ORIGINAL ARTICLE

Estimation of critical period for weed control in sesame (*Sesamum indicum* L.) in northern Ethiopia

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(Received in revised form: June 7, 2011)

ABSTRACT

A field experiment was conducted for three consecutive cropping seasons (2006, 2007 and 2008) to estimate the critical period of weed control and yield loss in sesame at Humera Agricultural Research Center, Northwestern Ethiopia. Quantitative series of both increasing duration of weedy and weed free periods were compared with complete weed free and weedy check. The experimental design used was RCBD with three replications. The results indicated that the experimental field was infested both with broadleaved (90.1%) and grassy (9.9%) weeds. Three years pooled data revealed that, *Ocimum basilicum, Corchorus trilocularis, Corchorus orinocensis and Hibiscus trionum* were among the dominant broadleaved weeds where as *Digitaria abyssinica and Digitaria ternata,* were the dominant grassy weeds. Significant difference in dry weed biomass was observed both under early and late competition periods in all the three years. Uninterrupted weed growth caused a reduction of 82.9%, 82.5% and 86.3% in 2006, 2007 and 2008 respectively, in yield as compared to complete weed free. On the other hand, the yield loss from weedy up to 14 and weed free up to 28 or more days after crop emergence were less than 10% and hence, the critical period of weed control in sesame at Humera area was found to be between 14 and 28 days after crop emergence with duration of 14 days.

Keywords: Critical period of weed control, Sesame, Threshold points, Yield loss

INTRODUCTION

Integrated weed management (IWM) involves a combination of cultural, mechanical, biological, genetic, and chemical methods for effective and economical weed control (Swanton and Weise, 1991). The principles of IWM should provide the foundation for developing optimum weed control systems and efficient use of herbicides (Mahmoodi and Rahimi, 2009). The critical period for weed control (CPWC) is a key component of an IWM program. It is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses (Zimdahl, 2004). Controlling weeds based on CPWC is the most appropriate way to optimize weed control applications (Swanton and Weise, 1991; Kavaliauskaite and Bobinas, 2006; Mahmoodi and Rahimi, 2009). With the aid of PWC it is possible to make decisions on the need for and timing of weed control, and to control weeds only when efficient weed control is required.

The CPWC is the time period in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield loss (Evans *et al*., 2003). It has been defined as the time interval between the maximum weed-infested period, or the length of time that weeds which emerge with the crop can remain uncontrolled before they begin to compete with the crop and cause yield loss, and the minimum weed-free period, or the length of time that the crop must be free of weeds after emergence (Kropff *et al*., 1993). Thus, it is the minimum period of time during which the crop must be free of weeds to prevent crop yield loss. Knezevic *et al*. (2002) described CPWC as a "window" in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield losses. The length of the CPWC may vary depending on the acceptable yield loss (Hall *et al*., 1992). The CPWC is determined by calculating the time interval between two components of weed interference. These are (1) the critical weed interference period or the maximum length of time during which weeds emerging soon after crop planting can coexist with the crop without causing unacceptable yield loss, and (2) the critical weed-free period or the minimum length of time required for the crop to be maintained weed-free before yield loss caused by late emerging weeds is no longer a concern (Evans *et al*., 2003; Mahmoodi and Rahimi, 2009; Uremis *et al*., 2009).

In Ethiopia, sesame is cultivated as market oriented commodity that provides raw materials for industries and is a source of employment. It grows well in the lowland areas of the country. Within the lowland, Setit Humera is the major sesame producing area, where, it is produced as commercial commodity. Area under sesame has increased to 211,312 ha in 2006/07 from 58,780 ha in 2001/02 and has become one of the leading export oil crops in Ethiopia where by 90% of the production is directed towards export (EASE, 2007). Weeds are one of the most important factors in sesame production in western Tigray. They cause important yield losses with an average of 15% despite weed control applications and 100% in the case of no weed control (Etibark, personal communication). Therefore, weed control is an important management practice for sesame production that should be carried out to ensure optimum seed yield. Weed control in sesame in the study area is carried out by hand hoeing.

Although this method is effective in controlling weeds, it increases production costs and has some disadvantages or side effects when applied intensively and/or repeatedly. To reduce the costs and risks of intensive weed control, the frequency or intensity of applications should be reduced or optimized. Studies have been conducted around the world to determine the CPWC in sesame, with a range of environmental conditions. Beltrao (1997) reported a weed-free period of 60 days after emergence (DAE) for sesame in order to prevent yield loss in Sausa whereas, 30 to 35 DAE in the Monteiro. The field study conducted in India showed that the most critical period of crop-weed competition in sesame occurred from 30 to 45 days after sowing (Venkatakrishnan and Gnanmurthy, 1998).

It can be concluded from the results of previous studies that the CPWC values are variable depending on the location or growing season. These differences can be attributed to variations in the composition of weed species, initial density or ground cover of weeds, as well as to climatic conditions, in which crop and weeds interfere (Knezevic *et. al*., 2002). Topography, climate, crop genetics, and cultural practices, such as tillage intensity, fertilization, seeding rate, and row width, are several factors that may influence the CPWC by directly affecting weed composition, weed density, time of weed emergence relative to the crop, or crop and weed growth (Mahmoodi and Rahimi, 2009). Thus, there is tremendous variability in the CPWC. In addition, many of the weed species studied are not common in western Tigray. Results obtained from previous studies also showed variability in the CPWC even with similar weed species because of site-specific factors such as planting pattern and environmental conditions (Beltrao, 1997; Venkatakrishnan and Gnanmurthy, 1998). In order to provide more precise information for growers, CPWC should be determined specifically for a particular region by considering the weed composition and climatic conditions (Knezevic *et al*., 2002). Therefore, this study aimed to estimate the optimum timing for weed control in sesame and to determine the effect of the timing of weed removal and the duration of weed interference on sesame yield under the growing conditions of Humera province in northwestern Ethiopia, an area for which this type of information is lacking.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted for three consecutive cropping seasons during 2006, 2007 and 2008 under hot to warm semi-arid lowland plains in Setit-Humera, northwestern Ethiopia. Its northern and southern boundaries coincide with $13^{0}14'$ to $14^{0}27'$N latitudes, and $36^{0}27'$ to $37^{0}32'$ E longitudes with an altitude of 568 m above sea level. The dominant soil type of the site is chromic black vertisol and characterized by deep (150 cm) clay textured with 40 to 60% clay content, electrical conductivity of 0.047 to 0.17 g mmohs/cm, low organic matter content (<2%), and CEC ranged from 37 to 77 meq/100g of soil (EARO, 2002). The annual rainfall of the area is about 448 mm and the mean annual temperature varies from 25^{0}C to 27^{0}C. Naturally occurring weed populations were utilized in all the experiments. The farmers and/or investors practiced sesame-sorghum rotation until few years back, but have completely shifted now to mono cropping of sesame due to its attractive market worldwide.

Experimental design and treatments

Plots were seeded on July 17, 2006, July 10, 2007 and July 8, 2008. Sesame was seeded in rows 40 cm apart. The seedlings were tinned at intra-row spacing of 10 cm, when the plants attained approximately 5 cm height. Each plot consisted of 10 rows of 3 m long with a net plot area of 2.4 m x 2 m for the determination of yield. The experimental treatments were arranged following the method described by Neito *et al*. (1968). The experimental design for each study was a randomized complete block design with three replications. Two series of weed removal treatments were included. In the first series, treatments of increasing duration of weed control were maintained weed free until 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days after crop emergence (DAE). In this series, the weeds were subsequently allowed to grow until the crop matures. The weeds were removed 10 days prior to final harvest to avoid leaf foliage and shedding of weed seeds. In the second series, weed interference treatments of varying duration allowed weeds to compete with sesame plants from crop emergence until 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 DAE. The plots were then weeded and kept weed free until crop maturity. Weeds were removed by hand pulling and hoeing using "mowled". These treatments are compared with complete weed free and weedy check.

Sampling and measurements

Count for weed flora present in the experimental field was taken from weedy check plots by placing a quadrate (0.5 m x 0.5 m) at two random locations of a plot in each replication. Weeds within the quadrate were counted and categorized as broadleaved and grassy weeds. Data on dry weed biomass was taken at the time of weed removal for early competition series and about 10 days before final harvest in the case of late competition series to avoid possible foliage and seed shedding. The harvested composite weeds from the two quadrates per plot were oven dried at 65^{0}C until constant weight was achieved to measure the above ground dry matter weight.

Estimation of critical period of weed control in sesame

The threshold point and duration of critical period was determined by using response curve adopted by Hall *et al.* (1992). The onset and end of critical period that is the duration within which weed control is mandatory was estimated by the response curve when both curves attained 90% of relative yield gain and 10% yield loss of the complete weed free. The critical period was determined and found to be in between these two threshold points. The yields of three-year treatments analyzed together were significantly different between years; thus, for this reason each year was analyzed separately. Yield loss due to weeds was estimated by comparing mean sesame yields obtained from treated and complete weed free check (Neito *et al.,* 1968). Yield data of individual plots were calculated as the percentage of their corresponding weed free plot yields. Relative yield data were subjected to analysis of variance with the use of the PROC GLM function of Statistical Analysis System (SAS, 1999), to assess the effect of the length of the weed-free period and increasing duration of weed interference on relative sesame yields. Yield loss was calculated for each year separately as follows:

$$\text{Yield loss}\,(\%) = \frac{\text{Yield of weed free plot} - \text{Yield of treated plot}}{\text{Yield of weed free plot}} * 100$$

RESULTS AND DISCUSSION

Weed flora and density

Both broadleaved and grassy weeds were found in the experimental field are listed in Table 1. The three year pooled data indicated that the relative density of broadleaved weeds (90.2%) was more than that of grassy weeds (9.8%). Among broadleaved weeds *C. trilocularis and O. basilicum* were the most dominant that contributed 28.9% to total weed population. Among the grassy weeds, *Digitaria abyssinica and Digitaria ternate* were the dominant ones.

Yield loss

For the less than 10% yield loss level, the time required for weed-free maintenance was similar in all the three years (Table 2). Likewise the greater the percentage loss, the less weed free time required for all the years considered. Uninterrupted weed growth resulted in 82.9, 82.5 and 86.3% reduction in yield as compared to complete weed free; whereas, 81.2%, 80.9% and 85% as compared to weedy up to 14 days (the beginning of critical period) and 81.1%, 81.1% and 85% as compared to weed free up to 28 days (end of critical period) in 2006, 2007 and 2008 respectively (Table 2).

Table 1. Weed flora and density (number m^{-2}) present in the experimental field

Weed flora	Number/m^2
Broad-leaved weeds	
Commelina benghalensis L.	10
Convolvulus arvensis L.	20
Corchorus orinocensis L.	26
Corchorus trilocularis L.	35
Hibiscus trionum L.	24
Melothria ciprianii Pichi-Serm.	17
Ocimum basilicum L.	30
Polygonum nepalense L.	17
Senna obtusifolia (L) Irwin &Bamby	18
Traxacum officinale L.	6
Grassy weeds	
Aristida oligantha Michx	2
Digitaria abyssinica (A.Rich) Stapf	6
Digitaria ternata (A. Rich.)	5
Dinebra retroflexa (Vahl.) Panzer	4
Rottboellia cochinchinesis L.	5

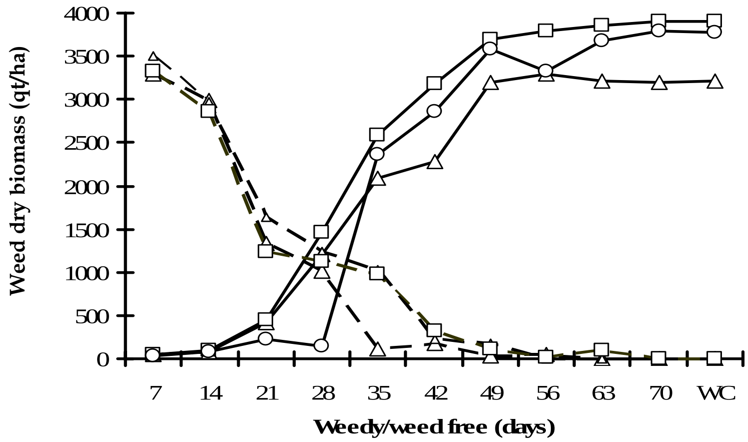

Figure 1. Weed dry weight as affected by increasing duration after emergence of sesame crop maintained as weed free (- - -) for increasing durations after emergence or weed infested (___) for increasing durations after emergence. Symbols represent means for each year: 2006 (Δ), 2007 (O) and 2008 (□).

Table2. Yield loss of treated plots as compared to complete weed free plot

Late competition (weed free up to)	Yield loss			Early competition (weedy up to)	Yield loss		
	2006	2007	2008		2006	2007	2008
7	73.0	73.0	80.4	7	4.1	4.1	3.0
14	55.9	55.9	78.3	14	8.0	9.2	8.6
21	41.2	41.2	77.8	21	52.5	55.2	29.2
28	8.3	8.3	9.1	28	67.9	67.9	42.5
35	6.9	6.0	7.8	35	69.9	69.9	49.3
42	4.1	5.0	6.5	42	80.7	80.7	53.4
49	2.7	2.7	6.2	49	81.0	81.0	56.0
56	2.0	2.0	4.0	56	81.2	81.2	64.0
63	1.2	2.0	3.0	63	81.9	81.9	78.0
70	0.9	0.9	0.7	70	81.9	81.9	80.0
Complete weed free	0.0	0.0	0.0	Weedy check	82.9	82.5	86.3

Generally, the yield loss in early competition increased with increased time of weed interference whereas in the increased weed free period the yield loss decreased as time increased. This indicated that the competitive ability of a given density of weeds which emerged with the crop and their dry matter production was strongly dependent on the length of the period they remained in the field with sesame. These results are inline with the findings of Aziz (1993), Kavaliauskaite and Bobinas (2006), Oad *et al*. (2007) and Kavurmaci *et al*. (2010).

Critical period for weed control in sesame

In the early competition, dry weed biomass remained relatively constant after 42 DAE in 2006 and 2007 while in 2008 the consistency was observed beginning at 63 DAE. In contrast, weed biomass at harvest was reduced when sesame was kept weed free up to 21 or more days after emergence in all the three years (Fig. 1). In this study, few weed seedlings emerged after 28 days in the weed free treatments. Weeds that emerged in this case grew in a competitive disadvantage in comparison with the plants of the crop. Sesame competition was sufficient to prevent yield losses from weeds that germinated after 21 days or more, which could be due to shedding effects of sesame plants. Several researchers (Frantik, 1994; Uremis *et al*., 2006; Mubeen *et al*., 2009; Kavurmaci *et al*., 2010) established the importance of time of emergence of the weeds. Generally, weeds that emerge simultaneously with the crop or shortly after the crop cause severe yield losses at very low densities. However, when the period of emergence is postponed the magnitude of yield loss decreases.

The beginning of the critical period was defined as the crop stage or days after crop emergence when weed interference reduces yields by a predetermined level (in this case 10%). The end of the critical period was defined as the crop stage or DAE until the crop must be free of weeds in order to prevent a predetermined level of yield loss (Hall *et al*., 1992). Results indicated that to prevent greater than 10% yield loss, the maximum time for which weeds could be allowed to grow after crop emergence was 14 days and the crop must be free of weeds to prevent a predetermined level of yield loss and that period was 28 DAE. In this study, the detrimental effect of early weed competition was more severe than the late competition (Fig.2). The critical period for weed competition for sesame in Humera area was found to be approximately 14 to 28 DAE with duration of 14 days (Fig. 2).

Removing weeds between these two points is usually adequate to prevent the sesame plants from damage due to weeds. Critical period at this location was earlier than that reported by different authors at different locations. Beltrao (1997) concluded that sesame crop should be kept free from weed competition from planting time to 60 DAE in Sausa, and from planting to 30 to 35 days after emergence in Montairo. The field study conducted in India showed that the most critical period of crop-weed competition in sesame occurred 30 to 45 days after sowing (Venkatakrishnan and Gnanmurthy, 1998).

Probably the differences could be explained partially due to the differences in the physiographic, edaphic, biotic and competitive effects that determined the occurrence and establishment of weeds (Evans *et al*., 2003; Norsworthy and Oliveira, 2004; Mahmoodi and Rahimi, 2009).

Further, earlier start of the critical period of weed interference in the present study as compared to other locations could also be attributed to higher density of broadleaved weeds (Table 1) their early emergence and establishment. Moreover, weeds were similar to crop which might have also offered more competition due to same type of root system thereby compete for the same resources from the same soil depth. Also at the study area weather was very hot which probably allowed the weeds to emerge and grow rapidly.

Knezevic *et al.* (2002) reported that the critical period of weed interference for a given crop can vary with the relative time of weed emergence, because earlier weed emergence can lead to the earlier beginning of the critical period. Weed control under these conditions should be based on post-emergence cultivation, but if any yield loss is unacceptable, control practices must be begun as soon as possible after sesame emergence.

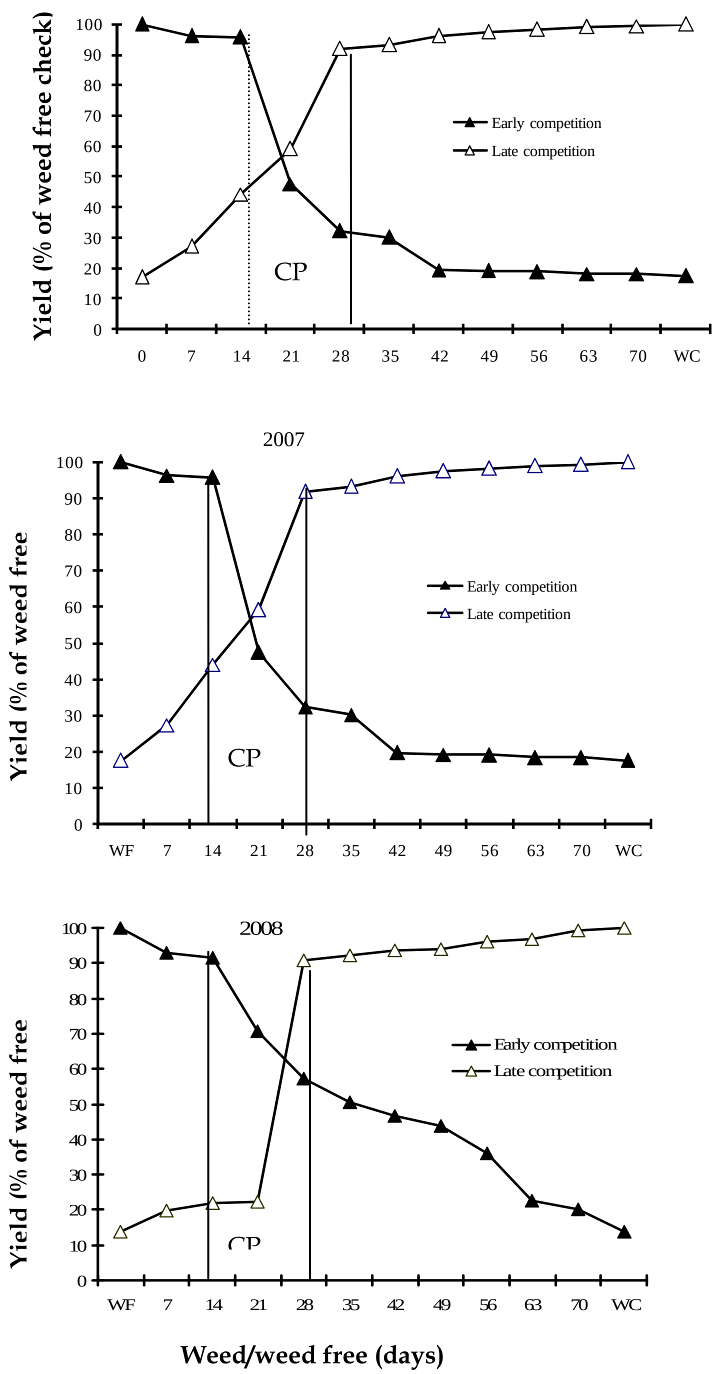

Figure 2. Sesame yield response to increasing length of weed free (late competition) or duration of weed interference (early competition) periods: CP (critical period).

CONCLUSION

Weeds are the bottlenecks that limit the production of sesame in the lowland plains of sesame producing areas of Humera. Farmers weeded their fields late in the season and as a result, faced a severe yield reduction every year due to weeds. Therefore, weeds should be removed at early sesame growth stage (up to 4 weeks after emergence). According to the results of this study, growers should remove weeds from their fields during the most appropriate critical period of weed control (14 to 28 DAE). Further studies should be conducted to determine the critical periods in other areas, where weed populations are different from those reported here.

ACKNOWLEDGEMENTS

The author would like to thank the Tigray Agricultural Research Institute for financial support and the staff of Humera Agricultural Research Center for their unreserved support during the field work.

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