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THE CRITICAL PERIOD FOR WEED CONTROL IN SAFFLOWER FIELDS OF TURKEY

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Abstract

Crop-weed competition is among the most significant topics in field crops if the crop is a weak competitor in this rivalry. Safflower is a valuable oil seed crop that is drought tolerant and used as a raw material in the food and biofuel industries. Although it has good drought tolerance, it is a sensitive crop against weed competition, especially wild mustard. The critical period for weed control (CPWC) is a useful tool to decide which time period is more suited for weed control economically. In this study, the beginning and end of the CPWC were determined for the summer safflower fields of Turkey. Weeds caused 50.61, 65.87, and 63.34% safflower yield reductions in 2017, 2018, and 2019, respectively. The beginning of the CPWC was 165, 198, and 225 air growing degree days (air GDD) for these years, while the end of CPWC varied 1348, 1837, and 2268 at 5% acceptable yield loss.

Key words: safflower, yield loss, weed, air growing degree days, critical period

Introduction. Safflower is an oil crop grown in a wheat-fallow rotation system to reduce fallow area in Turkey. Crop production has not reached the desired level because of pests, diseases and weed competition [1]. Weeds in safflower fields resulted in severe yield losses, reaching 63% [2]. The increase in production costs and the rising public interest in the use of agrochemicals force growers to decide

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more carefully about agricultural practices, especially weed control treatments. The critical period for weed control (CPWC) may be considered the most essential step to control weeds under sustainable weed control strategies. This period is a specific time to prevent crop yield from the suppressive and negative impacts of weeds [3]. However, the length of the period cannot be limited to a specific duration for each crop because it depends on many variables, such as variety, season, soil, weeds, irrigation, nutrition management, and location [4,5]. In practice, two periods are not considered important in terms of yield loss. The first is the time before weed interference, which is inferred to be the longest time until starting yield loss due to early emerging weeds, and the latter is the time after the critical weed-free period, which means the shortest time in the crop growth cycle where the reductive impact of weeds on yield loss must be minimized [3]. When weeds are controlled during the CPWC, excessive herbicide use, adverse effects of herbicides on the environment, and reduced production costs are prevented while maximizing crop yields.

The critical periods for major crops such as corn, cotton, sugar beet, and soybean have been determined in Turkey parallel to the world [6–9], but the studies on the critical period for minor crops were limited to red pepper, sesamum, etc. [10,11]. A few studies have been conducted to determine the critical period for fall-grown safflower [12,13]; however, no study was found in the available literature related to spring-grown safflower. Therefore, this knowledge could eliminate safflower growers' worries caused by the uncertainty of the most appropriate time for weed control and increase yield by reducing weed competition. The aim of this study was to determine the critical period of safflower production in Ankara, which is the province that produces the most safflower in Turkey.

Material and methods. The experiment was conducted in a safflower (*Carthamus tinctorium* L.) field covered by naturally occurring weed populations from 2017 to 2019. The experimental design was a randomized block design with three replications; each experimental plot was 1×4 m and had six safflower rows similar to the economic threshold study. Safflower (var. Hasankendi) was sown in rows spaced 15–17 cm apart at a density of 175–200 plants m^{-2}. The study covered two different components, the duration of weed interference and the weed-free period. In the former, the plots were temporarily left to natural weed populations to compete with safflower from the first week following crop emergence for 1, 2, 3, 4, 5, 6, 9, 10, and 11 weeks after emergence (WAE), and then the weeds were regularly removed from the plots up to harvest. In the latter, the plots were regularly protected from weeds through 1, 2, 3, 4, 5, 6, 9, 10, and 11 WAE, after the plots were persistently left to natural weed populations to infest and to compete with safflower until the end of the season. All weeds in the weed-free control plots were periodically removed manually for the entire growing season. Crop plants in the middle of rows were then evaluated to avoid field edge effects.

The yield obtained per treatment was regressed against an explanatory variable, the air GDD. To calculate this independent variable, temperatures were transformed to air GDD using the following formula

$$\text{GDD} = \sum \frac{(T_{\max} - T_{\min})}{2} - T_b, \tag{1}$$

where $T_{\max}$ and $T_{\min}$ indicate daily maximum and minimum air temperature (°C), respectively, and T_b is the base temperature (5 °C) [14].

ANOVA was then employed to assess the relationships between the critical timing of weed removal and the critical weed-free period by using R statistical program [15]. Statistical analysis was performed yearly due to differences in air GDD between years. Relative yield data were analysed using nonlinear regression to determine the critical period for weed control. For this analysis, a four-parameter log-logistic model was employed, as described by [16]. R statistical program was also used to calculate the yield loss values, where YL2.5, YL5, and YL10 indicate 2.5% yield loss, 5% yield loss, and 10% yield loss, respectively. Before these calculations, a lack-of-fit test was employed to test if the dose-response curve describes the data satisfactorily [17]. Safflower yield losses were expressed in the air GDD to qualify the impact of the period of weed interference. The air GDD estimate is equal to the relative yields, such as 97.5, 95 and 90%, derived from the following equation

$$Y = C + \frac{D - C}{1 + \exp[B(\operatorname{Log} X - \operatorname{Log} E)]}, \tag{2}$$

where Y is the relative yield, C is the lower limit, D is the upper limit (fixed to 100 according to KNEZEVIC et al. [16]), X is the air GDD calculated following crop emergence, and E and B are the point of inflection and its slope, respectively. Meteorological data are presented in Fig. 1.

Results and discussion. Experimental fields in Ikizce Agricultural Farm Station (IAFS) were mainly commonly covered by annual weeds such as wild mustard, redroot pigweed, fat hen, wild oat, perennial weeds, field bindweed, wild buck weed, and Canada thistle (Table 1). This weed composition is similar to the safflower weed flora of Ankara, which was represented by 35 taxa [18]. There was a high degree of similarity between the weed flora of the experimental fields because crop rotation was strictly performed in IAFS, and safflower was sown in the fields where wheat was grown in the previous season. Although the weed compositions of the safflower fields were similar to each other, the density of weeds varied depending on the soil seed bank and climatic conditions.

The competition between weeds and safflower resulted in severe yield losses in 2017–2019, and these losses were estimated by nonlinear regression with the log-logistic model. The CPWC was calculated separately for each year because there was a significant interaction between the experiments because the weather

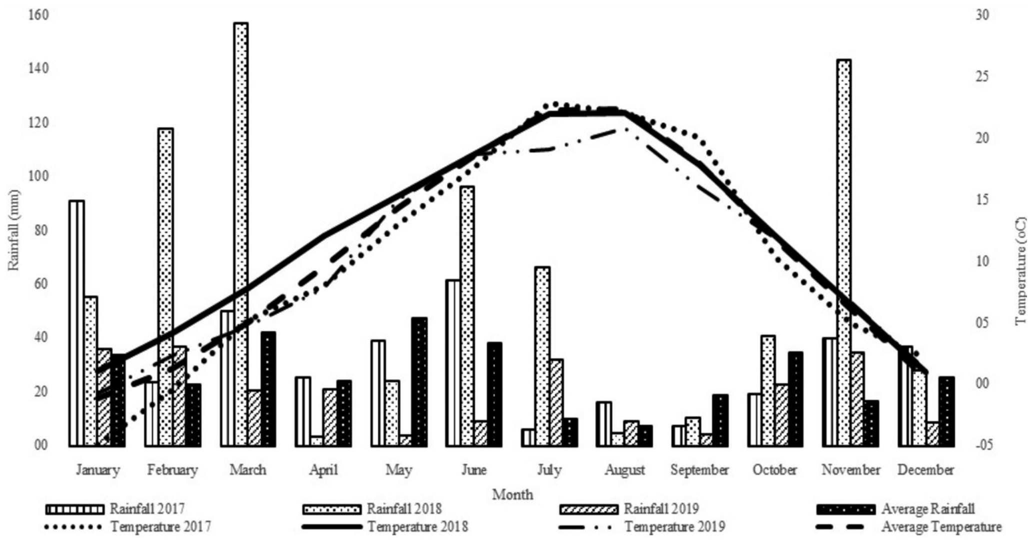

Fig. 1. Monthly average temperature and cumulative rainfall of safflower fields during 2017–2019

Table 1

Average coverage area of weed species in the experimental fields (%)

Weeds	2017	2018	2019
Chenopodium album L.	1.63	1.25	1.25
Convolvulus arvensis L.	4.63	3.95	2.50
Fallopia convolvulus (L.) Á. Löve	0.63	–	1.25
Sinapis arvensis L.	12.88	14.50	15.75
Amaranthus retroflexus L.	6.88	2.50	0.66
Setaria verticillata (L.) P. Beauv.	2.5	–	–
Avena fatua L.	4.50	0.25	0.85
Fumaria officinalis L.	0.38	–	0.40
Senecio vulgaris L.	0.63	–	–
Turgenia latifolia (L.) Hoffm.	0.63	–	–
Elymus repens (L.) Gould	0.50	–	–
Capsella bursa-pastoris (L.) Medik.	–	3.25	1.15
Sonchus arvensis L.	–	1.25	0.98
Cirsium arvense (L.) Scop.	–	1.75	0.66

conditions were not the same even if the weed flora of the experimental fields and their soil structures were very similar to each other. The efficacy of climatic variables on the regression parameters of the logistic model is shown in Table 2.

The beginning and end of the CPWC varied by YL in 2017, 2018, and 2019. The beginning of the CPWC was the lowest at 2.5% YL and the highest at 10% YL (Table 3). Contrary to the beginning time, the finish time of the CPWC was the highest at 10% YL and the lowest at 2.5% YL. The durations of weed interference were 11 DAE (165 air GDD), 13 DAE (198 air GDD), and 17 DAE (225 air GDD) for 2017, 2018 and 2019 at 5% YL, respectively.

Table 2

Estimated parameters and standard errors (in parentheses) by year for the four-parameter logistic model characterizing the safflower yield response to increasing durations of weed interference and the duration of the weed-free period

Year	Treatment	Regression parameters			
		B	C	D	I_{50}
2017	Weed-interference	1.86 (0.45)	29.69 (13.31)	100.25 (2.31)	807.75 (174.78)
	Weed-free	−9.38 (1.39)	1223.69 (119.17)	2403.07 (46.50)	984.92 (18.18)
2018	Weed-interference	2.60 (0.63)	19.71 (9.05)	98.23 (2.99)	616.49 (61.82)
	Weed-free	−4.05 (0.44)	680.24 (20.91)	1696.83 (44.90)	888.23 (31.12)
2019	Weed-interference	3.58 (0.44)	30.86 (2.43)	98.37 (1.54)	513.33 (17.18)
	Weed-free	−3.45 (0.33)	591.57 (13.77)	1480.17 (39.51)	964.94 (34.96)

B: the slope of the line at the inflection point; C: the lower limit; D: the upper limit; I_{50}: the growing degree days giving a 50% response between the maximum and the lowest limit

Table 3

Duration of the critical period of weed control in the air GDD at the 2.5, 5 and 10% yield loss thresholds and corresponding DAE

Year	Yield loss (%)	The beginning of the CPWC		The end of the CPWC	
		Air GDD	DAE	Air GDD	DAE
2017	2.5	122 (35)	8 (2)	1455 (119)	77 (6)
	5	165 (38)	11 (2)	1348 (91)	71 (4)
	10	247 (38)	15 (2)	1245 (66)	66 (3)
2018	2.5	180 (43)	10 (2)	2194 (247)	130 (14)
	5	198 (44)	13 (3)	1837 (174)	110 (10)
	10	264 (41)	17 (3)	1528 (116)	92.46 (7)
2019	2.5	184 (22)	14 (2)	2794 (340)	142 (114)
	5	225 (22)	17 (2)	2268 (233)	120 (10)
	10	278 (20)	21 (1)	1826 (153)	101 (7)

The end of the CPWC change over three years was 71 DAE (1348 air GDD), 110 DAE (1837 air GDD), and 120 DAE (2268 air GDD) for 2017, 2018 and 2019, respectively, at 5% AYL. The critical period finished before harvest in the first year; however, the period continued until harvest in the second and third years. The longest cultivation period was in the second year at 135 DAE because 2018 was a rainy year compared to the long-term rainfall data. New rainfall events improved the germination and emergence of new weeds and postponed the harvest time.

Safflower is grown as an annual summer crop in Turkey, but in other countries, such as Iran, it is cultivated as an annual winter or autumn crop. Therefore, no literature has been found on the CPWC of summer safflower. In winter-grown safflower, this period was found between 134 and 188 days after planting (DAP) in Iran [13]. This period started at early stem elongation and finished at lateral stem emergence in Iran. In another study, Miri and Ghadiri [12] estimated the CPWC for fall-grown safflower from 144 DAP (early stem elongation) to 220 DAP (flowering stage). In our study, the CPWC began in the second or third week after emergence for 5% ATL. This time was closely related to weed flora in safflower fields, especially for wild mustard, which was the major weed of safflower in Ankara, Turkey [18], and its germination and emergence times overlapped with safflower. Although the beginning of the CPWC for three years was close to each other, the ending of the CPWC varied for these years and continued until harvest, except in the first year, when the experimental field had less wild mustard.

The results of a 3-year study showed that safflower has a weak competitive ability against weeds. Therefore, competitor weeds in safflower fields should be controlled from the beginning of the second week to the end of the growing season. To provide good control in these fields, weeds should be controlled by hand weeding several times or by a residual soil herbicide.

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