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Assessment of Critical Period of Weed Competition in Sugarcane (*Saccharum* spp. Hybrid) at Tana Beles Sugar Development Project, Ethiopia.

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Abstract

Field experiment on assessment of critical period of weed competition in sugarcane was conducted at Tana Beles Sugar Development project during 2014/2015 G.C. The objectives of the study were to assess the effect of different periods of presence and absence of weeds on cane yield and yield parameters and to determine the critical period of weed competition in sugarcane for controlling weeds efficiently and economically. The experiment was conducted with sugarcane variety NCO334, in RCBD design replicated three times. The treatments were either kept weed-free or weedy for different periods, viz., 0, 25, 50, 75, 100, 125 and 150 Days After Planting (DAP). The data on weed density, weed dry weight, sugarcane emergence, tiller number, millable cane number, cane length, cane girth, cane weight and cane yield were collected and analyzed using SAS software and means were compared and separated by DMRT. The result showed that, tiller number, cane height, cane weight, millable cane number and cane yield were highly significantly ($p \leq 0.01$) as affected by treatments while cane girth was significantly ($p \leq 0.05$) affected by weed competition for different periods. This result indicated that increasing the weed free periods increased tiller production, cane height, cane girth, cane weight, millable canes and cane yield. Presence of weeds for season long duration caused a yield loss of 91.24% in sugarcane. The onset and end of critical periods of weed crop competition at the acceptable cane yield loss of 5% was found to be between 16 and 126 DAP. Therefore, weeds should be controlled during this time of interval.

Keywords: Cane Yield, Critical Period, Weed Competition, Yield Loss.

1. Introduction

Sugarcane (*Saccharum spp.* Hybrid) is the main sugar-producing crop that contributes nearly 70% of the total sugar pool at the global level (Verma, 2004). It is also one of the most important widely grown cash crops in Ethiopia (Yoseph, 2006). The current sugar production in Ethiopia provides only 60% of the annual demand (ISO, 2010). Thus, there is a high need to increase the production and productivity of sugarcane in order to have a reliable supply of sugar in the country to satisfy the highly growing demand and consumption of sugar in the society. However, weeds are major limiting factors in production of the crop (Phillips, 1992). Weeds reduce sugarcane yields by competing for moisture, nutrients and light during its growing period (Khan *et al.*, 2004). They compete throughout the life cycle of field crops but the crops are more sensitive to weeds at a specific period during their life cycle which is called critical period of weed competition where weeds accumulate maximum dry matter during this period (Verma, 2004). The length of this period vary depending on cane crop types, their competitive ability, variety, soil condition, planting techniques, weed flora composition and extent of weed infestation (Firehun *et al*., 2013). Cane yield losses in sugarcane production ranging from 20-90% were recorded due to weeds in different countries of the world (Taye, 1991). In Ethiopia, 83.5% cane yield loss was reported due to weed competition for the erect cultivar NCO334 (Firehun *et al*., 2013). In Ethiopia, the beginning and end of critical periods of weed interference on 5% acceptable cane yield loss level in the erect cultivar NCO334 grown at Wonjiwas found at 2.5 and 14 WAP, respectively (Firehun *et al*., 2013). Although different weeds may be superficially very similar, they differ in their time of maximum competition and response to individual control methods (Memon *et al*., 2013). To design effective weed control measures; identifying the critical period of weed competition in a certain area is an important step (Firehun, 2004). Therefore, this field experiment was conducted with the objectives to assess the effect of different periods of presence and absence of weeds on cane yield and yield components as well as to identify the critical period of weed-crop competition in sugarcane. This helps to develop effective and economic weed control strategy to start weed control measures before they cause economic damage on cane and sugar yields.

2. Materials and Methods

2.1 Description of the study area

The experiment was conducted at Tana Beles sugar development project, which is located in between $11^{0}07$'N and $36^{0}20$'E at an altitude of 1119 m.a.s.l in Amhara Regional State of Ethiopia. It is 650 km far from Addis Ababa, towards Northern part of the country, Awi Zone, Jawi Woreda and western Gojjam Zone, Achefer Woreda. Some fields of this plantation are also extended to Benshangul Gumuz regional state of Pawi Woreda. The average annual rainfall of Beles sub-basin is 1490 mm. The minimum and maximum temperature of the area is between 16.4 and 32.5 ^{0}C, respectively (Zeleke and Netsanet, 2015). There are two main soil types i.e., heavy soil and light soil. Majority of the plantation area is covered by heavy soil.

2.2. Experimental design, treatments and crop management

2.2.1. Physical and Chemical properties of the experimental field soil

Soil samples (0-30 cm depth) were collected and mixed to form one composite sample from the experimental field for chemical analysis. Accordingly, the pH, organic carbon content, total nitrogen content and available K values of the experimental soil were 6.63, 1.68%, 0.101% and 524 ppm respectively. The physical property of the experimental field was also characterized as sand (4%), silt (12%) and clay (84%) which is clay textured soil (Zeleke and Netsanet, 2015).

2.2.2. Experimental Design, Treatments and Crop Management

These treatments were arranged in a randomized complete block design (RCBD) and replicated three times. The treatments were comprised of weed-free periods (WF-0, 25, 50, 75,100,125 and 150 DAP) and weedy periods (Weedy-0, 25, 50, 75,100, 125 and 150 DAP). Plot size was 8.7 m x 5.0 m. NCO334 variety which is dominant in the estate was used. Total area of the experimental field was 3613.785 m^2. The field was selected, cleared, cultivated, disked, leveled and furrowed properly before planting. After furrow was prepared at 5 days before planting, pre-planting irrigation was given and furrow slope correction was done according to the gravity of irrigation water. Following furrow correction, seed canes from well fertilized crop with good growth performance, free from disease were selected and prepared. Planting was then done using three budded setts by end to end position and covering was then done properly. Subsequently, light irrigation was given immediately following planting on the same day. 45.68 kg DAP and 27.41 kg Urea was applied in the experiment. Moulding was also done when the crop attains 70 cm height. All the other agricultural practices were kept similar for all the treatments following the site implementation manual.

2.3. Method of Data Collection

Data of weeds were collected from inter-row spaces of the middle four cane rows. At each weeding, 0.25 m^2 quadrant was laid randomly at four points in the central part of rows of each plot to collect weeds. The collected weeds were identified species wise and counted through the method described by Taye and Yohannes (1998) and important weed species were selected. Moreover, the above ground portions of weeds were dried in oven at 80 ^{0}C for about 72 hours and dry weight was taken by weighing the oven dry sample by sensitive electrical balance.

Sugarcane data such as germination percentage (at 45 DAP), tiller number count (at 4th MAP), number of millable canes (at harvest), cane length and girth (at harvest), cane weight (at harvest) and Cane yield (at harvest) were also collected from the middle four cane rows for statistical analysis. Cane weight and cane yield were calculated using expressions;

$$\text{Millable cane average weight}\left(\frac{kg}{stalk}\right) = \frac{\text{Weight of 20 stalks (kg)}}{\text{20 Sampled stalks (plot)}}$$

$$\text{Cane yield}\left(\frac{t}{ha}\right) = \frac{\text{Cane yield}\left(\frac{kg}{plot}\right) \times 10}{\text{Plot area }(m^2)}$$

2.4. Data Analysis

1. Determination of critical period of weed competition

For determination of weed crop competition, two important equations were used. These equations were:

I. Gompertz equation:

The Gompertz equation described by (Firehun *et al.*, 2013) was used to predict the relationship between relative cane yields as influenced by the increasing duration of the weed-free periods as:

$$RY = A \times \exp\left[-B \times \exp(-K \times T)\right]$$

Where RY is relative cane yield (% of season-long weed-free yield), A is the yield asymptote; B and K are constants and T is the length of the weed-free period after planting of sugarcane in days.

The Gompertz model was used to provide a good fit to relative yield (RY) as it is influenced by increasing length of the weed-free period. Using the derived Gompertz equation, the critical duration (end) of the weed-free period for sugarcane in DAP was calculated for acceptable cane yield loss level of 5% as followed by Firehun *et al*. (2013).

II. Logistic equation:

A three-parameter logistic equation described by was used to predict the effect of increasing durations of weed interference on relative cane yield as:

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

Where, RY is the relative cane yield (% of season-long weed-free yield), T is the duration of weed interference measured in days after planting of sugarcane; C, D and F are constants derived by fitting the logistic regression equation.

By using derived logistic equation, the critical length of weed-infested period was calculated for acceptable cane yield loss level of 5%. Therefore, the logistic equation was used to determine the beginning of the critical period of weed competition (Hall *et al*., 1992). The 5% cane yield loss level was taken to be acceptable considering the present cost of weed control (labor and chemical cost) in Beles sugarcane plantations. Due to this reason, critical period of weed competition in Tana Beles sugar development project was determined by taking in mind that 5% yield loss is accepted.

2.5. Maximum cane yield loss

The maximum cane yield loss due to weed competition in the study area was calculated following the formula described by Firehun *et al*. (2013) as follows:

$$\text{Maximum cane yield loss} = \left(1 - \frac{\text{cane yield of weedy check}}{\text{cane yield of weed free check}}\right) x 100$$

All the collected data of the experiment were statistically analyzed by SAS statistical software version 9.2 for windows and means separation was done using Duncan Multiple Range Test (DMRT) (Duncan, 1955).

3. Results and Discussion

3.1. Weed species recorded in the experimental field

The dominant weed species recorded in the experimental field were: *Amaranthus graecizans*, *Cassia obtusifolia*, *Commelina benghalensis*, *Cyperus rotundus*, *Datura stramonium*, *Echinochloa colona*, *Eleusine indica*, *Euphorbia indica*, *Mimosa invisa*, *Nicandra physalodes*, *Oxygonum sinuatum*, *Ricinus communis*, *Sorghum arundinaceum* and *Xanthium strumarium*.

3.2. Weed density, Weed dry weight, Cane yield and Cane yield components of sugarcane

Table 1. Weed density(m^{-2}), Weed dry weight(gm^{-2}), Cane sprout(%), Cane tiller(ha^{-1}), Cane length(cm), Cane girth(mm), Millable cane number, Cane weight($kgstalk^{-1}$) and Cane yield($t\ ha^{-1}$) of Sugarcane

Treatment	Weed density	Weed dry weight	Sprout	Tiller number	Cane length	Cane girth	Mill able cane no	cane weight	Cane yield
WF-25 DAP	46^{fedc}	132.20^{c}	78^{a}	81094^{g}	149.4^{c}	21.95^{bac}	69962^{h}	0.88^{ba}	60.88^{e}
WF-50 DAP	36^{feg}	102.80^{d}	73^{a}	137588^{e}	178.2^{bac}	22.26^{bac}	100077^{egf}	0.95^{a}	92.38^{d}
WF-75 DAP	32^{fg}	82.37^{ed}	75^{a}	184517^{dc}	192.4^{ba}	22.53^{bac}	124981^{bdc}	1.00^{a}	122.76^{c}
WF-100 DAP	25^{hg}	35.00^{f}	73^{a}	200715^{bdc}	203.8^{a}	22.68^{bac}	134789^{bac}	1.00^{a}	136.87^{bac}
WF-125 DAP	18^{h}	11.50^{g}	77^{a}	237986^{ba}	210.6^{a}	22.73^{ba}	141149^{bac}	1.00^{a}	147.35^{ba}
WF-150 DAP	4^{i}	2.40^{g}	78^{a}	255775^{a}	209.9^{a}	22.93^{ba}	149042^{ba}	1.00^{a}	153.93^{a}
WF (check)	0^{i}	0.00^{g}	76^{a}	258289^{a}	214.0^{a}	23.41^{a}	153027^{a}	1.05^{a}	160.71^{a}
Weedy-25 DAP	34^{fg}	21.60^{gf}	77^{a}	221353^{bac}	178.8^{bac}	22.63^{bac}	120843^{edc}	0.95^{a}	124.90^{bc}
Weedy -50 DAP	58^{bac}	40.47^{f}	70^{a}	157931^{ed}	150.9^{c}	21.70^{bdac}	105134^{edf}	0.83^{ba}	88.20^{d}
Weedy -75 DAP	67^{a}	73.62^{e}	76^{a}	128567^{ef}	154.0^{bc}	21.55^{bdac}	89655^{hgf}	0.67^{bc}	57.83^{e}
Weedy -100 DAP	61^{ba}	97.60^{d}	77^{a}	86602^{gf}	99.3^{d}	21.03^{bdc}	80000^{hg}	0.53^{c}	42.74^{fe}
Weedy -125 DAP	50^{bedc}	145.93^{c}	78^{a}	76540^{gh}	99.4^{d}	20.94^{bdc}	68582^{h}	0.52^{c}	30.67^{fg}
Weedy -150 DAP	52^{bdc}	186.15^{b}	79^{a}	35922^{ih}	93.9^{d}	20.56^{dc}	41762^{i}	0.48^{c}	20.46^{fg}
Weedy (check)	42^{fed}	272.35^{a}	74^{a}	24286^{i}	87.5^{d}	20.43^{d}	28506^{i}	0.47^{c}	14.08^{g}
CV	21.29	14.26	8.52	17.03	13.87	4.72	13.21	14.99	14.74

3.2.1. Weed density and dry biomass production in sugarcane

According to the result, weed density and weed dry weight showed a highly significant difference ($p \leq 0.01$) due to presence and absence of weeds for different durations. As weed free periods increased weed density as well as weed dry weight decreased. On the other hand, as weed competition periods increased the density of weeds as well as their dry weight increased. However, the number of weeds decreased when weed competition period exceeded to 100 days after planting (Table 1).

Data pertaining to the effect of different weed free periods on weed density showed a significant decrease in number of weeds as the length of weed free period increased (Figure 2). This is due to the human interference on weeds that leads to the weed density to be decreased. This increased the competitive strength of the crop due to weed free environment.

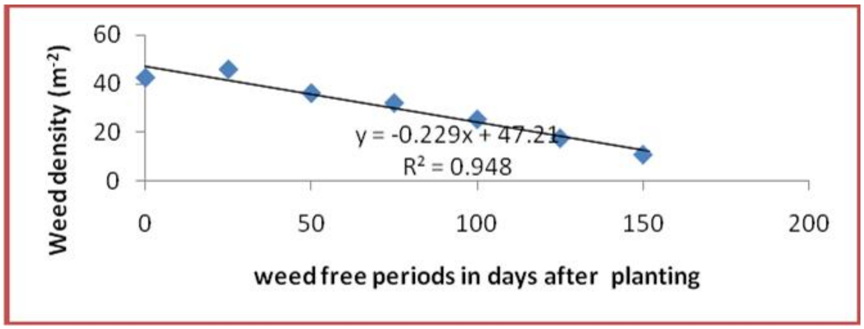

Figure 2: Weed density (m^{-2}) as influenced by different weed free periods in sugarcane

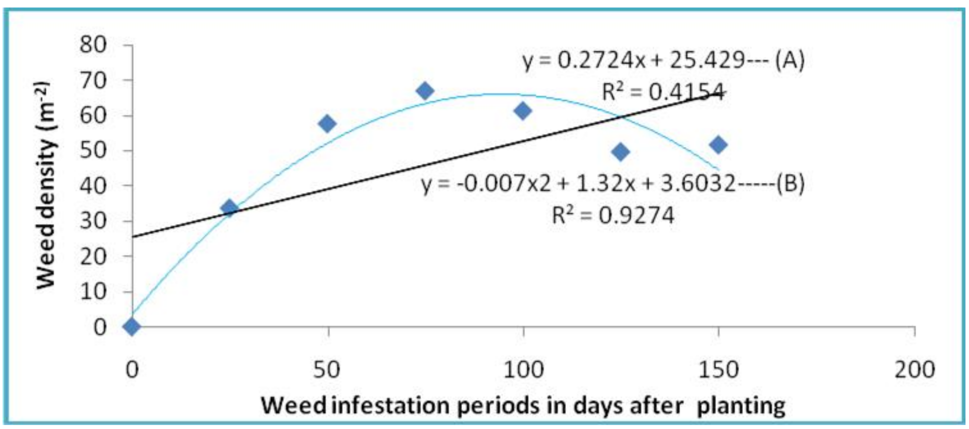

Figure 3: Weed density (m^{-2}) as influenced by different weed infestation periods in sugarcane

In the other hand, weed density increased progressively as weed crop competition increased up to 100 DAP (Figure 2). This was due to the reason that when cane started its emergence, many weeds germinated and grown well due to high moisture of pre-sowing irrigation. This was also due to more time availed to weed seeds to germinate fully from the soil seed bank. This agrees with the idea of Zubair *et al.* (2011). Milberg *et al*. (2000) also reported that the increment of weed populations reflect the effects of local weather conditions on recruitment, survival and competitive ability. However, after 100 DAP there was a decrease in weed density (Figure 3; B). This may be attributed to death of over populated weed plants due to severe competition among themselves (intra-specific competition) as at the time of cane sprouting many weed seeds germinated due to optimum moisture because of pre-sowing irrigation. The other reason is also attributed to death of some annual weeds due to completion of their life cycle. This result contradicted to the result of Zubair *et al.* (2011) who reported that the weed density increases as the weed crop association increases up to harvesting (Figure 3; A).

Weed dry weight was progressively decreased ($P \leq 0.01$) with increased weed free period throughout the study time (Figure 4).

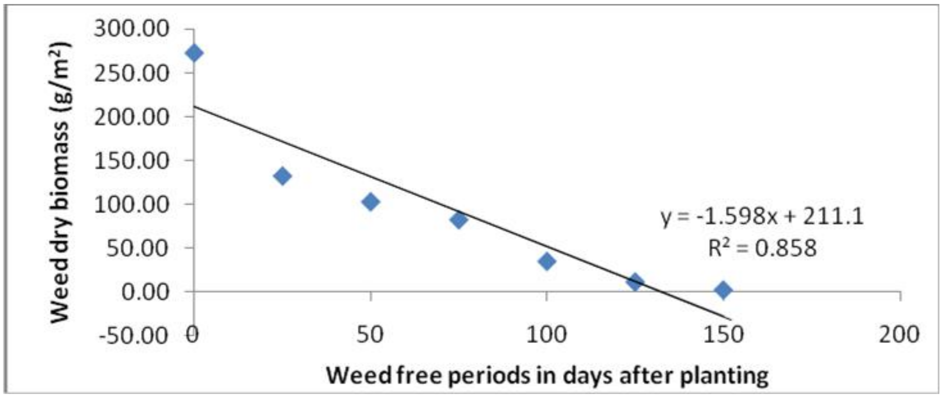

Figure 4: Weed dry weight (gm^{-2}) as influenced by different weed free periods in sugarcane

On the other hand, weed dry weight significantly increased as weed infestation period increased (Figure 5). The full season weed competition of the study produced highest weed dry weight (272.35 gm^{-2}).

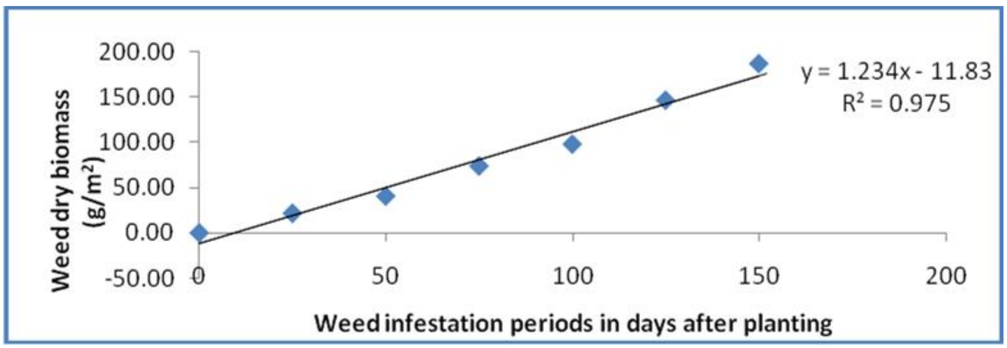

Figure 5: Weed dry weight (g) as influenced by different weed infestation periods in sugarcane

This increment in weed dry weight is due to increase in fresh weight of weeds as a result of prolonged weed growth due to being highly competent for essential plant nutrients, surface area, sunlight and water. This result is in lined to the result of Firehun *et al.* (2013) who reported as weed dry biomass decreased with increasing durations of weed free periods and with decreasing durations of weedy periods.

3.2.2. Cane yield and yield components in sugarcane

The result showed that tiller number, cane height, cane weight, millable cane number and cane yield were highly significantly affected ($p \leq 0.01$) by treatments while cane girth was significantly affected ($p \leq 0.05$) by weed competition for different periods (Table 1). However, sprouting percentage of buds on cane setts planted was not significantly different ($P \leq 0.05$) due to different weed competition periods (Table 1).

The highest (258, 289) number of tillers produced per hectare was in weed free check while the lowest (24, 286) was in weed infested check. Generally, as the weed free period increased tiller production was significantly increased and tiller production decreased as weedy periods were increased. This was due to high competition of weeds for space, essential nutrients and light; so that tiller production hindered. The disaster effect of weeds on the tillering ability of cane crop was also reported by Zubair *et al.* (2011). However, Firehun *et al.* (2013) reported the non-significant effects of weeds on the germination of cane and number of tillers produced. But, in reality the cane faced to weed infestation did not have tiller. The highest (214 cm) cane length was recorded in weed free check while the shortest (87.5cm) was recorded in the weedy check. So, as weed free period was increased stripped cane length was also increased. This was due to less competition of weeds with sugarcane for light, nutrient, space, air that produced suitable condition to the crop to be vigorously grown. On the other hand, as weed infestation period increased the length of stalk was decreased.

This was due to the effect of weeds on cane growth through high competition for nutrients, light, water and space. This result is in line with the finding of Firehun *et al.* (2013) . The highest cane girth (23.41 mm) stalk was also recorded in season long weed free period (weed free check) treatment while the thinnest (20.43 mm) stalk was recorded in season long weed infested period (weedy check). Furthermore, as weed free periods increased, stripped cane girth also increased significantly. However, as the weed competition periods increased stripped cane girth decreased due to negative effect of weeds on cane growth and development.

The result on milleable cane number also showed increment of millable canes number per hectare as weed free periods increased. On the other hand, as weed competition period increased, the numbers of millable canes per hectare decreased. The highest (15, 3027 ha^{-1}) millable canes were recorded in season long weed free period treatment while the lowest number (28,506 ha^{-1}) of millable canes were recorded in season long weed infested period. This showed 81.4% millable canes loss. Firehun *et al.* (2013) also reported suppression of the millable canes due to weed competition. The heaviest (1.05 kg/stalk) and the lightest (0.47 kg/stalk) cane stalks were also recorded in season long weed free and season long weedy treatments, respectively (Table 1). This confirmed the result revealed by Zubair *et al*. (2011) in which prolonged weed-crop competition periods reduced cane weight significantly.

The highest (160.71 t ha^{-1}) yield was recorded from the weed free check treatment while the lowest (14.08 t ha^{-1}) was obtained from the weedy check. High yield drop was observed in treatments that had been in weedy period for more than 25 days and weed free for less than 75 days after planting. Thus, the cane yield obtained from weedy up to 25 DAP treatment was 124.9 t ha^{-1}which show a yield loss of 22.8% as compared to the weed free check. Generally, cane yield losses of 45.12%, 64.02%, 73.41%, 80.92% and 87.27% were recorded in treatments, weedy up to 50, 75, 100, 125 and 150 days after planting, respectively. Likewise, cane yield losses of 23.6%, 14.83%, 8.31% and 4.22% were recorded in treatments of weed free up to 75, 100, 125 and 150 days after planting, respectively as compared to the yield recorded from weed free check. Similar study by Singh and Tomar (2003) in India confirmed 20.5, 21.9, 49.7 and 74.5% reduction in cane yield when weed-crop competition allowed for 30, 45, 60 and 75 days after planting. The maximum cane yield loss recorded in this study was 91.24%. This is due to higher competition of weeds due to limited essential resources i.e., light (due to highly shading by weeds starting from cane sett emergence), space, water and nutrients. In line with this study, Van Heemst (1985) reported the cane yield losses between 10% and 100% if weeds are not controlled depending on the competitive ability of the crop and other factors.

3.3. Critical period of weed competition and control in sugarcane

Critical period of weed competition at 5% acceptable cane yield loss was estimated on the basis of relative cane yield following logistic and compertz equations based on the onset and end of weed competition periods viz., the maximum time that the crop should remain weed free and minimum period in which weeds can remain in the crop field for NCO334 variety was determined. The critical period of weed competition t 5% acceptable cane yield loss was found between 16 and 126 days after planting. Therefore, the onset of weed competition in sugarcane crop for NCO334 cane variety at Tana Beles sugarcane plantation was found to be 16 days after planting while the end of weed competition period was found to be 126 days after planting.

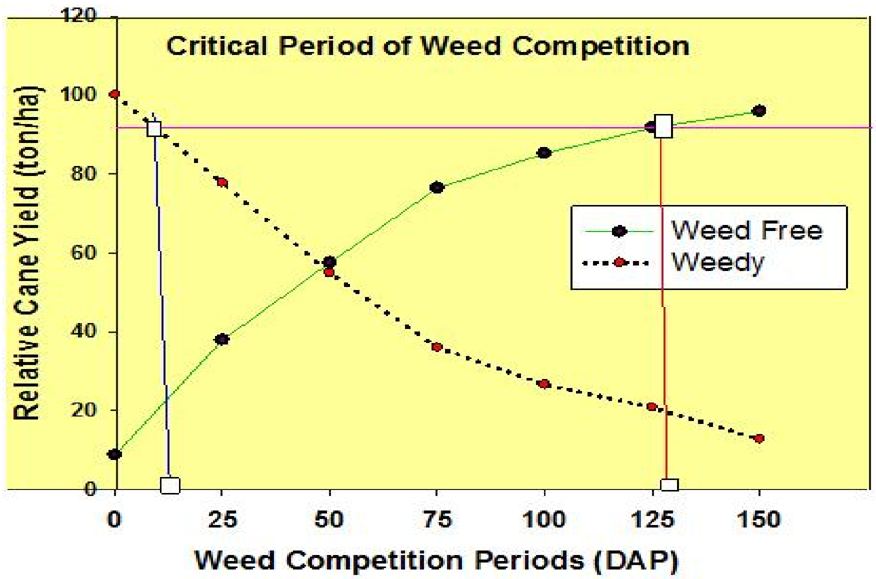

Figure 6: Onset and end of critical period of weed competition in sugarcane

The onset of the critical period of weed competition in the study area was found coincided with the initiation of cane sprout. Hall *et al*. (1992) reported that weed density appears to be important in the determination of the beginning of the critical period where the critical period tended to start later for experiments with lower weed density. In agreement with this result, Muhammad *et al.* (2010) reported that weeds should be removed immediately after emergence to get maximum cane yield. On the other hand, the end of weed competition period in which weed control is not necessarily important then after was found to be 126 days after planting. Therefore, after 126 days after planting, weeding is not needed but can increase cost of production in the area.

Conclusion and Recommendations

Weeds are the major cause of higher cost and lower yields in sugar cane. Maximum cane yield loss of 91.24 % was recorded for the used variety (NCO334; erect variety) in the study area. The onset and end of critical period of weed competition of this study was found between 16 and 126 days after planting. Therefore, best weed management options should be designed and used in sugarcane plantation of Tana Beles sugarcane plantation site from 16 to 126 days after planting for the said sugarcane variety to keep cane yield loss at the acceptable cane yield loss level of 5% and below. Based on the findings Sugarcane cane fields should be free of weeds starting from 16 up to 126 days after planting using different effective weed control methods in integrated manner to keep the yield loss level below 5%. A significant correlation was shown between cane yield and weed dry weight, weed density and cane yield parameters.

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