaceae and Asteraceae families, and similar weed species were seen in the experimental field of the current study. 17 different weed species, especially Poaceae and Amaranthaceae families, were identified in the experimental area, and important similar weed species were found in sunflowers, such as *C. album*, *C. vulvaria*, *H.*

**Table 3.** Hoeing treatments, data observation dates, and weed species in sunflower experimental field in 2018 and 2019, Adana

| Treatments | | Observation dates | | | Major weed species 2018-2019 | |
|---|---|---|---|---|---|---|
| | | Observation time | 2018 | 2019 | | |
| Weed-free | 15 days weed-free | Before harvest (7th) | 10 July | 15 August | Amaranthaceae | Chenopodium album L. |
| | 30 days weed-free | | | | Amaranthaceae | Chenopodium vulvaria L. |
| | 45 days weed-free | | | | Boraginaceae | Heliotropium europaeum L. |
| | 60 days weed-free | | | | Convolvulaceae | Convolvulus arvensis L. |
| | 75 days weed-free | | | | Cucurbitaceae | Cucumis melo L. var. agrestis Naudin |
| | 90 days weed-free | | | | Cyperaceae | Cyperus rotundus L. |
| | Weed-free | - | - | - | Euphorbiaceae | Chrozophora tinctoria (L.) Rafin. |
| | | | | | Euphorbiaceae | Euphorbia prostrata Aiton |
| | | | | | Fabaceae | Prosopis farcta (Banks and Sol.) Mac. |
| Weedy | 15 days weedy | 15 days (1st) | 18 April | 30 May | Papaveraceae | Fumaria officinalis L. |
| | 30 days weedy | 30 days (2nd) | 2 May | 14 June | Poaceae | Cynodon dactylon (L.) Pers. |
| | 45 days weedy | 45 days (3th) | 14 May | 28 June | Poaceae | Echinochloa colonum (L.) Link. |
| | 60 days weedy | 60 days (4th) | 30 May | 8 July | Poaceae | Echinochloa crus-galli (L.) P. Beauv. |
| | 75 days weedy | 75 days (5th) | 12 June | 19 July | Poaceae | Sorghum halepense (L.) Pers. |
| | 90 days weedy | 90 days (6th) | 26 June | 1 August | Polygonaceae | Polygonum aviculare L. |
| | Weedy | Before harvest (7th) | 10 July | 15 August | Polygonaceae | Rumex spp. |
| | | | | | Solanaceae | Physalis spp. |

*europaeum*, *C. arvensis*, *C. rotundus* and *P. farcta* (Table 3). In a study conducted in US, morphologies and development biologies of Abutilon theophrastii Medik., *A. retroflexus*, *C. album*, and *X. strumarium* species were examined and the small seed weeds were found more competitive than large seed weeds in sunflower (Selbert and Pearce 1993). In experimental areas of sunflower, Salera (1991) found that *A. retroflexus*, *C. album*, *E. crus-galli*, *Lolium multiflorum* Lam., *Polygonum aviculare* L., *P. persicaria*, *S. arvensis*, *S. nigrum* and *Sonchus arvensis* L. species were the most common weeds in Italy. Fleck et al. (1991) in Brazil determined that different weed species (Digitaria ciliaris (Retz.) Koeler, *Echinochloa* spp., *Amaranthus* spp., *Ambrosia artemisiifolia* L., *Bidens pilosa* L. *Fallopia convolvulus* (L.) Á.Löve, *Richardia brasiliensis* Gomes and *Silene gallica* L.) may also cause yield losses in sunflower.

Statistical analysis was performed in the fresh weed biomass and weed coverages (P≤0.05) in both years. With the increase of hoeing time in plots that are constantly infested by weeds, a decrease in fresh weed biomass and weed coverages has been observed. In 2018 and 2019, 0.51 g $m^{-2}$ and 40.41 g $m^{-2}$ fresh weed biomass were obtained in 90 days weed-free, 10.16 g $m^{-2}$ and 121.96 g $m^{-2}$ in 15 days weed-free, respectively. Weed coverages were 2.00% and 14.67% in 90 days weed-free, 28.67%, and 50.33% in 15 days weed-free. It was determined that the fresh weed biomass in the plots of 75 and 90 days weedy in both years varied between 48.81 and 276.67 g $m^{-2}$ (Table 4). It has been reported in a previous study that in sunflower cultivation hoeing should be done at least 2-3 times following by the sunflower emergence to control weeds and also to aerate the soil (Atakişi and Turan 1989). Çoruh and Zengin (2009) suggested that in Erzurum,

**Table 4.** The effects of the treatments determined in the experiment between 2018-2019 on fresh weed biomass (g $m^{-2}$) and weed coverages (%) in Adana province (+SD)

| Treatments | | Weed biomass (g m-2) (+SD) | | Weed coverage (%) (+SD) | |
|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 |
| Weed-free | 15 days weed-free | 10.16 a (11.98) | 121.96 abc (8.31) | 28.67 cd (1.92) | 50.33 bcde (4.35) |
| | 30 days weed-free | 18.69 a (14.99) | 102.08 ab (5.05) | 17.33 bc (4.19) | 49.33 bcde (2.17) |
| | 45 days weed-free | 4.43 a (6.35) | 99.95 ab (4.02) | 19.67 c (3.67) | 35.33 abcd (3.44) |
| | 60 days weed-free | 1.53 a (1.12) | 93.08 ab (5.89) | 14.33 bc (1.24) | 26.33 ab (7.36) |
| | 75 days weed-free | 1.39 a (1.93) | 74.25 ab (5.84) | 7.00 ab (11.26) | 14.33 a (6.52) |
| | 90 days weed-free | 0.51 a (0.85) | 40.41 a (4.38) | 2.00 a (2.12) | 14.67 a (1.91) |
| Weedy | 15 days weedy | 7.26 a (6.39) | 94.17 ab (40.64) | 15.33 bc (11.73) | 20.33 a (3.21) |
| | 30 days weedy | 24.41 ab (15.34) | 190.00 bcd (68.02) | 45.00 de (8.48) | 30.00 abc (9.00) |
| | 45 days weedy | 26.50 ab (26.26) | 177.50 bcd (60.15) | 58.33 ef (14.05) | 62.67 e (16.57) |
| | 60 days weedy | 18.14 a (8.54) | 204.17 bcd (51.37) | 73.33 fg (7.06) | 57.67 de (11.56) |
| | 75 days weedy | 94.37 b (69.95) | 276.67 d (84.31) | 96.67 h (7.45) | 53.67 cde (7.14) |
| | 90 days weedy | 48.81 ab (41.36) | 248.33 cd (71.55) | 85.33 g (1.25) | 56.00 de (9.13) |
| | Weedy | 45.36 ab (29.06) | 271.67 d (84.12) | 74.33 fg (3.94) | 64.33 e (10.26) |

*Statistically significant at P≤0.05 level.

weed management should be done between the 3rd and 6th weeks in sunflower fields with the weed emergence.

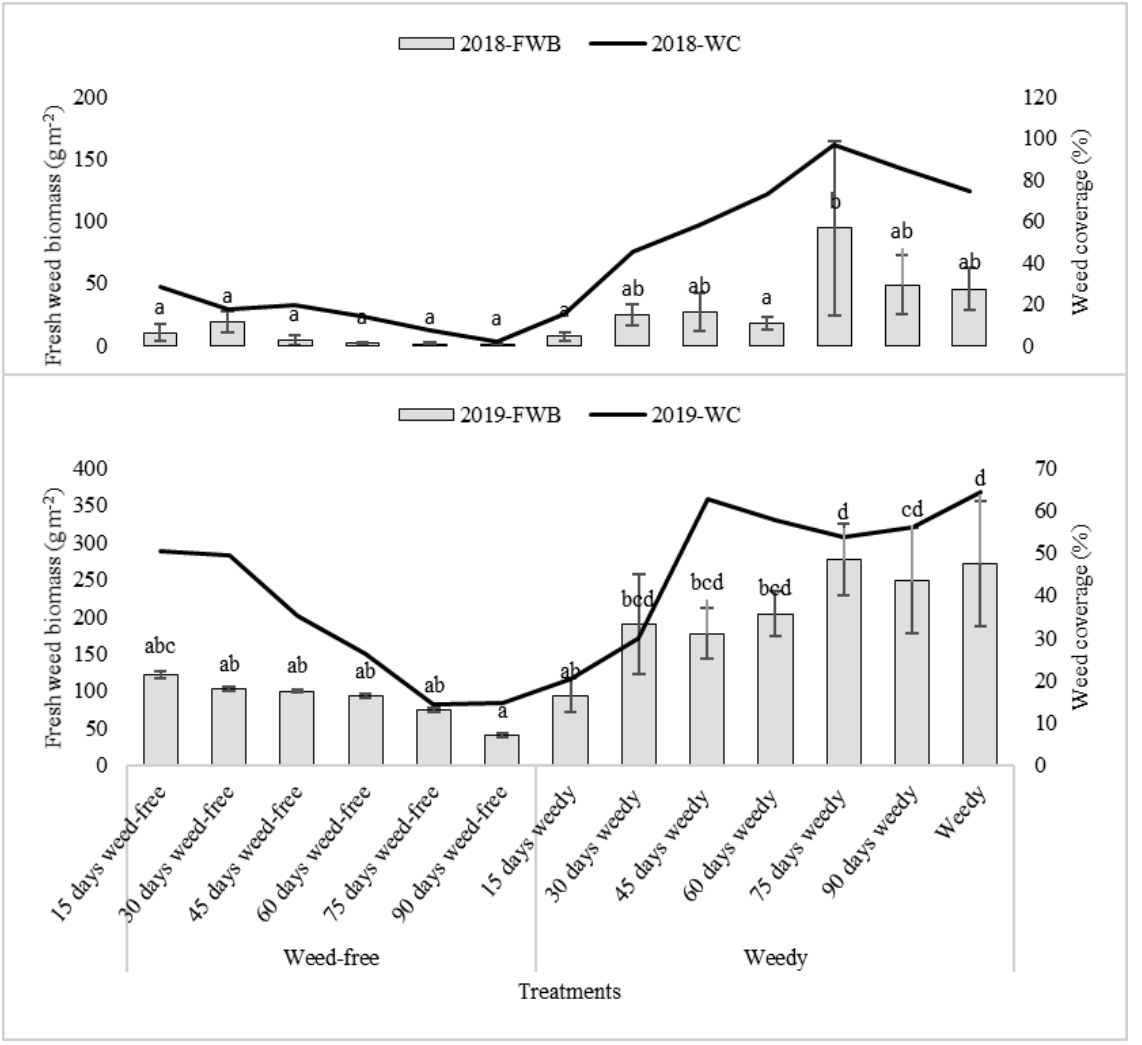


**Figure 2.** The interactions between the average fresh weed biomass (g $m^{-2}$) and average weed coverages (%) obtained from the plots in the experimental field

In another study conducted in Tokat, it was reported that the most suitable period for controlling weeds in sunflower was the period covered between the 4th and the 6th weeks in Turkey (Kaya et al. 2020).

It was found that the fresh weed biomass was higher in weedy plots with 75 and 90 days weedy. In Figure 2, it is seen that there is a decrease in weed coverages increasing the hoeing times. However, these parameters may differ according to climatic conditions and the characteristics of the weed species (Table 4). Sağlam (1992) compared two different harrowing methods and five different hoeing methods in sunflower and discovered that the best method for weed control is a milling hoe machine. As a matter of fact, he revealed that, in the plots allocated to the milling hoe machine, the sunflower heads (19.88 cm), sunflower stem, sunflower height (1.49 m), kernel weight (46.83 g), and yield (25.92 kg $ha^{-1}$) were higher than the other plots of hand hoeing. In a study conducted in 2008, it was observed that, with the increasing density of X. strumarium, decreasing in the seed yield per sunflower plant was 27.00% (65.87-90.28 g), in the oil quality was 16.00%, in kernel weight was 22.00% (60.54-47.08 g), in oil content was 51.00% (20.03- 9.72 kg $ha^{-1}$) and in the yield was 42.00% (43.07-24.88 kg $ha^{-1}$) (Erol 2010) in Tekirdağ. Also, it has been stated that A. retroflexus resulted in approximately a 50.00% decrease in sunflower yield depending on the density of the weed (Heidarian et al. 2012).

Natural weed emergence occurred in the experimental area. The density distribution of *C. dactylon*, *E. colonum*, *E. crus-galli*, *E. prostrata*, *F. officinalis*, *Physalis* spp., *P. aviculare*, *Rumex* spp. and *S. halepense* were found lowest. Statistically significant differences

**Table 5.** Weed species and numbers (weed $m^{-2}$) in treatments on sunflower in the experiment of Adana province in 2018-2019 (+SD)

| Weed species (weed $m^{-2}$) (+SD) | Full season weedy | | | | | | Full season weed-free | | | | | | | Average weed number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 days weed-free | 30 days weed-free | 45 days weed-free | 60 days weed-free | 75 days weed-free | 90 days weed-free | 15 days weedy | 30 days weedy | 45 days weedy | 60 days weedy | 75 days weedy | 90 days weedy | Weedy | |
| *Chenopodium album L.* | 0.97 ab (0.93) A | 0.56 a (0.88) A | 0.22 a (0.54) A | 0.78 ab (1.04) A | 0.17 a (0.40) A | 0.00 a (0.00) A | 2.36 bc (3.45) AB | 3.03 a (3.65) AB | 6.14 b (3.38) B | 3.06 a (1.92) AB | 3.72 a (3.48) AB | 5.64 b (4.91) A | 3.86 a (3.35) AB | 2.35 bc (2.86) |
| *Chenopodium vulvaria L.* | 1.56 ab (1.56) AB | 0.22 a (0.54) A | 2.22 bc (2.48) AB | 0.44 ab (0.68) A | 0.00 a (0.00) A | 0.67 ab (1.11) A | 0.67 ab (1.11) A | 1.56 a (2.00) AB | 0.89 a (2.18) A | 1.78 a (2.00) AB | 4.22 a (2.19) AB | 3.11 ab (1.45) AB | 5.78 a (3.09) B | 1.78 abc (2.97) |
| *Chrozophora tinctoria (L.) Rafin.* | 1.50 ab (0.98) BC | 0.81 a (0.96) AB | 0.83 ab (0.98) AB | 1.11 ab (1.10) ABC | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.17 a (0.25) AB | 0.92 a (1.06) AB | 0.25 a (0.41) AB | 0.17 a (0.40) AB | 0.42 a (0.66) AB | 1.56 ab (1.46) BC | 2.33 a (2.34) C | 0.77 ab (0.81) |
| *Convolvulus arvensis L.* | 2.45 ab (1.35) A | 3.75 bc (2.06) A | 2.44 bcd (2.72) A | 4.78 cd (2.34) A | 0.89 a (1.37) A | 0.44 ab (0.68) A | 1.11 abc (0.72) A | 1.56 a (1.31) A | 1.39 a (1.23) A | 2.22 a (1.22) A | 2.45 a (1.21) A | 2.44 a (1.39) A | 2.67 a (1.69) A | 2.20 bc (2.57) |
| *Cucumis melo L. var agrestis Naudin* | 0.17 a (0.40) AB | 0.67 a (0.81) B | 0.08 a (0.20) AB | 0.17 a (0.40) AB | 0.00 a (0.00) A | 0.25 a (0.41) AB | 0.33 a (0.60) AB | 0.25 a (0.41) AB | 0.17 a (0.25) AB | 0.17 a (0.40) AB | 0.33 a (0.60) AB | 0.17 a (0.25) AB | 0.58 a (0.73) AB | 0.26 a (0.36) |
| *Cynodon dactylon (L.) Pers.* | 0.45 a (0.45) B | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.03 a (0.17) |
| *Cyperus rotundus L.* | 7.39 c (2.06) ABC | 4.56 c (1.86) AB | 4.22 d (1.74) AB | 6.97 d (3.23) ABC | 3.50 b (1.82) A | 2.95 c (1.62) A | 2.86 c (1.37) A | 15.31 b (6.04) ABC | 12.61 c (2.67) ABC | 13.33 b (4.59) ABC | 16.84 b (5.63) BC | 18.06 c (5.54) C | 17.08 b (6.63) BC | 9.67 d (1.84) |
| *Echinochloa colonum (L.) Link.* | 0.75 a (1.25) AB | 1.17 a (1.80) B | 0.00 a(0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.15 a (0.57) |
| *Echinochloa crus-galli (L.) P. Beauv.* | 0.67 a (1.63) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.25 ab (0.61) A | 0.25 a(0.61) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.17 a (0.40) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.10 a (0.29) |
| *Euphorbia prostrata Aiton* | 0.78 a (0.88) AB | 1.44 a (0.95) B | 0.00 a (0.00) A | 0.70 ab (1.13) AB | 0.67 a (1.63) AB | 0.00 a (0.00) A | 0.08 a (0.20) A | 0.08 a (0.20) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.17 a (0.25) A | 0.25 a (0.61) A | 0.32 a (0.51) |
| *Fumaria officinalis L.* | 0.00 a (0.00) A | 0.44 a (0.68) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.22 a (0.54) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.67 a (1.11) A | 0.22 a (0.54) A | 0.45 a (1.09) A | 0.15 a (0.35) |
| *Heliotropium europaeum L.* | 1.72 ab (1.51) A | 1.75 ab (1.02) AB | 0.58 ab (1.02) AB | 0.50 ab (0.77) ABC | 0.42 a (0.49) ABC | 0.86 ab (0.99) ABC | 1.22 abc (1.47) ABC | 1.22 a (1.24) ABC | 1.22 a (1.50) ABC | 1.56 a (0.72) ABC | 1.86 a (0.89) ABC | 2.06 ab (1.54) BC | 2.20 a (1.30) C | 1.32 ab (0.85) |
| *Physalis spp.* | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.08 a (0.08) A | 0.08 a (0.08) A | 0.08 a (0.08) A | 0.33 a (0.17) B | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.05 a (0.13) |
| *Polygonum aviculare L.* | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.22 a (0.22) B | 0.00 a (0.00) A | 0.02 a (0.08) |
| *Prosopis farcta (Banks. and Sol.) Mac.* | 3.53 b (2.19) A | 4.78 c (2.15) A | 3.67 cd (1.83) A | 3.45 bc (1.56) A | 1.67 a (0.85) A | 1.75 bc (1.94) A | 1.08 abc (1.62) A | 1.92 a (1.08) A | 2.17 a (2.38) A | 3.08 a (1.39) A | 4.92 a (2.49) A | 3.33 ab (1.63) A | 3.42 a (1.58) A | 2.98 c (2.70) |
| *Rumex spp.* | 0.00 a (0.00) A | 0.22 a (0.22) A | 0.22 a (0.22) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.22 a (0.22) A | 0.67 a (0.67) A | 1.33 a (0.91) A | 0.00 a (0.00) A | 1.56 a (1.31) A | 1.33 ab (1.09) A | 0.67 a (0.46) A | 0.48 a (0.94) |
| *Sorghum halepense (L.) Pers.* | 0.92 ab (0.61) B | 0.00 a (0.00) A | 0.83 ab (0.53) B | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.00 a (0.00) A | 0.13 a (0.47) |
| Total | 22.83 C (5.12) | 20.36 BC (7.03) | 15.33 ABC (6.03) | 19.14 ABC (8.34) | 7.56 A (5.78) | 6.92 A (4.32) | 10.33 AB (7.88) | 26.75 CDE (13.19) | 26.25 CD (8.45) | 25.44 CD (10.65) | 37.31 DEF (10.79) | 38.30 EF (12.28) | 39.28 F (16.70) | |

* The average means have shown with different small letters in the same column and different capital letters in the same row are different from each other at the P≤0.05 significant level statically according to the Duncan Multiple Comparison Test.

**Table 6.** Sunflower kernel weight (g) and yield (kg ha$^{-1}$) parameters from the plots in the experimental field (+SD)

| Treatments | | Sunflower yield (kg ha$^{-1}$) (+SD) | | Kernel weight (g) (+SD) | |
|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 |
| Weed-free | 15 days weed-free | 35.91 a (3.84) | 29.89 bc (7.11) | 78.43 ab (6.17) | 82.06 cdef (3.55) |
| | 30 days weed-free | 34.60 a (2.41) | 35.45 abc (4.16) | 71.38 ab (8.35) | 83.60 cde (2.57) |
| | 45 days weed-free | 28.97 abc (0.88) | 35.98 abc (4.16) | 69.96 b (7.04) | 84.96 cde (0.97) |
| | 60 days weed-free | 34.47 a (0.87) | 36.11 abc (5.20) | 72.93 ab (1.34) | 88.08 cd (1.96) |
| | 75 days weed-free | 34.95 a (7.16) | 37.56 ab (5.04) | 67.67 b (5.70) | 93.55 bc (6.80) |
| | 90 days weed-free | 31.39 abc (4.71) | 39.28 ab (5.36) | 70.56 b (8.32) | 103.91 ab (13.93) |
| | Weed-free | 32.20 ab (0.85) | 42.06 a (7.27) | 86.67 a (12.60) | 110.96 a (13.11) |
| Weedy | 15 days weedy | 28.96 abc (3.99) | 33.33 abc (2.86) | 69.43 b (8.23) | 79.21 defg (1.41) |
| | 30 days weedy | 26.43 abcd (1.64) | 32.41 abc (3.68) | 68.63 b (13.26) | 76.78 defg (1.55) |
| | 45 days weedy | 24.63 bcd (4.14) | 32.67 abc (3.77) | 50.35 c (2.74) | 75.23 efgh (3.18) |
| | 60 days weedy | 28.85 abc (5.52) | 30.95 bc (2.09) | 66.61 b (11.45) | 73.41 efgh (5.86) |
| | 75 days weedy | 22.08 cd (6.11) | 30.82 bc (4.20) | 69.08 b (8.33) | 70.41 fgh (3.30) |
| | 90 days weedy | 28.65 abc (6.99) | 30.29 bc (4.65) | 62.57 bc (1.11) | 69.10 gh (3.26) |
| | Weedy | 18.99 d (2.96) | 26.19 c (6.55) | 63.95 bc (11.48) | 64.05 h (7.69) |

* Statistically significant at P≤0.05 level.

were determined between the numbers of weed species in treatment plots (P≤0.05). Considering the weedy and weed-free treatment plots, the most prominent species were *C. rotundus* 9.67 weed m$^{-2}$, *P. farcta* 2.98 weed m$^{-2}$, *C. album* 2.35 weed m$^{-2}$, and C. arvensis 2.20 weed m$^{-2}$ respectively (Table 5).

In the experiment, the lowest weed density was seen in C. dactylon, E. crus-galli, Physalis spp., P. aviculare and S. halepense (Table 5). It was observed that weed species of this experiment found similar to other studies in sunflower (Arslan and Kara 1997, Başaran et al. 2017, Çoruh and Zengin 2009, İyigün et al. 1997, Tursun et al. 2017).

*The effect of treatments on sunflower yield and yield criteria*

Since sunflower was sown in March-April in the Çukurova region, harvested towards summer, and due to the climate-dependent abiotic stress factors as well as being affected by weeds, changes were observed in the oil content of sunflower in 2018-2019. It was determined that there were no statistical differences in the obtained values of the sunflower head diameter and sunflower oil content (P≥0.05) (Figure 3). However, İyigün et al. (1997) compared 10 and 40 days weedy plots with weed-free plots (sunflower head weight 168.63 kg ha$^{-1}$, seed weight 74.17 kg ha$^{-1}$) in their experiments in Tokat (Kazova) between 1995-1996, and found that the yield loss in average sunflower head weights varied between 7.95-26.39% (124.13-155.23 kg ha$^{-1}$) and the yield loss in seed weights varied between 3.15-25.69% (71.83-55.12 kg ha$^{-1}$). In Erzurum, Kara (1986) reported that the loss in oil content of sunflower varieties varied between 31.10-50.50%, depending on the climate and environmental factors, and the average oil contents were changed between 8.08-38.05%. Cardinalli et al. (1986) reported that the oil quality rate in sunflower may vary between 31.30-50.00% depending on environmental factors. We can say that different data obtained in this study are due to the ecological locations where the experiments were established, and the sunflower varieties were cultivated.

In the first year of the experiment, there was close difference in sunflower height between weed-free and weedy plots during the season. In the second year, statistically significant differences were detected after it was determined that the highest plant height in the 75 and 90 days weed-free applications and in the weed-free control (Figure 3). Similar to this study, Erol (2010) reported that the increasing X. strumarium numbers in plots were affected the sunflower height, head, oil yield, and protein ratio. However, Johnson (1973) stated that in the first 4 weeks of sunflower development, weeds compete with sunflower and affect the sunflower head and height criteria. Likewise, Vasilev et al. (1991) reported in their studies conducted in Russia, weed populations affected sunflower yield between 2.09-2.39 t ha$^{-1}$, continued to increase densities for 3 months after sunflower emergence (>5-11 g m$^{-2}$), and the seed yield was negatively affected. Fleck et al. (1991) noted that continuous mechanical weed control with row hoeing in sunflower varied sunflower seed yield, seed weight, sunflower head-seed weight ratio, sunflower head, and height in Brazil. Similar to other studies, different sunflower varieties, ecological and climatic conditions can also affected the sunflower growth parameters except weed treatments. The values of the yield (kg ha$^{-1}$) and kernel weights (g) were obtained at sunflower harvest are given in Table 6 (P≤0.05).

In the field studies were carried out during the sunflower growing season, the plots yield of 15 days to 90 days

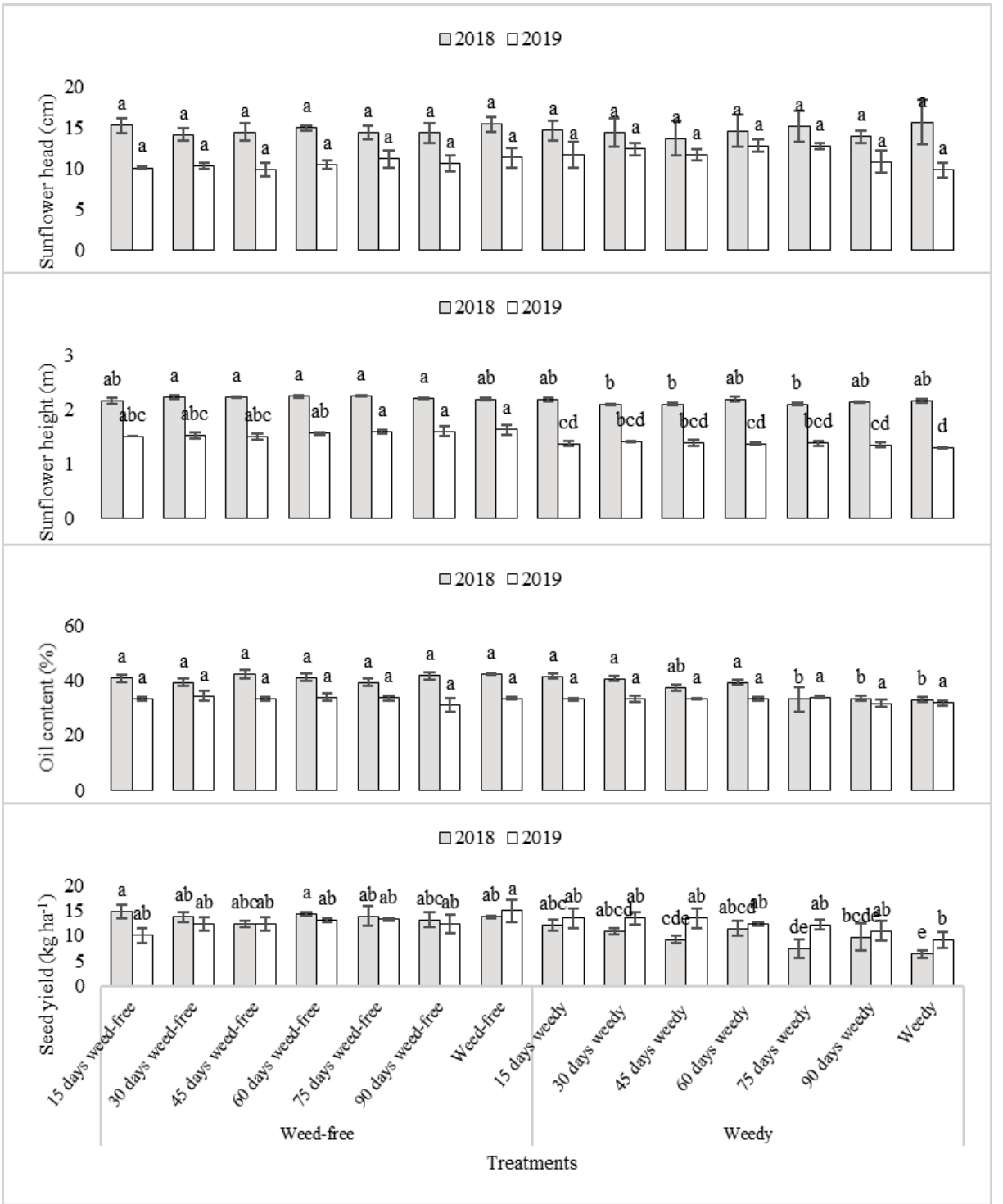


**Figure 3.** Sunflower head (cm), height (m), oil content (%), and seed yield (kg ha$^{-1}$) parameters from the plots in the experimental field

weed-free in 2018 were obtained as close to each other as 28.97-35.91 kg ha$^{-1}$, and the weed-free plot was 32.30 kg ha$^{-1}$. Similar to 2018, parameters between 35.45-39.28 kg ha$^{-1}$ were observed in 30 days to 90 days weed-free (except for 15 days weed-free), and weed-free was found to be 42.06 kg ha$^{-1}$ which was the highest value in 2019. Thus, as hoeing time increased in both years, rising sunflower yields were observed in plots (Table 6). In Iran in 2007, it was determined that season-long weedy treatments, according to weed density, resulted in yield losses up to 27.50% in seed yield and 43.00% in oil content compared to weed-free treatments throughout the season in sunflower (Hossein et al. 2010).

When the kernel weights were examined, different effects were observed in weed-free and weedy treatment plots. In plots where 15-90 days weed-free was carried out in the first and second years, variations between 69.96-78.43 g (excluding 75 days weed-free) and 82.06-103.91 g were determined respectively. Moreover, kernel weights in weed-free plots were found to be the highest in both years (Table 6). In many studies, changes were observed in yield and kernel weights depending on weeds (Çoruh and Zengin 2009, Fleck et al. 1991, İyigün et al. 1997, Kara 1986, Vasilev et al. 1991). It has been reported that early weed management is important in early development periods of sunflower, and it is necessary to control weeds in the first 4-5 weeks. Because it has been revealed that weeds cause yield losses up to 60% in the sunflower yield approximately if it is late to manage weeds (D'Alessandro et al. 1992).

In both years, it was observed that the fresh weed biomass and weed coverages were the highest between 30 and 90 days weedy plots during the season and the fresh weed biomass and weed coverages decreased as the time of the hoeing was extended. Duration of weed hoeing did not change the sunflower head and oil content. Depending on climatic conditions and environmental factors, the highest parameters of sunflower height and oil content were obtained between 30 and 90 days in weed-free plots during the season. Similarly, it is observed that the yield obtained from sunflower yield and kernel weight were the highest as the hoeing time is extended.

As a result; it was determined that weed management must be performed in the development period of sunflower, which is one of the important oil cultivated crops. In addition to this, as the hoeing time increases, the values of the sunflower yield and yield criteria increase. With the study carried out, it has been revealed that it is important to implement the appropriate long-term hoeing times for managing weeds after the sunflower growing period.

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**ÖZET**

Ayçiçeği yetiştiriciliğinde yabancı otlarla mücadelede çapalama süresi önemli olup, yabancı ot yoğunluklarının azaltılmasında etkilidir. Bu çalışmada, Adana ili ayçiçeğinde yabancı ot mücadelesi için mekanik çapalama sürelerine olan etkilerinin belirlenmesi amacıyla 2018-2019 yılları arasında gerçekleştirilmiştir. Deneme kurulan tarlalarda yabancı ot kontrol zamanlarını belirlemek için ayçiçeğinin çıkışından hasada kadar geçen sürede mekanik çapalamanın 15 gün ara ile etkileri belirlenmiş, yabancı otlanmanın doğal koşullarda oluşması sağlanmıştır. Parseller kurularak, ayçiçeği yetiştirme döneminde periyodik olarak yapılan mekanik çapalamanın yabancı ot-ayçiçeği verim kriterlerine olan etkileşimleri gözlemlenmiştir. Deneme sonunda yabancı otların yaş ağırlığı ve kaplama alanı ile çapalama süresi uzunluğunun ayçiçeği verimi, dane verimi, yağ verimi, yağ kalitesi, tabla çapı ve bitki boyuna olan kriterler belirlenmiştir. İki yıllık çalışma sonucuna göre ayçiçeği verimi ile dane verimi en yüksek 75 ve 90 gün boyunca çapa yapılmış parsellerde olduğu, en düşük ise 60, 75 ve 90 gün boyunca yabancı otlu bırakılan çapa yapılmayan parsellerde olduğu görülmüştür. Yağ veriminin çapa süresi daha uzun bırakılan parsellerde yüksek olduğu, ancak yağ kalitesinin değişmediği saptanmıştır. Çapa süresine bağlı olarak ayçiçeği bitki boy gelişimlerinin birbirine yakın olduğu, tabla çaplarının ise etkilenmediği ortaya çıkarılmıştır. Çapa süresi daha az olan yabancı otlu parsellerde yabancı ot kaplama alanlarının artışına bağlı olarak yabancı ot yaş ağırlıklarında da artışların olduğu kaydedilmiştir. Sonuç olarak ayçiçeğinde yabancı ot yönetiminde uzun süre çapa yapılmasının verimi arttırdığı ve ayçiçeğinde yabancı otlarla mücadelede çapalama süresinin önemli olduğu belirlenmiştir.

Anahtar kelimeler: çapalama süresi, ayçiçeği, yabancı ot yönetimi, verim ve verim unsurları

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