Critical Crop - Weed Competition Period and Yield Loss Determination in Transplanted Tomato (*Lycopersicon esculentum* M.) at Guder Ethiopia

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Abstract

A field experiment was conducted for two consecutive cropping seasons of 2013 and 2014 to determine the critical period of weed competition and yield loss in tomato at Guder, Ethiopia. Quantitative series of both increasing duration of weedy and weed free periods were compared with complete weed free and weedy check. The experiment comprised of fourteen treatments laid in a randomize complete block design (RCBD) with three replications. The experimental site was infested with different weed species belonging to different families. In 2013 cropping season, 11 weed species belonging to 9 families were identified. Among the identified species, 81.81% were broadleaf weeds whereas sedges and grass made up 9.09% and 9.1% respectively. In 2014 cropping season the experimental site was infested with 12 different weed species belonging to 8 different families. Eighty three percent were broad leaved weeds while the remaining 8.33 % and 8.33 % were sedges and grass weeds, respectively. Pooled data revealed that, Amaranthus spp, Amaranthus hybridus L., Bidens pilosa L., Commelina benghalensis L., Datura stramonium L., Guizotia scabra (Vis.) Chiov., Galinsoga parviflora Cav., Ipomea cariocarpa and Nicandra physalodes Scop were among the predominant broadleaved weeds, whereas Digitaria abyssinica (A. Rich.) Stapf and Cyperus esculentus L. were the common grass and sedge weeds respectively. Significant differences in density, weed dry biomass, tomato yield and relative yield loss were observed in both years. Unweeded plots resulted in a yield reduction of 87.5 in 2013 and 90.8% in 2014 when compared to the yield recorded in weed free condition. Results indicated that to prevent greater than 10% yield loss, the maximum time for which weeds could be allowed to grow after crop transplant was 30 days, and the crop must be free of weeds from 60-75 days after transplanting to prevent a predetermined level of yield loss.

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

Introduction

Tomato is a popular and widely grown vegetable crop in Ethiopia, ranking 8th in terms of annual national production (Jiregna *et al.*, 2011). It is produced by both small scale farmers and commercial growers for local consumption as well as for processing industries. It is used in fresh as well as processed form in a variety of dishes. It is an important cash crop for small scale formers and also provides employment in production and processing industries (Jiregna *et al.*, 2011). The average yield is low, ranging from 6.5-24.0 Mg ha^{-1}compared with average yields of 51, 41, 36 and 34 Mg ha^{-1}in America, Europe, Asia and the entire world, respectively (FAOSTAT, 2010).

Growers have been challenged by inconsistent production and low yields, due to a number of factors of the constraints limiting tomato production, weeds appear to have the most deleterious effect causing yield reduction (Sanok *et al.*, 1979; Usoroh, 1983, Sinha and Lagoke 1984).

Adigun *et al.* (1993) reported 40 to 82% reduction in tomato fruit yield due to unchecked weed growth throughout the crop life cycle. Inorder to reduce the impact of weeds, farmers practice different weed control methods which includes cultural, mechanical, chemical methods and integrated weed management (Ashton and Monaco, 1991).

However, the pre request for designing a successful weed management strategy is to identify the critical period for weed control (Swanton and Weise 1991). Furthermore knowledge of the CPWC and the factors that affect it is essential for making decisions on the appropriate timing of weed control and in achieving the efficient use of herbicides (Van Acker *et al.*, 1993; Knezevic*et al.*, 2002; Mulugeta and Boerboom, 2000). The critical period of weed control is the portion of the life cycle of a crop during which it must be kept weed-free to prevent yield loss due to weed interference (Martin *el al.*, 2001). Furthermore, the period of the crop growth when it is most susceptible to weed interference has been regarded as the critical period of weed competition The knowledge of critical period of crop-weed competition is a pre-requisite for a good harvest. (Nieto *et al.*, 1968).

In Ontario, Canada, Friesen (1979) reported that the tomato crop kept weed-free from 24-36 days. The author, however, observed that when weeds were allowed to remain in the crop for more than 24 days after transplanting, yields were progressively reduced. In Maryland in the United States of America, Beste (1979) reported that, tomatoes needed to be kept weed-free for 6 weeks after transplanting to avoid reduction in yield. In South Western Nigeria, Usoroh (1983) demonstrated that weed competition in most cultivated varieties of tomato is most critical between transplanting and 6 weeks later. According to Adigun (2005) the crop was most critically affected by weed interference between 3 and 6 Weeks after transplanting. However, most farmers in the tropics frequently fail to control weeds at appropriate time. This could be due to lack of capital and the knowledge of the critical period of weed control and its impact on crop yield.

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). Additionally, in Ethiopia extensive weed competition studies have not been undertaken yet in vegetable crops in general and in tomato in particular. By considering climate and weed composition variability this study was to determine the critical period for weed competition on transplanted tomato and to investigate the effect of weed competition on tomato yield.

Materials and Methods

Description of study area

Critical weed completion period and yield loss determination on tomato (*Lycopersicon esculentum* L.) was conducted in west Showa Zone of Oromia National Regional State at Guder, Toke kutaye district, Ethiopia, which is situated at 128 km west of Addis Ababa and 12km from capital town of West Showa Zone, Ambo under farmers' field condition in 2013 and 2014 growing season. The altitudinal range of the area is between 1,600 and 3,192 m. a. s. l. The major soil types are vertisols and nitosols. The mean annual rain fall is 800 and 1000mm. The minimum and maximum temperature is 10 and 29ºc.

Treatments and experimental design

The experiments were carried out for two consecutive years during the 2013.and 2014 growing season. Two types of weed interference treatments were implemented after transplanting. The first treatment consisted of keeping the crop weed free for seven period of increasing number of days from the crop transplanted onwards. Weeds emerging after each period were left on the plots. Weed removal was started immediately after transplanting and the plots were kept weed-free up to harvest from 15, 30, 45, 60, 75 and 90 days after transplanting by periodic hand hoeing. The second set of treatments consisted of allowing the weed vegetation to grow for equivalent period of weed free arranged in randomized complete block design with three replications using the same interval of 15, 30, 45, 60, 75 and 90 days after transplanting. Fourteen treatments were included in each experiment. The weed free and weed infested treatments were established at level that was facilitate the determination of minimum time of weed free and maximum time weed infested period that is the onset and ends of critical period of weed control. Control plots were kept free of weeds or left weedy throughout the growth period (days after transplanting). Naturally occurring weed populations were utilized during the study period. The plot used for each treatment was a 3.5 m × 3 m size, 70 cm was left between rows and 30 cm between plants. Each plot has got 5 rows of tomato plant. The two outer rows was used as buffer rows and the 3 middle rows were used for weed biomass and yield assessments. Other agronomic practices were carried out as per recommendation of the crop. All the phosphorus and half dose of nitrogen were applied at the time of transplantation, while remaining half dose of nitrogen was applied 20 days after transplantation.

Data collection

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

$$Relative\ Yield\ Loss = \frac{Yield\ from\ weedfree\ plot - Yield\ from\ treated\ plot}{Yield\ from\ weed\ free\ plot} X100$$

Data analysis

The onset and the end of critical period of weed control were

weed infested response curve. The onset of critical period of weed control was set at 10% and defined as the time at which a 10% reduction is expected due to weed interference. The Hall *et al.* (1992) logistic model was adopted to describe the effect of increasing duration of weed interference on tomato yield and to determine the onset of the critical period.

$$Y = [(1/ \{exp[c \times (T - d)] + f\}) + [(f - 1) / f]] \times 100$$ ---------- (Logistic equation)

Where, Y is the yield (% of season-long weed-free yield), T is the time (DAE), d is the point of inflection, c and f are constants.

While the end of critical period of was defined as the time during which the crop must be free of weed to prevent the yield loss exceeding 10 %.

$Y=a \exp(-b \exp(-k T))$ ----- (Gompertz equation)

Where Y is the relative yield (percent of season-long weed free yield), a is the yield asymptote or maximum yield in the absence of weed interference, b and k are constants, and T is the length of the weed-free period. The threshold point and duration of critical period was determined by using response curve adopted by Hall *et al.* (1992).

Relative yield loss was calculated for each year as follows:

All the data were subjected to analysis of variance using the SAS PROC GLM computer software package (SAS, 2009). Mean separation was done for treatments that show significant effect using the least significant difference (LSD) method at 5% probability level.

Result and Discussion

Weed flora and density

The result of the study showed that in the 2013 cropping season, the tomato crop was infested with 11 weed species belonging to 9 families. Among these, 81.81% were broadleaved weeds, whereas the remaining 9.09% and 9.1 were sedges and grass weeds, respectively. During 2014 cropping season the experimental field was infested with 12 weed species belonging to 8 families. Of the total weed flora, 83.3 % were broad leaved weeds, whereas the remaining 8.33 % and 8.33 % were sedge and grass weeds respectively. Family and species wise density varied in composition between the two growing seasons (Table 1). During 2013 cropping season, *Galinsoga parviflora* Cav (31.76 m^{-2}) was the dominant weed followed by *Amaranthus hybridus* L.(29.00 m^{-2}), whereas in the 2014 cropping season, *Amaranthus hybridus* L.(33.5 m^{-2}) was the dominant weed followed by *Galinsoga parviflora* Cav (21.53 m^{-2}) (Table 1).

Table 1. Predominant weed flora and mean density (number m-2) present in the experimental field

S.No	2013		2014	
	Weed species	Density (m^{-2})	Weed species	Density (m^{-2})
1	*Amaranthus hybridus*L.	29.00	*Amaranthus spps*	6.47
2	*Bidens pilosa* L.	0.53	*Amaranthus hybridus* L.	33.5
3	*Chenopodium procerum* (Hochst ex.) Moq.	1.61	*Bidens pilosa* L.	4.69
4	*Commelina benghalensis* L.	5.11	*Commelina bengnalensis* L.	6.00
5	*Cyperus esculentus* L.	4.24	*Cyperus esculentus* L.	2.14
6	*Datura stramonium* L.	2.39	*Datura stramonium* L.	1.47
7	*Digitaria abyssinica* (A. Rich.) Stapf	8.32	*Digitaria abyssinica* (A. Rich.) Stapf	3.14
8	*Galinsoga parviflora* Cav.	31.76	*Galinsoga parviflora* Cav.	21.53
9	*Guizotia scabra* (Vis.) Chiov.	5.68	*Guizotia scabra* (Vis.) Chiov.	2.06
10	*Nicandra physalodes* Scop.	1.07	*Ipomea ariocarpa*	0.92
11	*Polygonum nepalense* Meisn.	16.01	*Nicandra physalodes* Scop.	3.64
			Raphanus raphanistrum L	1.75
Total		87.31		105.72

Weed dry weight

The relationship between weed dry weight and weedy /weed free days is shown in Figure 1. As weed free period increased there was reduction in weed dry weight (gm^{-2}), may be due to lower density and short period of interference between the crop and weed to accumulate biomass whereas with increased in unweeded days there was increased weed dry weight (gm^{-2}) in both cropping seasons.

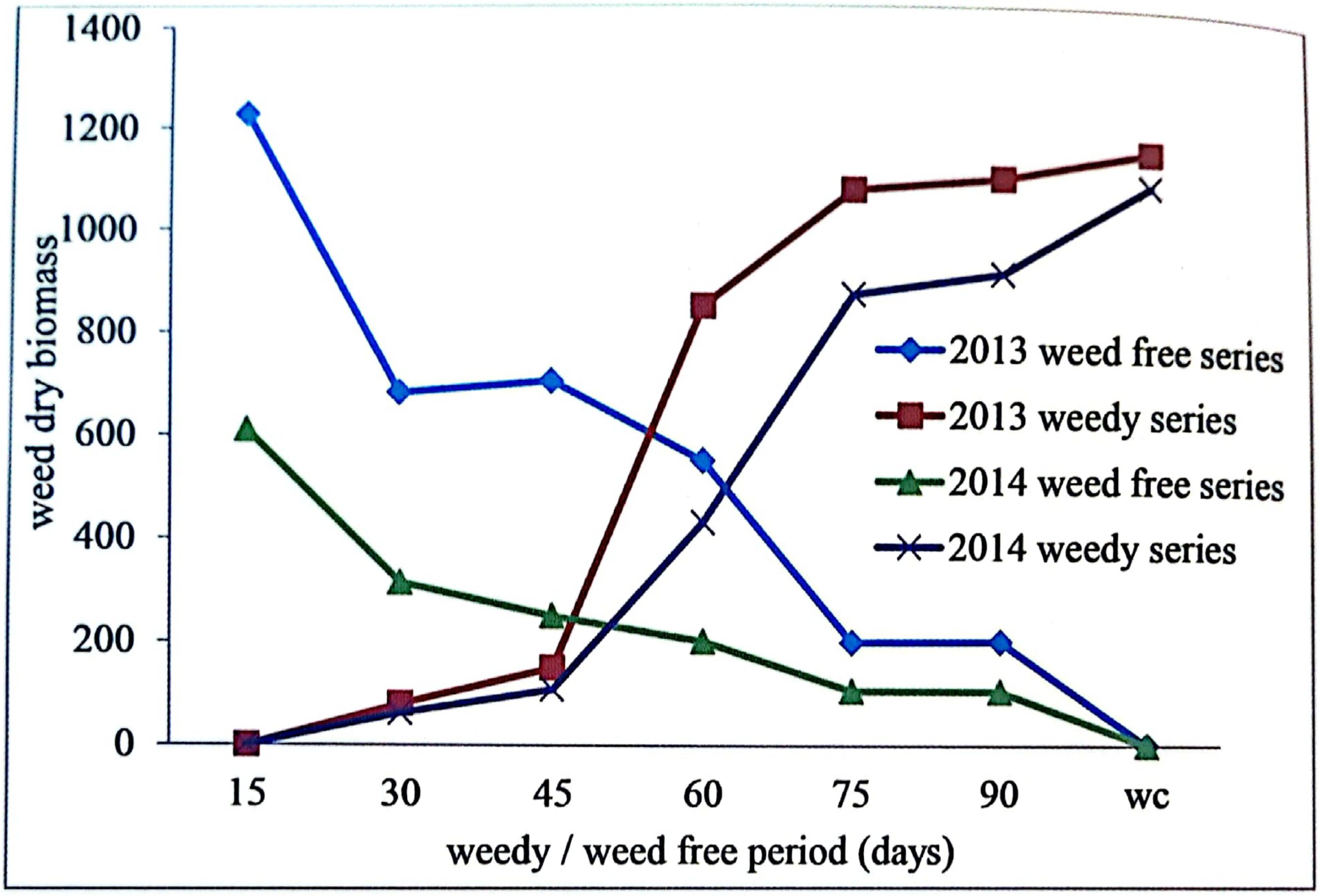


Figure 1. Weed dry weight as affected by increasing duration of weed free and/or unweeded condition after transplanting of tomato.

Relative Yield Loss

Data on the relative yield loss (%) presented in the Table (2) indicated that in the late competition, the highest relative yield loss (71.5%, 74.9 %) was recorded from weed free up to 15 days after transplanting whereas the lowest was recorded from weed free condition up to harvest (0.00%, 0.00%) which was not statistically significant from weed free up to 90 days after transplanting (1.4%, 3.2%) in 2013 and 2014 cropping season respectively. This may be due to higher weed crop competition for growth factors such as nutrient, water and space and higher density and dry biomass in weed free up to 15 days afte transplanting.

In early competition, also the relative yield loss was significantly affected, where the lowest relative yield losses (6.6, 6.4 %) were observed from 15 days after transplanting and the highest loss was recorded from the unweeded plots up to harvest (87.5, 90.8%) in 2013 and 2014 cropping season respectively. This may be due to lower weed crop competition for the growth and development factor (nutrient, water and space) and lowered density and dry biomass of weeds in unweed free up to 15 days after transplanting. While comparing the cropping season the highest yield losses was recorded during 2014 cropping season because there was higher density and biomass as compared to 2013 cropping season. Similarly early competition also caused higher yield loss as compared to late competition. This implied that early competition is more significant that the late competition in causing deleterious effect on productivity of tomato.

Table 2. Relative yield loss in late and early competition as compared to complete weed free plot

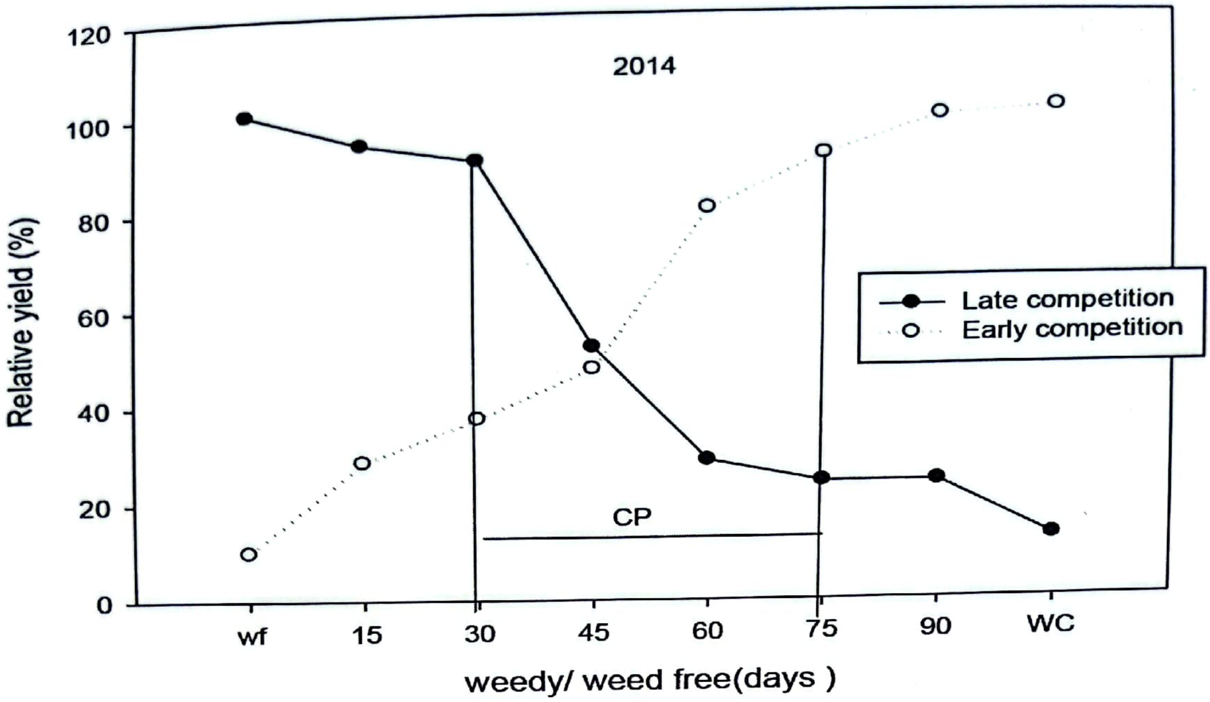
Late competition (weed free upto)	Relative yield loss		Early competition (weedy upto)	Relative yield loss	
	2013	2014		2013	2014
15 DAT	71.5a	74.9a	15 DAT	6.6d	6.4d
30 DAT	60.3b	54.4b	30 DAT	8.8d	11.2d
45 DAT	52.4c	17.7c	45 DAT	60.8c	51.9bc
60 DAT	30.2d	13.3cd	60 DAT	71.3bc	74.9ab
75 DAT	12.5e	4.4cd	75 DAT	75.9ab	79.7ab
90 DAT	1.4f	3.2d	90 DAT	75.9ab	82.3a
Complete weed free	0.0f	0.0d	weedy check	87.5a	90.8a
LSD (0.05)	7.58	13.53	LSD (0.05)	12.56	29.91
CV	13.05	31.71	CV	11.59	27.99

LSD= least significant difference, CV= coefficient of variation, DAT= Days after transplanting

Generally, the yield loss in early competition increased with increased time of weed interference whereas in late competition the increased weed free period the yield loss decreased. 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 along with tomato. Thus early period of crop- weed competition is more important that late competition in terms of yield reduction in crops

Critical period of weed control

The beginning of critical period is defined as the crop stage or days after crop emergence when weed interference reduces yields by a predetermined level (in this study 10%). The end of the critical period was defined as the crop stage or days after planting until the crop must be free of weeds in order to prevent a predetermined level of yield loss (Hall *et al.*, 1992). Results of this study indicated that to prevent greater than 10% yield loss, the maximum time for which weeds could be allowed to grow after crop transplant time was 30 days and the crop must be free of weeds up to 60-75 day after transplanting to prevent a predetermined level of yield loss. The critical period for weed competition for tomato crop at Guder area was approximately 30- to 60/75 DAT with duration of 30-45 days (Figure. 2). Removing weeds between these two points is usually adequate to prevent the tomato plants from damage due to weeds. Critical period at this location was later than that reported by different authors from different locations. Adigun (2005) concluded that the crop was most critically affected by weed interference between 3 and 6 WAT. 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). Also at the study area the weather was cold which probably allowed the weeds to emerge and grow slowly. 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 later weed emergence can lead to the later beginning of the critical period. Weed control under these conditions should be based on post emergence cultivation



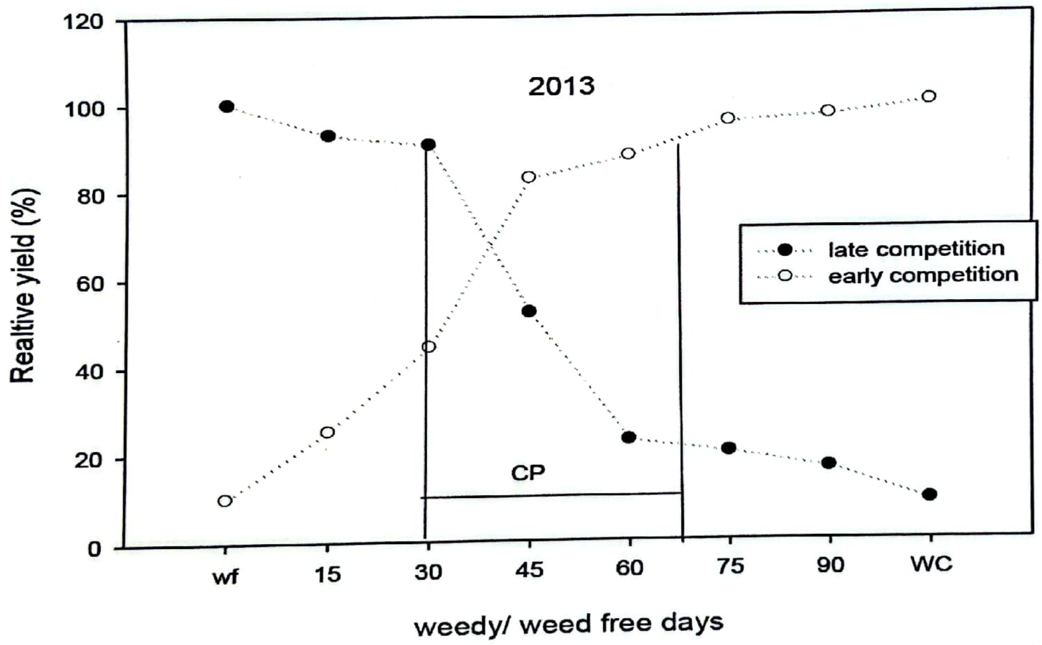


Figure 2. Tomato fruit yield response to increasing length of weed free (late competition) or duration of weed interference (early competition) periods: CP (critical period), wc = weedy check, wf = weed free

Conclusion

Weeds are the major biotic constraints that limit the production in the tomato producing areas of Guder. Farmers usually weed their fields late in the season, and as a result severe yield reduction was caused every year due to weeds. Uncontrolled weed growth caused a yield reduction of 87.5, 90.8% in 2013 and 2014 respectively, in yield as compared to weed free condition. Therefore, weeds should be removed at early tomato growth stage up to 4 weeks after emergence. Based on the results of this study, tomato producers are advised to keep their field from weeds from 30 to 68 days after transplanting.

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