Determination of Critical Period of Weed Control on Soybean in Assosa, Western Ethiopia

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Abstract

An experiment was conducted for three years (from 2013 to 2015) to determine the critical period of weed control (CPWC) in soybean (*Glycine max* (L.) Merr.) at the research farm of Assosa Agricultural Research Center in Assosa zone, Western Ethiopia. CPWC is an estimate of a duration that weed control must be effective to prevent weed interference from reducing yields or a time interval when it is essential to maintain a weed free environment to prevent crop yield losses. The study included two categories of treatments: WF0 = weed interference season long (no weed control), WF15, WF30, WF45, WF60, WF75, WF90 = weed free for 15, 30, 45, 60, 75 and 90 days after crop emergence (DACE), respectively; and WI0 = weed free season long (no weed infestation), WI15, WI30, WI45, WI60, WI75, WI90 = weed interference for 15, 30, 45, 60, 75, and 90 DACE respectively. Seed yield and yield components of soybean increased as the weed free period increased, and decreased as the weed interference period increased. When weeds were allowed to compete with the soybean for the whole growing season (WF0), the crop yield was reduced by 49.34% compared to the whole season weed free treatment (WI0). Based on 20 % acceptable yield loss (AYL) value model, results of this study revealed that the CPWC started at 15 DACE and ended at 60 DACE. Therefore, controlling weeds during this period, possibly two weed removal operations at the beginning and end of the critical period, is necessary to prevent a significant soybean yield loss.

Keywords: Soybean, CPWC, weeds, interference, acceptable yield loss

Introduction

In Ethiopia, soybean (*Glycine max* (L.) Merr.) was introduced in the 1960's (EIAR 1982). The crop is grown from sea level up to 2200 meters above sea level (Gurmu 2007). However, according to the report of Ronner and Giller (2012), Benshangul Gumuz, Southern Nations, Nationalities and People (SNNP) regions, and some parts of Oromiya region (areas around Jimma, Bedele and Chawaka) were high potential areas for soybean production in Ethiopia.

Soybean is economically and nutritionally important crop and provides a variety of benefits such as income generation for smallholder producers, improvement of nutritional diet, alternative market potentials for product diversification and value addition. In addition to being a potentially profitable cash crop, soybean also has potential agronomic benefit of rejuvenating soils by fixing atmospheric nitrogen in to the soil and decaying root residues to improve soil fertility (Mary *et al.* 2013).

Soybean production in Ethiopia is very low as compared to other pulses like Faba bean, Common bean and Chick pea in both area coverage and amount of tons produced. According to CSA (2015) report, Ethiopia cultivated soybean on 35259.76 hectares of land and from these 72183.745 tones of seed were harvested. In addition, the productivity of this commodity on farmers' field has been very low when compared to research field (Abush 2012). The low yields can be attributed to several yield reducing factors. Among the factors, weed infestation is the one that induces grain yield reduction of soybean. It is obvious that, weeds compete with field crops for light, water and nutrients. This competition decreases plant vigor, yield and crop quality. In addition to these, weeds also serve as alternative hosts to other agricultural pests (like diseases, insects, viruses and nematodes) and weed infestation make hand harvest difficult.

Presence of weeds in a field does not always mean that crop yield will be reduced and there are some periods during the growing season when weeds will not cause considerable yield loss. These implied weed management at proper time should be given importance because weeds use resources that would otherwise be available to the crops (Zimdahl 2004). Thus, this calls for the determination of a critical period of weed control (CPWC), which is the base of an Integrated Weed Management (IWM) strategy.

According to Hall *et al.* (1992) and Knezevic *et al.* (2002) the CPWC is an estimate of the duration that weed control must be effective to prevent weed interference from reducing yields. Swanton and Weise (1991) also defined CPWC as the time interval when it is essential to maintain a weed free environment to prevent crop yield losses. Therefore, CPWC determines the points or times when to control weeds in field crops and it can help growers to control weeds within the crop at this points or times to prevent yield loss and/or minimize yield loss to an acceptable yield loss (AYL) by minimizing their competition with the crop throughout the growing season (Amir 2013). Evans *et al.* (2003) found that, the end of the CPWC is not stable and is highly related to density, competitiveness and emergence periodicity of weed populations present in the field. For estimating the CPWC, researchers usually apply two types of treatments or different intervals of weed control and weed presence, in field experiments. Moreover, the length of the CPWC could be different depending on the level of acceptable yield loss (AYL). In case of Benishangul Gumuz region (particularly Assosa zone), yet there was no research study made on soybean weed management; even though, the crop (soybean) was currently becoming popular crop in area. Taking this in to consideration, knowing the CPWC will help soybean growers to manage weeds effectively and help them make decisions on the timing of weed control. Therefore, this study was conducted with the aim of determining CPWC in soybean at 20 % level of AYL.

Materials and Methods

Description of the study area

The experiment was conducted from 2013 to 2015 cropping seasons on naturally infested fields with common annual broadleaf and grass weed species at the research farm of Assosa Agricultural Research Center, located at 10° 03 N and 34° 59' E. The site has a *Dystric Nitosols* soil type. Total rainfall received during crop growing periods in 2013, 2014 and 2015 years was 1132.9 mm, 906.9 mm and 1133.5 mm respectively, with respective ranges of minimum and maximum temperatures of 14.54 °C to 15.38 °C and 27.08 °C to 27.72 °C.

Experimental design and treatments

Soybean variety, Belessa-95, was sown in 18 m^2 (5 m x 3.60 m) plots at a rate of 60 kg ha^{-1} (*i.e.* the spacing between rows and plants was 60 cm and 5 cm, respectively). The experimental design was a Randomized Complete Block Design (RCBD) with three replications and 14 treatments (Table 1). Treatments were categorized as weed free or weed interference at different days after crop emergence (DACE). In the weed free treatments, weeds were removed from soybean emergence until 15, 30, 45, 60, 75 and 90 DACE and then weed growth allowed up to crop harvest. In the weed interference treatments, weed vegetation were allowed to grow until 15, 30, 45, 60, 75 and 90 DACE and then plots maintained weed free up to crop harvest. In addition, season-long weed free and weed infested checks were included for comparison. Weeds were removed by hand and hand hoeing in all plots according to the treatments. For quantification of yield, the 4 central rows in each plot were harvested and the seed yields were adjusted to 12.5 % moisture.

Table 1. Treatment descriptions for CPWC determination for soybean in Assosa zone

Weed free treatments			Weed interference treatments		
Treatment codes		Descriptions	Treatment codes		Descriptions
T1	WF15	Weed free for 15 DACE	T 8	WI15	Weedy for 15 DACE
T2	WF30	Weed free for 30 DACE	T 9	WI30	Weedy for 30 DACE
T3	WF45	Weed free for 45 DACE	T 10	WI45	Weedy for 45 DACE
T4	WF60	Weed free for 60 DACE	T 11	WI 60	Weedy for 60 DACE
T5	WF75	Weed free for 75 DACE	T 12	WI75	Weedy for 75 DACE
T6	WF90	Weed free for 90 DACE	T13	WI90	Weedy for 90 DACE
T7	WI0	Weed free until crop harvest	T14	WF0	Weedy until crop harvest

Data analysis

Yield data of each plot were computed according to Gill and Vijayakumar (1969) as the percentage of their corresponding weed-free plot yields; relative yield or percentage of yield loss, with equation 1 described as follows:

$$RY(\%) = \left(\frac{Ywf - Y}{Ywf}\right) * 100 \ldots\ldots\ldots (1)$$

Where; RY = observed yield loss, Ywf = grain yield in weed free plots and Y = grain yield from each infested plots.

Relative yield data were subjected to analysis of variance with the use of the PROC MIXED function of SAS 9.2, to assess the effect of the length of the weed-free period and increasing duration of weed interference on relative soybean yields (Knezevic *et al.* 2002). The statistical significance of treatment was evaluated at 5% level of probability.

Nonlinear regression analyses with the PROC NLMIXED function of SAS 9.2 were used to estimate the relative yield of soybean as a function of increasing duration of weed interference or as a function of the length of the weed-free period, according to Knezevic *et al.* (2002). The logistic equation, (equation 2 below) modified by Knezevic *et al.* (2002) was used to describe the effect of increasing duration of weed interference on soybean relative yield:

$$Y = \left(\left(\frac{1}{\exp(c * (t - d)) + f}\right) + \left(\frac{f - 1}{f}\right)\right) * 100 \ldots\ldots\ldots (2)$$

Where; Y = the relative yield (percent of season-long weed free yield), t = the duration of weed interference measured from the time of soybean emergence in days after crop emergence (DACE), d = the point of inflection in DACE, and c & f = are constants.

The Gompertz model has been shown to predict the relationship between relative yields, as influenced by the length of the weed-free period (Hall *et al.* 1992; Knezevic *et al.* 2002). The model has the following form (equation 3):

$$Y = a * \exp(-b * exp(-k * t)) \ldots\ldots\ldots\ldots\ldots (3)$$

Where; Y = the relative yield (percent of season-long weed free yield), a = the yield asymptote or maximum yield in the absence of weed interference, t = the length of the weed free period after soybean emerged in DACE and b & k = are constants.

In order to estimate the CPWC, nonlinear regression models were fit to the data (Knezevic *et al.* 2002) a logistic equation (equation 2) was used to determine the beginning of CPWC, and the Gompertz equation (equation 3) to determine the end of the CPWC at an acceptable yield loss level (AYL) of 20 % for this study. Combined analysis of variance of other yield and yield component means was performed using PROC GLM of SAS software. The level of significance is indicated by the least significant difference between the means (LSD) at 5% probability.

Results and Discussions

The results of the analysis of variance showed that there were significant difference for grain yield, plant height, number of branches, number of pods per plant, and number of seeds per pod in both the weed interference and weed free treatment categories at $p<0.05$ (*Table 2*). Weed competition had a strong impact on number of pods. A decreasing trend in number of pods was observed when weed-infestation time increased. The higher number of pods per plant was obtained from treatment WI15 DACE and WI30 DACE in weed interference category. As shown in *Table 2*, number of pods per plant were reduced from 36.44 (WI15-30 DACE) to 24.69 (weedy check) when weed interference period increased. In weed interference category, the test crop had higher number of pods per plant in the first 30 days after crop emergence; indicating that soybean can compete well with weeds up to 30 DACE. But, in the weed free treatment category, WF30 and WF45 DACE and WF90 and WI0 DACE treatments had comparable higher number of pods per plant.

In general, weed infestation had affected the number of pods, number of branches and plant height when compared to WI0 treatment. This is due to the competition of weeds for essential resources needed for crop growth (Kropff and Van Laar 1993). Also, Bahram and Reza (2013) and Eftekhari *et al.* (2006) reported that the number of branches per plant in soybean decreased significantly when the period of weed interference increased.

The highest grain yield (1977 kg ha^{-1}) was obtained from season long weed free treatments (Table 2). Likely, WF75 DACE treatment gave 1918 kg ha^{-1} grain yield, which is almost the same with season long weed free treatment. Soybean grain yield was intensively affected by weeds interference period of time i.e. grain yield increased from 1001.7 kg ha^{-1} in weedy check (WF0) treatment to 1977.4 kg ha^{-1} in WI0. Likewise, the grain yield of soybean in weed interference up to 30 and 60 DACE (1736.5 and 1579.4 kg ha^{-1}) were increased in weed free plots up to 30 and 60 DACE (1857.9 and 1819.7 kg ha^{-1}), respectively.

Percent of soybean grain yield loss varied from 3.02 % to 49.34 % depending on the weed interference period. When weeds were allowed to compete with the soybean for the whole growing season (WF0), the soybean grain yield was reduced by 49.34 % (Table 2) compared to the whole season weed free treatment (WI0).

Table 2. Means[a] of grain yield and yield components of soybean from 2013 to 2015 seasons, Assosa

Treatments (DACE)	Plant height (cm)	No. of pods per plant	No. of seeds per pod	No. of branches per plant	Grain yield (kg ha^{-1})	Yield loss (%)
			Category-I: weed interference treatments			
WI15	64.27^{abc}	30.76^{abcde}	2.73^{abcd}	3.60^{abc}	1723.2^{abcd}	12.86
WI30	62.78^{bc}	36.44^{a}	2.87^{a}	4.36^{a}	1736.5^{abcd}	12.18
WI45	60.62^{cd}	29.73^{bcde}	2.82^{ab}	3.67^{abc}	1687.5^{bcd}	14.66
WI60	57.13^{d}	24.82^{e}	2.76^{abcd}	1.98^{d}	1579.4^{cde}	20.13
WI75	62.07^{bcd}	29.00^{cde}	2.82^{ab}	3.76^{abc}	1484.0^{de}	24.95
WI90	66.96^{ab}	25.71^{de}	2.62^{bcd}	3.02^{bc}	1338.3^{e}	32.32
WF0	64.31^{abc}	24.69^{e}	2.58^{cd}	2.73^{cd}	1001.7^{f}	49.34
			Category-II: weed free treatments			
WF15	65.18^{abc}	28.02^{cde}	2.56^{d}	3.4^{abc}	1704.2^{bcd}	13.82
WF30	66.76^{ab}	31.80^{abcd}	2.82^{ab}	3.82^{ab}	1857.9^{ab}	6.04
WF45	65.30^{abc}	31.44^{abcd}	2.71^{abcd}	4.2^{a}	1658.9^{bcd}	16.11
WF60	66.04^{abc}	29.18^{cde}	2.78^{abc}	2.91^{bcd}	1819.7^{abc}	7.98
WF75	61.82^{bcd}	28.91^{cde}	2.89^{a}	3.73^{abc}	1917.6^{ab}	3.02
WF90	63.49^{abc}	33.47^{abc}	2.78^{abc}	3.56^{abc}	1863.5^{ab}	5.76
WI0	68.40^{a}	35.78^{ab}	2.73^{abcd}	3.80^{ab}	1977.4^{a}	0
CV	**9.24**	**22.60**	**8.18**	**32.11**	**16.57**	
LSD	**5.54**	**6.35**	**0.21**	**1.04**	**259.13**	

[a]Values followed by the same letter within a column did not significantly differ at 5% according to LSD test

Also, when weed interference was allowed for 15, 30 and 45 DACE, soybean grain yield was reduced by 12.86 %, 12.18 % and 14.66 % respectively. This indicates that, when the period of weed interference increases there was an increase in grain yield reduction. But, the period of weed free increase resulted in lowest grain yield reduction (Table 2).

Figure 1 shows Gompertz (fitted curve for determining the CPWC in soybean and the logistic fitted curve for determining the CPWC in soybean is shown in figure 2. In Figure 3, the two models cross each other at 30 DACE; this means 30 DACE is a critical point for weed competition in soybean. Thus, soybean has responded favorably to keeping weeds out for the first 30 DACE. This indicates that weed competition in the first 30 DACE is damaging for soybean.

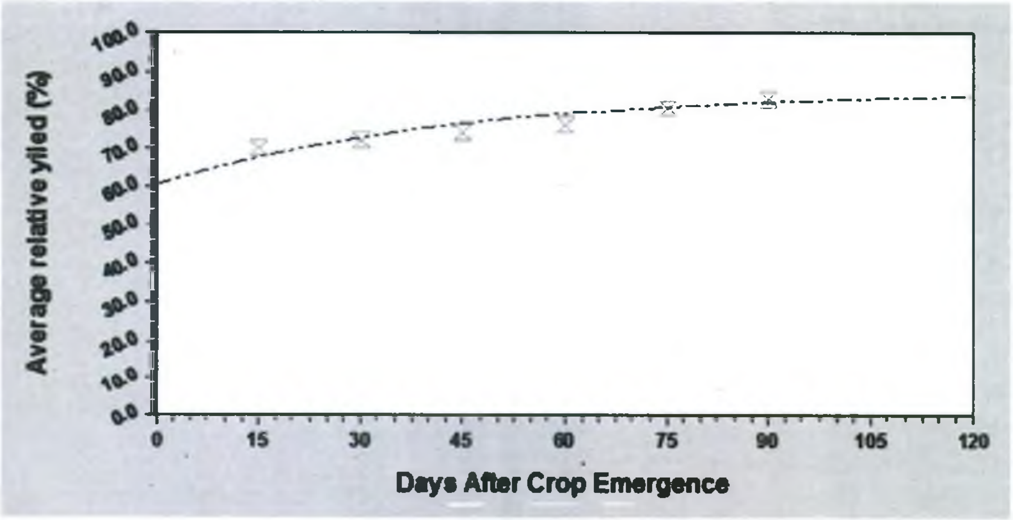

Figure 1 Gompertz fitted curve for determining the CPWC in soybean

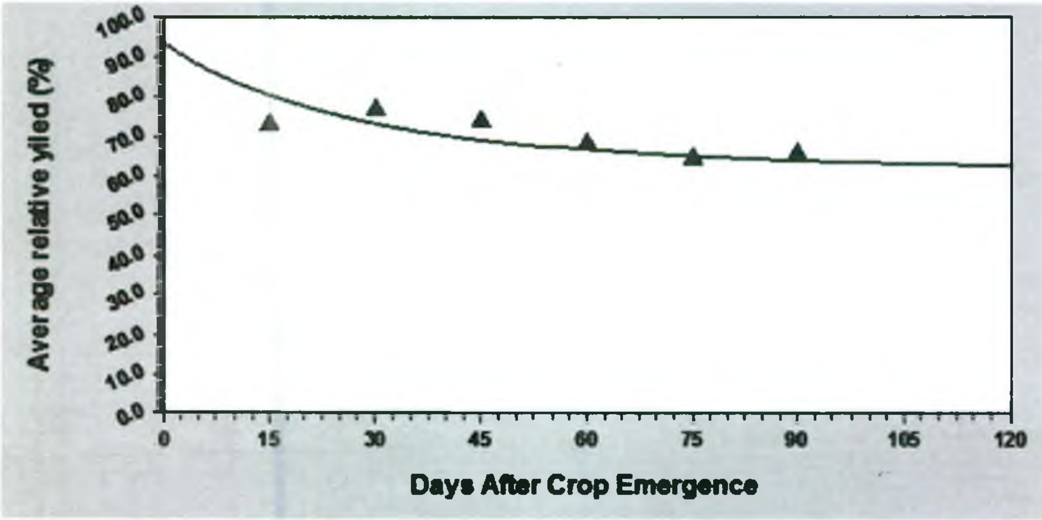

Figure 2 Logistic fitted curve for determining the CPWC in soybean

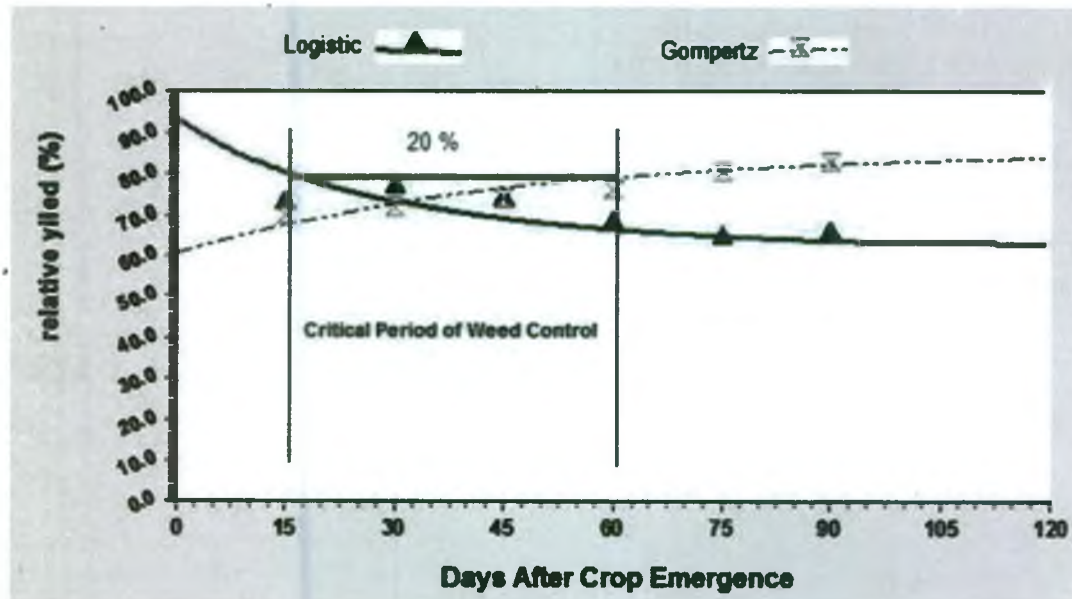

Figure 3. Critical period of weed control in soybean at Assosa

Furthermore, on the bases of 20 % AYL, the CPWC was started from 15 DACE and ended at 60 DACE (Figure 3). This indicated early emerging weeds (before 15 DACE) and late emerging weeds (after 60 DACE) were not as competitive as weeds emerging in between 15 to 60 DACE. Also, this means, the yield reductions for both marginal weed interferences (i.e. before 15 DACE and after 60 DACE) were not as higher as the yield reduction occurred between 15 to 60 DACE. This is because well field preparation had affected the weeds competitive ability by providing good growing condition for soybean and allowed the crop to escape the competition in the former treatment (prior to 15 DACE), while in the later (after 60 DACE) soybean had already completed the vital reproductive stage and was established well to compete with weeds effectively. On the other hand, significantly greater reduction in soybean yield occurred from 15 to 60 (DACE).

Conclusions

Generally, results of this study revealed that season long weed interference can cause up to 49.34 percent crop yield reduction in soybean. The onset, end and duration of the CPWC were determined based on 20 % AYL model. The threshold points 15 DACE (onset) and 60 DACE (end), of the critical weed competition period were defined using decreasing and increasing responses curves. The CPWC therefore consisted 45 days during the crop growing period. Hence, controlling weeds during this period, possibly two weed removal operations at the beginning and end of the critical period, is necessary to prevent significant soybean yield loss.

Acknowledgements

The authors would like to present special thanks to the Ethiopian Institute of Agricultural Research (EIAR) and Assosa Agricultural Research Center (AsARC) in financing and providing research facilities for this study. Special grateful goes to Mr. Ermiyas Tefera for his volunteer in providing seed of the test crop. Heartfelt thanks are also extended to Mr. Addisu Dereje and Mrs. Lanchisil Bitew for their invaluable data collection and field management.

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