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Critical period for weed control of chickpea in a semi-arid region

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Abstract

Field studies were conducted to determine the critical period of weed control in chickpea (*Cicer arietinum* L.) cv. 'Jam'. The treatments consisted of two different periods of weed interference and weed control. Weed interference and weed-free treatments were set up after the crop emergence. Beginning of CPWC was determined by allowing weeds to compete or were kept weed-free at 2 weekly intervals for 2 (weed-free control) to 12 weeks after emergence (WAE). The Gompertz and logistic equations were fitted to relative yield and total dry matter representing the critical weed-free and the critical time of weed removal, respectively. Results indicated that Crop yield, total dry matter, 100 seed weight, number of pod in plant and number of seed in plant declined steadily as the duration of weed competition increased, indicating weed infested conditions for the entire growing season led to 76.4-85.8% and 78.5-85.7% reduction in chickpea dry matter and seed yield compared with full-season weed-free treatments. Also, the major weeds in experiment were *Stachys byzantine*, *Tragopogon dubius, Gypsophila pilosa* and *Euphorbia helioscpia*. To prevent >10% yield and total dry matter loss, the maximum time weeds could be allowed to grow after crop emergence were 43 and 36 DAE respectively and Also, critical period for weed control at 5 % yield and total dry matter loss was 36-60 DAE and 26-71 DAE. But critical period at 2.5 % yield and total dry matter loss was widespreader than other loss level. These results suggested that weed control upgraded all of agronomical traits of chickpea especially seed yield and to minimizing loss level of yield removal weeds must be done at 19-80 DAE.

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Introduction

The critical period for weed control (CPWC) is a key component of an integrated weed management program. Determining the appropriate timing of weed control tactics is valuable in developing integrated weed managements systems (Knezevic *et al.,* 2002; Rajcan and Swanton 2001) and has been the subject of extensive research in agronomic crops (Zimdahl, 2004). A common approach in such research is to quantify the CPWC; a phase of the crop growth cycle when weed interference results in unacceptable yield losses. The CPWC is determined by characterizing functional relationships between two separately measured competition components: crop yield as a function of the duration of weed interference to identify the beginning of CPWC, and crop yield as a function of the duration of the weed-free period to identify the end of CPWC. In theory, weed competition before or after the CPWC will not reduce crop yield below acceptable levels (Williams, 2006). CPWC approaches crop–weed competition from an applied aspect because results have the potential for direct application to crop production, especially in cropping systems with a reliance on POST herbicides (Knezevic *et al.,* 2002).

Chickpea is commonly grown as a rotation crop in west and north-west Iran as a source of human and animal feed and to enhance soil nitrogen (Mohammadi *et al.,* 2005) and it is a very sensitive crop to weed competition, which generally results in heavy yield loss. The reduction in number of pods in plant, 1000-grain weight and crop yield of chickpea occurred when field be kept weed-infested from emergence to full flowering stages (Rashid *et al.,* 2009; Fathi *et al.,* 2010). 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 (Williams, 2006). 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). While the CPWC in chickpea has been studied, the results have been variable. Results have been showed that the addition of nitrogen fertilizer and planting date delayed the beginning and hastened the end of the critical period of weed control (Evans, *et al*., 2003; Mohammadi and Amiri, 2011; Gower *et al.,* 2002).

In other study, Ahmadvand *et al.* (2009) reported that the yield and its components of chickpea were increased significantly when chick pea density upgraded. Also, Mohammadi *et al.* (2005) 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. In one location in Iran, in western Iran, Mashhadi and Ahmadi (1998) estimated a CPWC of 27 to 44 DAE, between the 6 and 14 leaf stage. Al-Thahabi *et al.* (1994) in Jordan estimated 35 to 49 DAE; Masood-Ali (1993) in India estimated 0 to 56 DAE. The average of these estimates is 23 to 52 DAE, but the estimates for the lower and upper limit ranged from 0 to 35 and 42 to 60 DAE, respectively (Yenish, 2007). Smitcher (2010) appointed that Full season weed interference with 'Sierra' chickpea caused yield reductions of 45% and so, based on a 5% yield loss threshold, the CPWC for the 'Sierra' chickpea was 16 to 26 DAE. All of this research defining the CPWC in chickpea has been conducted in Asia and the Middle East where >70% of the world's chickpeas are grown (Yadav *et al.,* 2007). Tepe *et al.* (2011) argued 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. Therefore, weeds are of crucial importance since effective and proper weed control time will result in higher seed yields of chickpea. Due to the lack of relevant information about estimation of critical period of weed interference for chickpea in three loss level for crop yield and dry matter, thus the present study was designed.

Materials and methods

Experiments approach

The field experiments were conducted in Saghez (33°16′N, 49°16′E, and 1523m asl) Kurdistan province, Iran. The spring chickpea (*Cicer arietinum* L.) cv. 'Jam' was used during the trials. Soil samples from the farm analyzed chemically and physically. The soil type was silty loamy with average pH of 7.6 and about 0.83% organic matter. The experiment was conducted in a randomized complete block design with six period of weed interference and weed-free as control (from 2 weeks after emergence to harvesting by 14 day interval times) which replicated 4 times. Plot size was 3 × 64 m. The soil was deeply ploughed in the autumn and 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 150 kg. ha^{-1}. Seeds was planted in rows 25×15 cm at a rate of 40 seeds m^{-2} on 25 April 2012. Seedlings emerged uniformly 14 days after sowing (DAS) and carried out in rain-fed conditions with no additional irrigation. Weed interference and weed-free treatments were set up after the crop emergence. Beginning of CPWC was determined by allowing weeds to compete or were kept weed-free at 2 weekly intervals for 2 (weed-free control) to 12 weeks after emergence (WAE). Natural weed populations were used in the experiments and weed removal within and between crop rows was carried out by hand hoeing. Weeds were counted before application of each treatment. Seed number in pod, pod number, 1000-grain weight, total dry weight and crop yield was evaluated by measuring one square of each plot was hand harvested. Moisture content of harvested chickpea grains was approximately 12% according to *Van Gastel et al* .(2007).

Statistical analysis

Data from the yield experiments were subjected to F-test for homogeneity of variance between the years of experiment to determine whether data could be pooled. Analysis of variance (ANOVA) was performed in SAS PROC GLM and PROC NLIN (SAS, 2003) and relative yield and total dry matter 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. To describe the effect of increasing duration of weed interference on relative yield and total dry matter, Gompertz model used to provide a good fi t to yield under increasing length of the weed-free period (Gompertz and Rawling, 1992) as:

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

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 DAE. A logistic equation (Jamali *et al.,* 2011) was used to describe the effect of increasing lengths of weed-infested period on elative yield and total dry matter which described as following equation:

$$Y = \exp(a+b/T).$$

Y is the yield as a percentage of the weed-free control, A and B are curve parameters, and T is time in DAE. Yield loss of 2.5, 5 and 10 % was chosen to calculate the beginning and end of the critical period. Using the derived equations, the critical duration of the weed-free period and the critical length of weed-infested period were calculated for specific yield loss level in DAE.

Results and discussion

The major weeds in experiment and weather data are shown in Tables 1 and 2. Weeds: *Stachys byzantin* and *Conrengia orentalis* had the highest and the lowest density during growing season respectively and the most density of Stachys *byzantine* find in 42-56 DAE. The Previous results for the major weeds in chickpea have been variable. Rashid *et al.* (2009) reported that in rainfed areas the important weeds of chickpea are *Medicago polymorpha* L., *Annagalis arvensis* L., *Cypress rotundus* L., *Convolvolus dactylon* L., *Lathyrus aphaca* L., and *Carthamus* *axycantha*. But Tepe *et al.* (2011) showed that the major weed species of *Centaurea depressa* Bieb., *Bromus tectorum* L., *Salsola ruthenica* Iljin., *Amaranthus* spp., *Sisymbrium septulatum* DC. and *Heliotropium europaeum* L. were determined as the main weed species.

Table 1. Weather data (temperature and precipitation) during the growing season.

Month	Temperature (ºC)		Precipitation(mm)
	Mean max	Mean min	
21March-4April	17.1	2.6	16.2
5 April-20April	16.1	1.3	50.2
21April-5 May	17.2	4.1	66.8
6 May-21 May	22.1	4.5	18.2
22 May-5 June	27.3	5.9	0.3
6 June -21 June	30.1	6	1.6
22 June-6 July	32.8	6.8	0
7 July-22 July	35.4	12.2	3.7

Table 2. Major weed species and average their densities (plant/m²) in interference periods at chick pea.

Species/DAE	14	28	42	56	70
Stachys byzantina	0.3	20	30	31	18
Aristolochia mororuam	1.3	0.3	0	0	0
Tragopogon dubius	3	2	2.3	9.3	0.6
Lactuca spp.	0.3	0.6	0.6	0	0
Gypsophila pilosa	1	1	0.6	0.6	0.6
Euphorbia helioscpia	0.6	0.6	3.3	3	0.3
Gypsophila pilosa Conrengia orentalis	0.3	0.6	0.3	0	0
Total	6.8	25.2	37.1	43.9	19.5

Table 3. Analysis variance of square means of the traits under different weed-free (control) and weed -infested (interference).

Variable	df	Pod in plant	Seed in plant	1000-grain weight	Dry matter	Yield
			Interfaces			
R	2	ns 1.5	279.5**	**27160.8	ns 13.16	ns 76603.5
T	5	**47.43	**2651.9	**952750.2	**49181.2	**5265582.4
Error	10	0.83	20.76	1543.82	254.76	42630.3
CV		5.88	6.46	2.6	5.3	7.12
			Control			
R	2	ns 78853.1	ns 187.5	ns 3267.05	ns 1.55	ns 0.66
T	5	**5033702.5	**39948.7	**874938.8	**11.42	**66.23
Error	10	25161.7	516.68	2108.7	1.28	1.6
CV		5.18	7.24	2.77	6.38	7.98

Clearly, analysis variance showed that the impact of interference weed periods on all of the traits were significantly (P<0.01, Table 3). Reduction in seed yield caused by the increased length of weed interference period, was associated by contemporary diminish in pod in plant, seed in plant, 1000 grain weight, and total dry matter (Table 4). A similar results were reported on chickpea by Al-Thahabi *et al.* (1994), Rashid *et al.* (2009), Tepe *et al.* (2011) and Fathi *et al.* (2011) where weed interference decreased simultaneously number of pod per plant and 1000 grain weight. Conversely, the beneficial effect of reduced weed competition saw on pod in plant, seed in plant, 1000 grain weight, and total dry matter, which is ultimately reflected in seed yield. Weed infested conditions for the entire growing season led to 76.4-85.8% and 78.5-85.7% reduction in chickpea dry matter and seed yield compared with full-season weed-free treatments (Table 4). Also, seed yield and dry matter loss increased as a response to increasing weed dry weight (data not showed).

Table 4. Means values of the traits under different weed-free (control) and weed -infested (interference) at chick pea.

Variable/Period	Pod in plant	Seed in plant	1000-grain weight(g)	Dry matter(g/p)	Yield(kg/ha)
			Control		
82	22.66 a	21 a	1980 a	416.66 a	4133.3 a
70	19.66 b	19 ab	1936.6 b	385.66 a	4015 b
56	16.3 c	17.6 bc	1880 c	376.67 ab	3815 c
42	13.6 d	17 bc	1835 d	341.66 b	3413.3 d
28	12.6 d	16.33 c	1731 d	273.3 c	2111.3 d
14	10 e	15.66 c	566 e	98.33 d	885 e
LSD(0.05)	2.3	2.06	83.54	41.35	288.58
			Interfaces		
14	21 a	25 a	1746.6 a	387.3 a	3921.7a
28	18.6 b	24.3 a	1745.3 a	378 a	3814.4 a
42	16.3 c	21.6 a	1744 a	372.3 ab	3647.3 ab
56	14.3 d	21 a	1740 a	344 b	3347 b
70	12.3 e	20.6 a	1725 a	267.3 c	2100.3 c
84	10.3 f	10.3 b	360.6 b	55 d	555 d
LSD(0.05)	1.66	8.29	71.48	29	375.63

Table 5. Parameters estimated for the Gompertz model used to fit yield and dry matter data for increasing interference and weed periods.

Variable	mean ±se	K±se	b ±se	a ± se	R^2	CV
Yield	289.11 ±3062.17	0.006 ±0.067	0.59 ±4.18	97.95 ±4205.7	0.99	4.81
Dry matter	25.90 ±313.72	0.009 ±0.086	0.87 ±4.56	8.48 ±395.1	0.99	3.21

Table 6. Parameters estimated for the Logestic model used to fit yield and dry matter data for increasing interference and weed periods.

Variable	mean ±se	b ±se	a ± se	R^2	CV
Yield	540.82 ±2897.33	3.42 ±9.76	0.15 ±7.66	0.89	3.1
Dry matter	52.24 ±300.5	3.38 ±8.4	0.15 ±5.44	0.91	5.4

Table 7. The critical duration of weed controlling in chick pea in days after crop emergence, as calculated by the Gompertz and Logestic equations .

	Loss level (%)					
Variable/Time/level	Begin			Finish		
	10	5	2.5	10	5	2.5
Yield	43	36	31	53	60	66
Dry matter	36	26	19	48	71	80

The CPWC provides a guideline for timing controlling of weeds and the critical period of weed interference can be varied between crops with the relative time of weed emergence, because it can lead to the earlier beginning of the critical period (Knezevic *et al.*, 2002). The coefficients of Gompertz and Logestic models are presented in in Tables 3 and 4. Models generally described data well, as appointed by the R^2 value and lower value of CV (Table 3, 4).

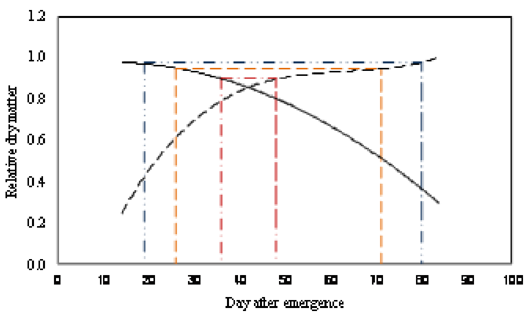

Fig. 1. Chickpea dry matter response to increasing length of weed-free and weed- infested in three loss level (2.5, 5, 10%).

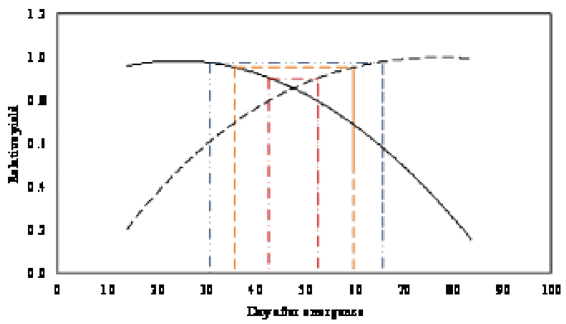

Fig. 2. Chickpea seed yield response to increasing length of weed-free and weed-infested in three loss level (2.5, 5, 10%).

Results showed that in order to prevent >10% yield and total dry matter loss, the maximum time weeds could be allowed to grow after crop emergence were 43 and 36 DAE respectively(Fig. 1, 2). In other words, critical period of weed control at 10% yield and total dry matter loss were form 43-53 DAE and 36-48 DAE respectively (Table 5). Also, critical period for weed control at 5 % yield and total dry matter loss was 36-60 DAE and 26-71 DAE. But critical period at 2.5 % yield and total dry matter loss was widespreader than other and was 31-66 DAE and 19-81 DAE for yield and total dry matter loss respectively. Smichger(2010) reported that Based on a 5% yield 193 loss threshold, the CPWC for the 'Sierr a' chickpea was 16 to 26 DAE. In western Iran, Mashhadi and Ahmadi (1998) estimated a CPWC of 27 to 44 DAE, between the 6 to 14 leaf stage, and 205 to 385 GDD. Al-Thahabi *et al.* (1994) in Jordan estimated a CPWC from 35 to 49 DAE; Masood-Ali (1993) in India estimated a CPWC from 0 to 56 DAE; Ahlawat *et al.* (1981) in India estimated a CPWC from 28 to 56 DAE. The average of these estimates is 23 to 52 DAE, but the range of 189 estimates for the lower and upper limits were 0 to 35 and 42 to 60 days after emergence, in other crops, it has been reported that weed interference can be tolerance up to a certain period (Mohammadi *et al.,* 2004). However, Kenzevic *et al.* (1997) suggested that in most situations the relative weed emergence time was more important than actual weed density. Slow crop emergence and canopy closure allow weeds to establish without significant suppression by the crop. Early establishing weeds have a competitive advantage over chickpea and will severely reduce crop yields if not controlled (Hock *et al.,* 2006; Jeschke *et al.,* 2009; Kropff *et al.,* 1992).

Conclusion

Finding of this research coordinate with other results show that critical period for weed control in chickpea field are not stable and it dependent on environmental conditions, species and loss level, thus it recommended that in west northern of Iran weeds in chickpea must be controlled in 19-80 DAE for minimizing of loss in yield and dry matter.

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