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Critical period of weed control in chickpea under non-irrigated conditions

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Abstract: The present study was conducted during the growing seasons of 2005, 2006, and 2007 to determine the critical period of weed control (CPWC) in chickpea (cv. Aziziye 94). In order to evaluate the beginning of CPWC, weeds were allowed to compete at weekly intervals for 1 to 8 weeks after emergence (WAE) and, at the end of CPWC, plots were kept weed-free at weekly intervals for 1 to 8 WAE by periodic hand hoeing. The beginning and the end of CPWC were based on 5% acceptable yield loss (AYL) levels, which were determined by fitting logistic and Gompertz equations to relative yield data, representing increasing duration of weed-interference and weed-free period, estimated as growing degree days (GDDs). The major weed species were *Centaurea depressa* Bieb. and *Bromus tectorum* L. for the 1st year, *Salsola ruthenica* Iljin., *Amaranthus* sp. and *Heliotropium europaeum* L. for the 2nd year and *Amaranthus* spp., *Salsola ruthenica* Iljin., *Sisymbrium septulatum* DC. and *Heliotropium europaeum* L. for the 3rd year. Overall weed density was 190 plants m^{-2} in 2005, 215 plants m^{-2} in 2006, and 191 plants m^{-2} in 2007. Yield losses were 26.4% in 2005, 31.5% in 2006, and 25.0% in 2007 when the crop was not weeded. It was found that at the 5% AYL level CPWC was 2.32 WAE to harvest in the 1st year, from emergence to harvest in the 2nd year, and from 0.34 WAE to harvest in the 3rd year. The present findings suggest that the determination of CPWC is crucial in chickpea production.

Key words: Chickpea, critical period, weeds, weed competition

Kuru tarım koşullarında yetiştirilen nohutta yabancı ot mücadelesinde kritik dönemin belirlenmesi

Özet: Nohutta (Aziziye 94 çeşidi) yabancı ot mücadelesinde kritik dönemin belirlenmesi amacıyla yapılan çalışma 2005, 2006 ve 2007 yıllarında yürütülmüştür. Kritik dönemin başlangıcını belirlemek için çıkıştan sonraki 8 haftalık süre içinde parsellerde birer hafta aralıklarla yabancı otların rekabetine olanak sağlanmıştır. Kritik dönemin sonunu belirlemek için ise 8 haftalık sürede birer haftalık aralıklarla elle yabancı ot mücadelesi yapılarak parsellerin yabancı otsuz kalması sağlanmıştır. Kritik dönemin başlangıcı ve sonu % 5 seviyesinde kabul edilebilir verim kaybına göre, lojistik ve 'Gompertz' modeller kullanılarak belirlenmiştir. Bu modellemede mücadele zamanı, nohudun yetişme sürecindeki toplam sıcaklık isteği esas alınarak yabancı otlu ve yabancı otsuz parsellerden elde edilen eğrilerin karşılaştırılması ile belirlenmiştir. Deneme alanlarında birinci yılda *Centaurea depressa* Bieb. ve *Bromus tectorum* L.; ikinci yılda *Salsola ruthenica* Iljin., *Amaranthus* sp. ve *Heliotropium europaeum* L.; üçüncü yılda ise *Amaranthus* spp., *Salsola ruthenica* Iljin., *Sisymbrium septulatum* DC. ve *Heliotropium europaeum* L. en yoğun yabancı otlar olarak tespit edilmiştir. Yabancı ot yoğunluğunun

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2005 yılında metrekarede 190 bitki, 2006 yılında 215 bitki ve 2007 yılında ise 191 bitki olduğu belirlenmiştir. Yabancı ot mücadelesi yapılmayan parsellerde üründeki verim kayıpları 2005 yılında % 26.4, 2006 yılında % 31.5 ve 2007 yılında % 25.0 olarak gerçekleşmiştir. Çalışmada % 5 seviyesinde kabul edilebilir verim kaybına göre kritik dönem, birinci yıl için çıkıştan sonra 2.32'inci hafta ile hasat arası, ikinci yıl için çıkış ile hasat arası ve üçüncü yıl için 0.34'üncü hafta ile hasat arası dönemler olarak tespit edilmiştir. Bu sonuçlara göre, nohut üretiminde yabancı ot mücadelesinde kritik periyodun belirlenmesinin oldukça önemli olduğu görülmektedir.

Anahtar sözcükler: Kritik dönem, nohut, rekabet, yabancı ot

Introduction

Turkey is an important chickpea (*Cicer arietinum* L.) producer following India and Pakistan. According to the latest statistics of FAO (2009), chickpea is the first leading grain legume crop in Turkey covering 500,000 ha with a production of 523,553 t. Chickpea has been commonly grown as a rotation crop. Its high protein content makes it a valuable human food and animal nutrition as straw.

Chickpea is a very sensitive crop to weed competition, which generally results in heavy yield loss. The reduction in grain yield may vary from 23% to 87% depending on the weed species and their densities in various countries (Bhan and Kukula 1986). Weeds mainly compete with crop for nutrients, soil moisture, and sunlight by covering over crop and space. Severity of yield loss depends upon weed infestation, duration of infestation as well as climatic conditions which affect weed and crop growth. Weeds can remove plant nutrients from soil more efficiently than crops. In a non-irrigated crop system, efficient water use by weeds may increase severity of drought and results in a low crop yield. Most weed species can grow faster and taller than chickpea and inhibit growing, curtail sunlight, and affect photosynthesis and plant productivity adversely (Rao 2000). Therefore, weeds are of crucial importance since effective and proper weed control time will result in higher seed yields of chickpea. Weed control programs should be set by considering critical period. Delayed weeding until late stages could result in irreversible damage due to weed competition. Furthermore, removal of heavier weeds requires more power with little economic return and causes serious physical damage to the crop (Solh and Pala 1990).

Zimdahl (2004) defines the critical period as the last term or point in which weed control could be effectively made without posing a remarkable effect on yield. The critical period of weed control (CPWC) in a particular crop is the minimum period of time during which weeds must be suppressed in order to prevent yield losses (Weaver and Tan 1983). Swanton and Weise (1991) identified the CPWC as a key component of a successful integrated weed management (IWM) program.

The beneficial effect of reduced weed competition is apparent from the dry matter accumulation of chickpea under weed-free and weed-infested environments, which are ultimately reflected on seed yield (Bhan and Kukula 1986). Ahlawat et al. (1981) reported that clean weeding increased the seed yield of chickpea by 107% and the first 4 to 6 weeks were the most critical period for weed competition. Dry matter accumulation of the chickpea under different weed levels followed more or less identical patterns up to 30 days in Syria (Solh and Pala 1990). However, competition became more severe after 60 days. Hence, the first 30 to 60 days after emergence (DAE) were the most critical for weed control as also indicated earlier by Saxena et al. (1976).

In another study, the critical period of weed interference in chickpea was determined in field experiments in Iran (Mohammadi et al. 2005). Results of these experiments indicated that chickpea must be kept weed-free between the 5-leaf and full flowering stages (24 and 48 DAE) and from the 4-leaf to beginning of flowering stages (17 and 49 DAE) at the 2 sites, respectively, in order to prevent more than 10% seed yield loss.

So far, no single method related to critical period has been fully effective and widely adapted to all environments and situations. Critical period knowledge that increases the capabilities of the farmer is an important consideration in the choice of weed control method. Critical period consideration will also help to set an integrated approach involving chemical, cultural, and mechanical methods that provide an effective weed control system in chickpea.

The critical period of weed control might vary with the environmental conditions, level of weed infestations, composition of weed population, soil moisture, and the fertility level. Due to the lack of relevant information, the present research was conducted to determine the effects of timing of weed removal and duration of weed interference on chickpea yield in Turkey.

Materials and methods

Experimental details

The effects of duration of weed-free and weed-interference period on seed yield of chickpea were studied in Van Province (33°44′N, 43°17′E, 1654 m elevation), Turkey. The field experiments were conducted between the years 2005 and 2007 in the experimental research area of Agricultural Faculty of Yüzüncü Yıl University. Having the semi-erect growing habit, the spring chickpea (*Cicer arietinum* L.) cv. 'Aziziye 94' was used during the trials.

Soil samples from the experimental area for 3 years were taken according to Jackson (1985) and analyzed chemically and physically (Table 1). Soil texture by a hydrometric method (Bouyoucos 1951), pH by a potentio-metric method (Chapman and Pratt 1961), lime by Scheibler calcimeter (Çağlar 1949), organic matter by Walkley-Black method (Zabunoğlu and Karaçal 1983), salt content by a conductivity-meter (Richards 1954), total nitrogen content by Kjeldahl method (Zabunoğlu and Karaçal 1983), available phosphorus by Olsen et al. (1954), and available potassium by atomic absorption spectrophotometer (Jackson 1985) were analyzed. The soils of the trial areas were of loamy texture with high $CaCO_3$ content, low organic matter, and nitrogen (N) and phosphorus (P) contents while available potassium (K) content was sufficient (Aydeniz 1985). They had low salt content and were slightly alkaline and were classified as 'regosol' according to the WRB classification system (FAO 2006).

Some local climatologic data for the years of the experiments are presented in Table 2. Climatic properties of the experimental area are classified as 'warm summer continental (Dsb)' according to the Köppen-Geiger climatic classification (Peel et al. 2007). In the years 2005, 2006, and 2007 precipitation throughout the growing season (from April to July) was 105.0, 97.5, and 151.8 mm, respectively, and the long-term average for the same period was 121.8 mm. Average temperature for the 3 years was higher than the long-term average. Moreover, precipitation in the 1st and 2nd years of the trial was less, compared with the 3rd year.

Weed interference and weed-free treatments were set up after the crop emergence. Beginning of CPWC was determined by allowing weeds to compete at weekly intervals for 1 (weed-free control) to 8 weeks after emergence (WAE). To determine the end of the critical period, plots were kept weed-free at weekly intervals for 1 (weedy control) to 8 WAE with periodic hand hoeing. The experiments were conducted in a randomized complete block design with 4 replications. Plot size was 2.5 × 4 m. The soil was deeply ploughed after cereal harvest then disc-harrowing and rotary-harrowing were applied before chickpea seed sowing in spring. Soil fertilizer (DAP, diammonium phosphate) was applied at sowing at a rate of 140 kg ha^{-1}. Chickpea was planted in rows 30

Table 1. Chemical and physical properties of trial soils.

Years	Texture class	$CaCO_3$ (%)	Salt (%)	Organic matter (%)	pH	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
2005	Sandy clay loam	16.8	0.08	0.85	8.42	0.062	6.41	448
2006	Sandy clay loam	15.6	0.07	0.96	8.18	0.078	6.72	471
2007	Sandy clay loam	17.2	0.09	0.88	8.57	0.065	6.57	485

Table 2. Climatologically characteristics of experimental years in Van, Turkey

	Precipitation (mm)				Average temperature (°C)			
Month	2005	2006	2007	LTA*	2005	2006	2007	LTA*
January	34.4	90.4	18.1	41.5	–3.3	–3.1	–4.6	–3.6
February	27.2	47.7	10.6	30.5	–3.3	–1.3	–0.9	–2.5
March	59.1	45.7	35.0	46.2	2.5	3.0	3.0	1.9
April	55.9	39.6	86.8	58.7	8.9	9.8	5.9	7.8
May	35.8	35.4	27.3	38.9	13.3	14.6	15.7	13.8
June	13.0	0.1	9.1	13.0	18.7	21.5	19.9	19.0
July	0.3	22.4	28.6	11.2	24.1	22.3	22.7	22.6
August	4.0	2.4	7.2	4.0	23.4	24.1	21.8	22.5
September	9.2	-	-	11.1	17.2	18.0	17.8	17.4
October	35.4	46.9	7.6	37.6	11.2	11.6	12.2	11.1
November	29.3	49.3	75.2	49.6	4.6	3.0	4.2	4.2
December	34.3	44.2	43.9	39.1	1.9	–3.4	–2.0	–1.0
Total	337.9	424.1	349.4	381.2				
Average					9.9	10.0	9.6	9.4

*LTA = Long-term average (1949-2007) (TSMS, 2008).

cm apart at a rate of 45 seeds m^{-2} on 19 April 2005, 12 April 2006, and 15 April 2007. Seedlings emerged uniformly 18 days after sowing (DAS) in 2005 and 2006, and 20 DAS in 2007. The experiments were carried out in rain-fed conditions with no additional irrigation.

Weed and crop measurements

Natural weed populations were used in the experiments. Weeds were counted before application of each treatment. Three square meter samples were randomly collected from each plot. Total weed densities, weed biomass and major species for each year were determined. Weed biomass (above-ground dry weights) was determined by clipping weeds at the soil surface in each quadrate and dried at 70 °C for 48 h. Weed removal within and between crop rows was carried out by hand hoeing. Crop yield was evaluated by measuring seed yield. At maturity, a 3-m length of the 6 central rows of each plot was hand harvested (10 July 2005, 1 July 2006, and 14 July 2007). Moisture content of harvested chickpea grains was approximately 12% according to Van Gastel et al. (2007).

Meteorological data

The meteorological data were collected from Van Province State Directorate of Meteorology as daily maximum (T_{max}, °C) and daily minimum (T_{min}, °C) temperatures for calculating growing degree days (GDDs) by Equation 3.

Statistical analysis

Data from the yield experiments were subjected to Levene's test for homogeneity of variance between the years of experiment to determine whether data could be pooled. Analysis of variance (ANOVA) also was performed on data from the yield experiment in SAS PROC GLM (SAS 2004), to evaluate the effect of the weed-free period length and increasing duration of weed interference on relative chickpea yields (Evans et al. 2003; Knezevic et al. 2002; Norsworthy and Oliveira 2004). When the F-value of the ANOVA was significant at the $P < 0.05$ level of probability, means were separated using standard error (SEM) (Cochran and Cox, 1957). Relative yield of each treatment was calculated in percent of the corresponding weed-free yield. The significance of year effect or treatments was evaluated at the 5% level of probability. A 3-parameter logistic equation proposed by Hall et al. (1992) and modified by Knezevic et al. (2003), was used to describe the effect of increasing duration of weed interference on relative yield and to determine the beginning of critical period. For this purpose the following equation was used:

$$RY = \left[\frac{1}{\exp(C \times (T - D)) + F} + \frac{F - 1}{F}\right] \times 100 \quad (1)$$

In this equation, RY is the relative yield (% of season-long weed-free yield), T is the duration of weed interference measured from the time of sowing in days, D is the inflection point in GDDs, C is a parameter that determines the curvature of the function, and F is the lower asymptote – expected proportion of yield loss for the longest period of time of weed competition.

The Gompertz model has been shown to provide a good fit to yield under increasing length of the weed-free period (Hall et al. 1992; Knezevic et al. 2002). The model has the following form:

$$RY = A \times \exp(-B \times \exp(-K \times T)) \quad (2)$$

where RY is the relative yield (% of season-long weed-free yield), A is the theoretical maximum or asymptotic yield, B is yield as time equals zero, and K represents the slope, and T is the length of the weed-free period after crop sowing in GDDs. At all trials, GDDs were accumulated from date of seeding using a base temperature (T_b) of 4 °C (Verghis et al. 1999) according to the following equation:

$$GDD = [(T_{max} + T_{min})/2 - T_b] \quad (3)$$

where T_{max} is daily maximum air temperature (°C) and T_{min} is daily minimum air temperature (°C).

Determination of the CPWC was calculated on the basis of a 5% acceptable yield loss level (AYL), which is commonly accepted by farmers for most crops in Turkey (Isik et al. 2006).

Results

Weed and crop measurements

Relations between GDDs, WAE, and crop development stages in 3 years are presented in Table 3.

The weed community was composed of 14 species in 2005, 8 species in 2006, and 9 species in 2007. Overall weed density was 190 plants m^{-2} in 2005, 215 plants m^{-2} in 2006, and 191 plants m^{-2} in 2007. Major weed species of the 1st year were *Centaurea depressa* Bieb. and *Bromus tectorum* L. As for the 2nd year *Salsola ruthenica* Iljin., *Amaranthus* sp. and *Heliotropium europaeum* L. and for the 3rd year *Amaranthus* spp., *Salsola ruthenica* Iljin., *Sisymbrium septulatum* DC. and *Heliotropium europaeum* L. were determined as the main weed species (Table 4). Weed biomass showed significant differences depending on years and type of weed interference. Weed biomass ranged from 894 to 2781 kg ha^{-1} in 2005, from 16 to 787 kg ha^{-1} in 2006, and from 161 to 999 kg ha^{-1} in 2007 (Table 5).

Differences between weeks were significant in terms of seed yield of chickpea in both weed-free and weed-infested applications in all the 3 years. Seed yield of chickpea on the weed-free plots (WFC) was 607 kg ha^{-1} in 2005 and 2006 and 1064 kg ha^{-1} in 2007 (Table 6). Yield loss was 26.4% in 2005, 31.5% in 2006, and 25.0% in 2007 for untreated weed-infested plots. Based on statistical analysis of actual yield data subjected to Levene's homogeneity test to determine critical period (CPWC), relative yield data were not pooled across the years due to significant interaction among years and the treatment levels. Gompertz and logistic equations parameters were obtained for each year and differences between the onset and end of CPWC were tested by year. Predicted and observed relative yields, as affected by duration of weed interference or weed-free period are shown in Figures 1-3. Coefficients for the parameters used to fit the Gompertz and logistic models are listed in Table 7.

Critical period of weed control at 5% AYL were from 2.32 WAE to harvest in the 1st year, from emergence to harvest in the 2nd year, and from 0.34 WAE to harvest in the 3rd year (Figures 1-3).

Table 3. Crop development stages (CDS) and growing degree days (GDDs) at different weeks after chickpea emergence (WAE).

WAE	2005		2006		2007	
	GDDs	CDS	GDDs	CDS	GDDs	CDS
1	35	3-leaf stage	30	3-leaf stage	23	3-leaf stage
2	71	5-leaf stage	62	5-leaf stage	49	5-leaf stage
3	108	8-leaf stage	102	8-leaf stage	81	8-leaf stage
4	145	Early flowering	137	Early flowering	114	Early flowering
5	183	Full flowering	180	Full flowering	148	Full flowering
6	228	Pod setting	222	Pod setting	184	Pod setting
7	272	Seed-filling	263	Seed-filling	226	Seed-filling
8	311	Maturity	312	Maturity	265	Maturity

Table 4. Major weed species and their average densities (plants m^{-2}).

Species	2005	2006	2007
Amaranthus spp.	-	20	86
Anchusa azurea Miller.	1	-	-
Bromus tectorum L.	22	-	-
Buglossoides arvensis (L.) Johnst.	1	-	-
Centaurea depressa Bieb.	149	1	1
Ceratocephalus testiculatus (Crantz) Roth	1	-	-
Cichorium intybus L.	-	4	1
Cnicus benedictus L.	1	-	-
Cynodon dactylon (L.) Pers.	1	3	2
Echinophora orientalis Hedge and Lamond	-	1	1
Euphorbia heteradena Jaub. and Spach	3	-	-
Geranium tuberosum L.	2	-	-
Glycyrrhiza glabra L.	-	-	2
Heliotropium europaeum L.	-	10	11
Hypecoum pendulum L.	2	-	-
Muscari comosum (L.) Mill.	1	-	-
Ranunculus arvensis L.	3	-	-
Roemaria hybrida (L.) DC.	1	-	-
Salsola ruthenica Iljin.	2	172	71
Sisymbrium septulatum DC.	-	4	16
Total	190 (20.8)	215 (58.5)	191 (45.6)

Values in parentheses indicate standard errors of means

Table 5. Weed response to different periods of weed interference during 2005, 2006, and 2007.

Treatments	Weed biomass (kg ha^{-1})		
	2005	2006	2007
WI 1 WAE (WFC)	0	0	0
WI 2 WAE	894 (149)	16 (2)	161 (18)
WI 3 WAE	1785 (303)	93 (29)	159 (46)
WI 4 WAE	1799 (251)	158 (53)	317 (99)
WI 5 WAE	2104 (205)	423 (76)	639 (107)
WI 6 WAE	2221 (136)	432 (39)	692 (81)
WI 7 WAE	2451 (196)	538 (34)	809 (117)
WI 8 WAE	2781 (516)	787 (40)	999 (94)

Values in parentheses indicate standard errors of means
WI, weed interference; WAE, weeks after crop emergence; WFC, weed-free control.

Table 6. Crop responses to different periods of weed-free and weed interference treatments for 3 years in chickpea

Treatments	Seed yield (kg ha^{-1})		
	2005	2006	2007
WF 1 WAE (WC)	447 (23.5)	416 (20.6)	798 (39.9)
WF 2 WAE	456 (19.5)	452 (28.7)	941 (27.4)
WF 3 WAE	503 (20.0)	531 (19.1)	978 (50.0)
WF 4 WAE	499 (29.8)	593 (34.6)	1017 (13.7)
WF 5 WAE	521 (24.6)	594 (19.3)	975 (20.5)
WF 6 WAE	545 (26.0)	627 (23.5)	1055 (53.7)
WF 7 WAE	560 (29.8)	640 (11.8)	1014 (29.3)
WF 8 WAE	581 (28.7)	726 (9.2)	1059 (19.7)
WI 1 WAE (WFC)	607 (36.7)	607 (53.3)	1064 (81.5)
WI 2 WAE	589 (24.1)	577 (19.7)	920 (117.6)
WI 3 WAE	566 (18.7)	578 (20.9)	854 (26.5)
WI 4 WAE	532 (25.7)	519 (53.6)	731 (40.1)
WI 5 WAE	520 (33.1)	439 (33.2)	700 (16.1)
WI 6 WAE	506 (33.5)	390 (62.4)	514 (73.3)
WI 7 WAE	503 (47.2)	280 (38.7)	478 (100.2)
WI 8 WAE	482 (52.5)	186 (31.1)	463 (24.0)

Values in parentheses indicate standard errors of means
WF, weed-free; WI, weed interference; WAE, weeks after crop emergence; WC, weedy control; WFC, weed-free control.

Discussion

The composition, densities, and biomass of weed species showed significant differences between the years (Tables 4 and 5), which could be attributed to management practices in previous crops and climatologic conditions (Table 2) as well as differences between experimental soils in terms of weeds seed bank (Thompson 2000; Fenner and Thompson 2005). It is known that weeds compete for water with crops and the amount of rain affects the growth of weeds, which results in an increase or decrease in their biomass.

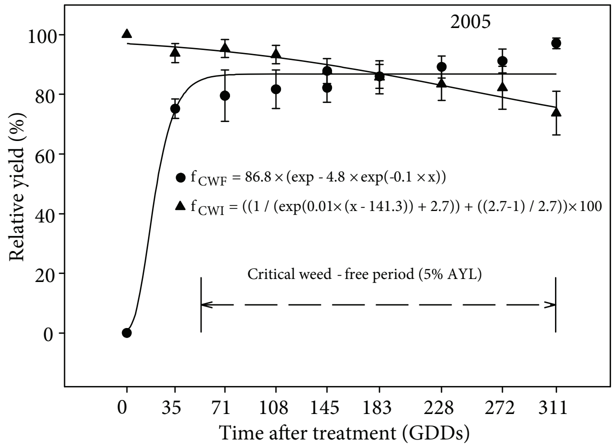

Figure 1. Effect of weed interference of chickpea in 2005. Symbols represent observed data; solid lines represent fitted curves (that is, logistic equation for increasing duration of weed interference (p); Gompertz equation for increasing weed-free period (˜)); horizontal dashed lines indicate the 5% acceptable yield loss level used to determine the CPWC, whereas vertical lines indicate the beginning and end of CPWC. Estimated parameters for fitted curves are given in Table 7.

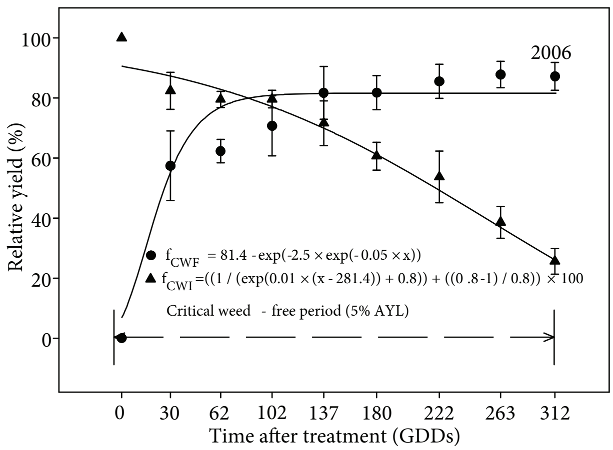

Figure 2. Effect of weed interference of chickpea in 2006. Symbols represent observed data; solid lines represent fitted curves (that is, logistic equation for increasing duration of weed interference (p); Gompertz equation for increasing weed-free period (˜)); horizontal dashed lines indicate the 5% acceptable yield loss level used to determine the CPWC, whereas vertical lines indicate the beginning and end of CPWC. Estimated parameters for fitted curves are given in Table 7.

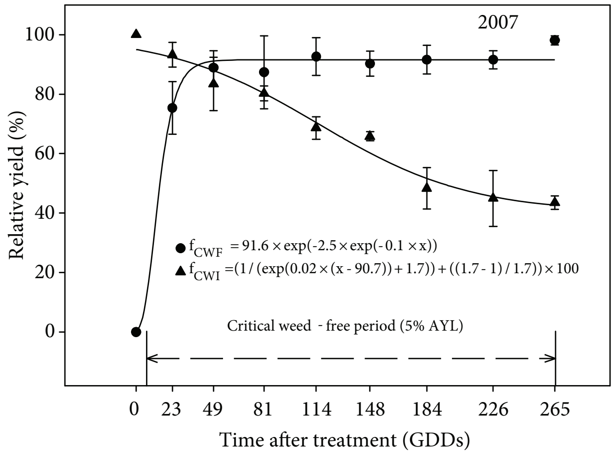

Figure 3. Effect of weed interference of chickpea in 2007. Symbols represent observed data; solid lines represent fitted curves (that is, logistic equation for increasing duration of weed interference (p); Gompertz equation for increasing weed-free period (˜)); horizontal dashed lines indicate the 5% acceptable yield loss level used to determine the CPWC, whereas vertical lines indicate the beginning and end of CPWC. Estimated parameters for fitted curves are given in Table 7.

Table 7. Parameters estimated for the logistic and Gompertz models used to fit yield data for increasing weed interference and weed periods, respectively.

Parameters	2005	2006	2007
Logistic model[a]			
C	0.01	0.01	0.02
D	141.2	281.4	90.7
F	2.74	0.83	1.67
Gompertz model[b]			
A	86.8	81.4	91.6
B	4.7	2.5	5.4
K	0.10	0.05	0.14

[a] Logistic model:

$$RY = \left[\frac{1}{\exp(C \times (T - D)) + F} + \frac{F - 1}{F}\right] \times 100$$

[b] Gompertz model: $Y = A \times \exp(-B \times \exp(-K \times T))$

As the duration of weed presence increased the seed yield decreased. This was a likely result of major weed species competition with chickpea and their biomass accumulation. Wide variations in seed yield losses may be due to differences in intensity of weed infestation and presence of different weed species.

Chickpea yield loss related to weed competition is a major constraint in chickpea production in the Mediterranean region (Bhan and Kukula 1986). Another research result shows that weeds present a serious threat to the crop and yield losses up to 98% (Solh and Pala 1990).

Critical period of weed control began 2.32 WAE in 2005, at the stage of emergence in 2006 and 0.34 WAE in 2007 and continued up to harvest (8th week) in order to prevent excess of 5% chickpea yield loss (Figures 1-3). The length of weed-free period implies that chickpea is susceptible to the weed competition and almost season-long weed control requires the prevention of unacceptable yield loss. These findings are in agreement with the results of Mohammadi et al. (2005) that show that critical period of weed competition was between the first 3 weeks and 7-8 weeks in order to prevent excess of 10% acceptable yield loss level in chickpea. Al-Thahabi et al. (1994) reported that the critical period of weed interference was found between 5 and 7 weeks after emergence in chickpea in the Mediterranean region. Although critical periods vary among site, years, and crops, CPWC provides useful information to producers about the best time for controlling weeds or for a common weed spectrum (Norsworthy and Oliveira 2004).

Season-long weed control with minimal yield loss can be acceptable as long as yield losses are below 5% AYL. However, long critical period time indicates that chickpea is very sensitive to weed competition. If the weed densities are high, the efforts must be taken to protect chickpea from weed interference soon after emergence as evidenced by the early beginning of the CPWC and should proceed until harvest. Under these circumstances, a residual herbicide would be needed at planting.

Findings of the present research and those of other researchers show that the beginning and the end of CPWC are not stable but are rather highly dependent on the species, density, competitiveness, and emergence periodicity of the weed spectrum as well as climatic conditions, soil type, site, and irrigation conditions. The present study also reveals that if season-long weed control is not practiced under non-irrigation conditions, high yield loss is likely to occur.

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