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Assessment of critical period of crop-weed competition in grain sorghum under Sudanian conditions of Southern Senegal

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ABSTRACT

Weeds are among the most harmful factors limiting sorghum production under Sudanian conditions of southern Senegal. Despite, the taxonomic structure of the flora is relatively well known, few studies have focused on crop-weed competition. Field experiment was carried out to determine the critical time for weed competition in grain sorghum. Ten treatments, weedy for initial 15, 30, 45 and 60 DAS and then weed-free, and weed-free for initial 15, 30, 45 and 60 DAS and then weedy, weed-free and weedy up to harvest were assigned in a randomized block design with four replications. The beginning and the end of critical period of weed competition were determined respectively under fertilized and unfertilized conditions. The results showed that more the weeds competition is longer, more sorghum parameters of growth and yield are reduced. Sorghum yield were significantly influenced by many factors such as year, nitrogenous fertilization and weeding periods. The highest plant height, dry matter, and yield were recorded in weed free treatment followed by weed free up to 60 DAS and weedy up to 15 DAS. Plant height, dry matter and yield decreased significantly with each increase in competition period. Therefore, the lowest growth parameters and yield were noticed in weedy check treatment followed by weedy up to 60 DAS and weed free up to 15 DAS. Moreover, our findings showed that sorghum height, dry matter and grain yield increased significantly under fertilized conditions compared to unfertilized conditions, which is widely used in traditional cropping system. The maximum competition between crop and weed was between 15-45 and 15-55 DAS under unfertilized conditions (F0) and 10-55 and 15-55 DAS under fertilized conditions (F1), which can be considered as critical period of crop-weed competition. The weeding practice should be adopted during these periods for getting optimum sorghum production under Sudanian conditions of Senegal.

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal crop for farmers located in the south-eastern part of Senegal. It's a staple food and the only crop that is capable of producing a reliable yield under the marginal environmental characterized by several biotic constraints and low inputs. In this part of country, sorghum occupies with pearl millet, 75% of arable lands (Fofana et al. 2009). Average productivity is 0.7 ton. ha^{-1} (ANSD, 2015) which is still low compared to the potential yields of 3.5 tons. ha^{-1} (Ndiaye et al. 2005).

Among the factors limiting sorghum production, inadequate weed control had been identified as a major obstacle in increasing the grain sorghum yield. Sorghum is a poor competitor against weeds due to slow growth and poor early vigor for the first 20-25 days, although it eventually establishes a dense canopy (Rizzardi et al. 2004; Arslan et al. 2016). Yield losses due to uncontrolled weed growth in sorghum varied from 15 to 97% of production (Gworgwor and Weber, 1991, Arslan et al. 2016). Manual and hand weeding are the common practices for weed control in traditional sorghum cultivation which limit land extension and absorb from 20 to 50% of farmer's occupation during rainy season (Scalla, 1991). According to Caussanel (1989), presence of weeds is always harmful for crop despite harmful is not equally throughout the growth period. Some stages are most sensitive to weed infestation and if weeds are not controlled in this stage maximum yield loss will occur which period is called the critical period for weed control (Kumar et al. 2013). Several studies (Kumar et al., 2015; Tursun et al. 2015; Yadav et al. 2018) reported that weed interference outside the critical period of weed control had a negligible effect on crop yield. Hence, determination of this critical period is essential for better management of weed and was the first step for integrated weed management (IWM) strategies (Knezevic et al. 2002). It helps in making decision on appropriate timing of weeding, efficient use of herbicide and higher productivity (Kumar et al. 2015; Yadav et al. 2018).

In Senegal, studies on the determination of critical periods of weed control were mainly conducted in the Groundnut Basin for groundnut and pearl millet (Noba, 2002), intercropping pearl millet/cowpea (Mbaye, 2013) and maize (Bassène, 2014) but not for sorghum neither in Sudanian zone of the country. Therefore, our present investigation was carried out to determine the critical period of weed competition in sorghum rainy crop under mineral fertilizer and also unfertilized conditions which is widely used in traditional cropping system.

Materials and Methods

A field experiment was conducted during two rainy seasons 2016 and 2017 at Senegalese Institute for Agricultural Research of Kolda. The climate is Sudanian with alternating rainy season from June to October and a dry season for the rest of the year. Cumulative rainfall was 1186.3 mm in 2016 and 1335.9 mm in 2017. The soil was sandy to sandy-clay. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications, one under unfertilized condition (F0) which is widely used in traditional cropping systems and other under fertilized condition (F1) with recommended dose of mineral fertilizers. In order to evaluate the earlier critical period of competition, plot left weedy up to 15 (WF1), 30 (WF2), 45 (WF3) and 60 (WF4) days after sowing and kept weed-free until harvest. To determine the end of the critical period plots were kept weed free up to 15 (W1), 30 (W2), 45 (W3) and 60 (W4) days after sowing and left weedy until harvest. Two weed control treatments a weedy check (WC) treatment where plot left infested from sowing till harvest and a weed free (WFC) treatment where plot kept free of weed from sowing till harvest. Also, there were four agronomic practices (P1, P2, P3 and P4) where two hand weeding were performed respectively 15 and 30 DAS (P1), 15 and 45 DAS (P2), 30 and 45 DAS (P3) and 30 and 60 DAS (P4). However, the agronomic practices treatments were just add to assess the effect of the most common weed management in farmer's field on sorghum production and were not include determining the critical period.

Sorghum seed (*Sorghum bicolor* [L.] Moench variety "*F2-20*") was sown by hand in rows 75 cm apart with 30 cm between plants. The plot size was 5.4 m^2 (1.8 × 3.0 m). Growth parameters and yield of each treatment was recorded and seed yield worked out as per cent of weed-free check to determine the critical period of crop-weed competition (Nieto et al., 1968).

Before hoeing, all the species found in survey plot were reported and a cover value assigned according to the Braun-Blanquet scale (Le Bourgeois and Guillerm, 1995). The study of the infestation is carried out by the determination of the relative frequency and the recovery of each species. An analysis of variance was conducted for all data and differences between treatment means were compared at the 5% level of significance using the Student Newmann-Keuls test. All statistical analyses were conducted using the R 3.5.0 software from R Development Core Team (2018) (Library Agricolae).

Results and Discussion

Weed recorded

During this study a total of 115 species has emerged as weeds in experimental plot. The pattern of infestation based on the abundance-dominance mean and frequency showed that ten species were the most common weeds in sorghum fields. Among them four species including *Digitaria horizontalis*, *Hyptis suaveolens*, *Spermacoce stachydea* and *Mariscus squarrosus* were potentially the most injurious against sorghum field because of higher recovery (Abundance-Dominace mean > 1.25) and were found during all phases of crop growth (table 1). These four species belong to annual weeds that are characterized by their adaptations to environments disturbed by agronomic interventions (Fenni, 2003). They have a short cycle, produce a large number of seeds and for some of them both sexual and vegetative mode of reproduction are operative for their proliferation. *Striga hermonthica* is one of the biggest constraints in this part of Senegal despite its frequency still low. This state is due to the fact that the species is not visible at the beginning of the crop cycle, despite their damage occurs during the fixation phase on the host's roots and the underground phase of its development (Ramaiah et al. 1983).

Table 1. Weeds recorded in experimental plot and their distribution according to the degree of infestation.

Group	Weed Species	Family	RF	AD average
	Digitaria horizontalis	Poaceae	88.9	1.71
	Hyptis suaveolens	Lamiaceae	76.3	1.48
	Mariscus squarrosus	Cyperaceae	50.4	1.34
	Spermacoce stachydea	Rubiaceae	87.4	1.26
Major weeds	*Mitracarpus villosus*	Rubiaceae	57.8	1.24
	Dactyloctenium aegyptium	Poaceae	81.5	1.15
	Kyllinga squamulata	Cyperaceae	53.3	1.19
	Commelina benghalensis	Commelinaceae	51.9	0.96
	Fimbristylis hispidula	Cyperaceae	53.3	0.81
	Striga hermonthica	Orobanchaceae	18.5	1.26
Others	105 species		-	-
Total emerged weed	115 species		-	-

Fr= relative frequency; AD= abundance-dominance

Effect of time of weed removal on sorghum plants height

For plots without fertilizer, the highest plants heights were observed in treatments WF, W4, WF1, W2 and W3 with respectively 81.2, 77.1, 68.8 and 63.5 centimeters during the rainy season 2016 while the lowest weight were noted in treatment WC (10.5 centimeters) and P2 (9.2

centimeters). In 2017, the best height was recorded in treatments WF1, WFC, WF2 and W4 over than 133 cm for each treatment. The lowest treatment was noticed in treatment P2 (60.6 centimeters) and WC (16.4 centimeters) (Table 2).

Table 2. Effect of time of weed removal on sorghum plants height

Treatment	Height (centimeters)			
	2016		2017	
	F_0	F_1	F_0	F_1
WFC	81,2[a]	119,9[ab]	133,9[a]	216,7[a]
W4	77,1[a]	114,3[ab]	133,8[a]	201,2[a]
WF1	68,9[a]	154,3[a]	134,5[a]	198,6[a]
W2	68,8[a]	88,8[bc]	85,1[ab]	196,2[a]
W3	63,5[a]	111,2[ab]	96,7[ab]	200,3[a]
WF2	56,6[ab]	118,9[ab]	133,9[a]	162,1[ab]
WF3	54,3[ab]	88,7[bc]	46,6[bc]	84,9[ab]
W1	53,8[ab]	31,33[cd]	53,5[abc]	134,9[ab]
P4	37,1[ab]	43,3[cd]	88,5[ab]	131,1[ab]
P1	36,3[ab]	77,5[bcd]	95,3[ab]	164,7[ab]
P3	30,2[ab]	52,0[bcd]	105,1[ab]	137,7[ab]
WF4	29,6[ab]	38,6[cd]	43,6[bc]	97,6[ab]
P2	9,2[c]	60,6[bcd]	38,1[bc]	130,0[ab]
WC	10,5[c]	16,4[d]	0,8[c]	44,5[b]
Mean	48,4	79,7	85,0	150
Coefficient of variation	25.4	23.1	24.7	21.1
Significant values	<0.001***	<0.001***	<0.001***	<0.001***

Any two means not sharing a letter in common in a column differ statistically at 5% probability level.

When the plots received the recommended fertilizer, the highest plant height (154.3 centimeters) are recorded in sub-plots weedy up 15 DAS treatment and significantly higher to rest of the treatment. It was followed by WFC, WF2, and W4 treatment with respectively 133.9, 133.9 and 133.8 centimeters. Plant height recorded in treatments WC, P2, WF4 and WF3 were the lowest. In 2017, the highest plants were found in treatment WFC, W4, W3, WF1 and W2 which are significantly higher to the rest of the treatments. The lowest height of sorghum plants was found in weedy control treatment with an average of 44.5 centimeters (Table 2). The plant height, dry weight and yield increased significantly in weed free treatment, with the increase in initial duration of weed-free condition up to 60 days after sowing and with the decrease in initial duration of weedy condition up to 15 days after sowing. Sorghum plant has a low competitive ability against weeds at early growth stages therefore critical period would start sooner. According to Chantereau et al. (2013) around ten days after emerged, the nodal roots of sorghum take over from the seminal root and the seedling invests more in underground organs which makes seedlings vulnerable against weed competition, drought, parasitical attack and nutrients deficit. Furthermore, the weeds were more competitive at initial stage of crop growth because sorghum grows slower in earlier stage (Chantereau et al. 2013) while weeds are growing faster under tropical zone because of high temperature and moisture conditions during rainy season (Merlier and Montégut, 1982; Baudry et al. 1989).

Effect of time of weed removal on sorghum dry matter

Sorghum dry matter at different weed crop competition periods under fertilized and unfertilized systems are shown in table 3. The sorghum dry matter was significantly affected by the weeding interval treatments. For plots without fertilizer, grain sorghum dry matter was increased significantly with each decrease in competition period and the highest dry weight was obtained in treatments WFC, W4 and WF1 with respectively 2.6; 2.7 and 2.8 tons per hectare. In 2017, maximum sorghum biomass was observed in treatments WFC (5.5 ton hectare^{-1}), WF1 (5.0 ton hectare^{-1}) and W4 (4.8 ton hectare^{-1}). The lowest dry weight of sorghum around 0.5 ton per hectare was recorded in treatments W1, WF3, WF4 which showed an effect of long competition period on sorghum yield component.

Table 3. Effect of time of weed removal on sorghum dry matter.

Treatment	Yield of dry matter (kg.ha^{-1})			
	2016		2017	
	F_0	F_1	F_0	F_1
WFC	2819^{a}	6728^{a}	5556^{a}	12056^{a}
W4	2783^{a}	5111^{abc}	4889^{ab}	9667^{ab}
WF1	2583^{a}	5128^{abc}	5056^{ab}	11972^{a}
W2	2136^{ab}	3753^{bcde}	2111^{abc}	7556^{abc}
W3	1744^{abcd}	4006^{abcd}	2361^{abc}	8722^{abc}
WF2	1956^{abc}	5806^{ab}	3389^{abc}	5222^{abc}
WF3	1319^{abcd}	3108^{bcdef}	583^{c}	2167^{bc}
W1	1406^{abcd}	1078^{def}	611^{c}	6444^{abc}
P4	1125^{abcd}	1214^{def}	1736^{bc}	4083^{abc}
P1	1653^{abcd}	2261^{cdef}	2639^{abc}	8764^{abc}
P3	642^{bcd}	2361^{cdef}	2782^{abc}	3333^{abc}
WF4	492^{bcd}	806^{ef}	556^{c}	2556^{bc}
P2	261^{cd}	1933^{def}	1556^{bc}	4444^{abc}
WC	44^{d}	519^{f}	-	381^{c}
Mean	1497	3129	2601	6240
Coefficient of variation	25.9	25.7	27.1	22.9
Significant values	<0.001***	<0.001***	<0.001***	<0.001***

Any two means not sharing a letter in common in a column differ statistically at 5% probability level.

In 2016, under fertilized conditions, the best biomass production was obtained in treatments WFC, WF2 and W4 with respectively 6.7, 5.8 and 5.1 tons per hectare. The lowest dry matter was recorded in treatments WC, WFC and W1 with respectively 0.5, 0.8 and 1.1 ton per hectare. In 2017, significant higher sorghum biomass of 12.0 and 11.9 ton/ha were recorded in weed free control (WFC) and weed up 60 DAS (W4) treatments. Dry matter of sorghum recorded in treatments WF3, WF4 and WC was the lowest.

The lowest dry matter and grain yield recorded in weed check plots may be ascribed to the maximum density and dry matter of weeds which compete with the crop plant.
Moreover, the highest sorghum plant consumption is noted during the flowering stage (House 1987; Sène, 1995). At this stage, water stress causes less nitrogen mobilization for the crop (Sène, 1995) and increased vulnerability against weed competition which impact negatively sorghum dry matter production.

Effect of time of weed removal on sorghum grain yield

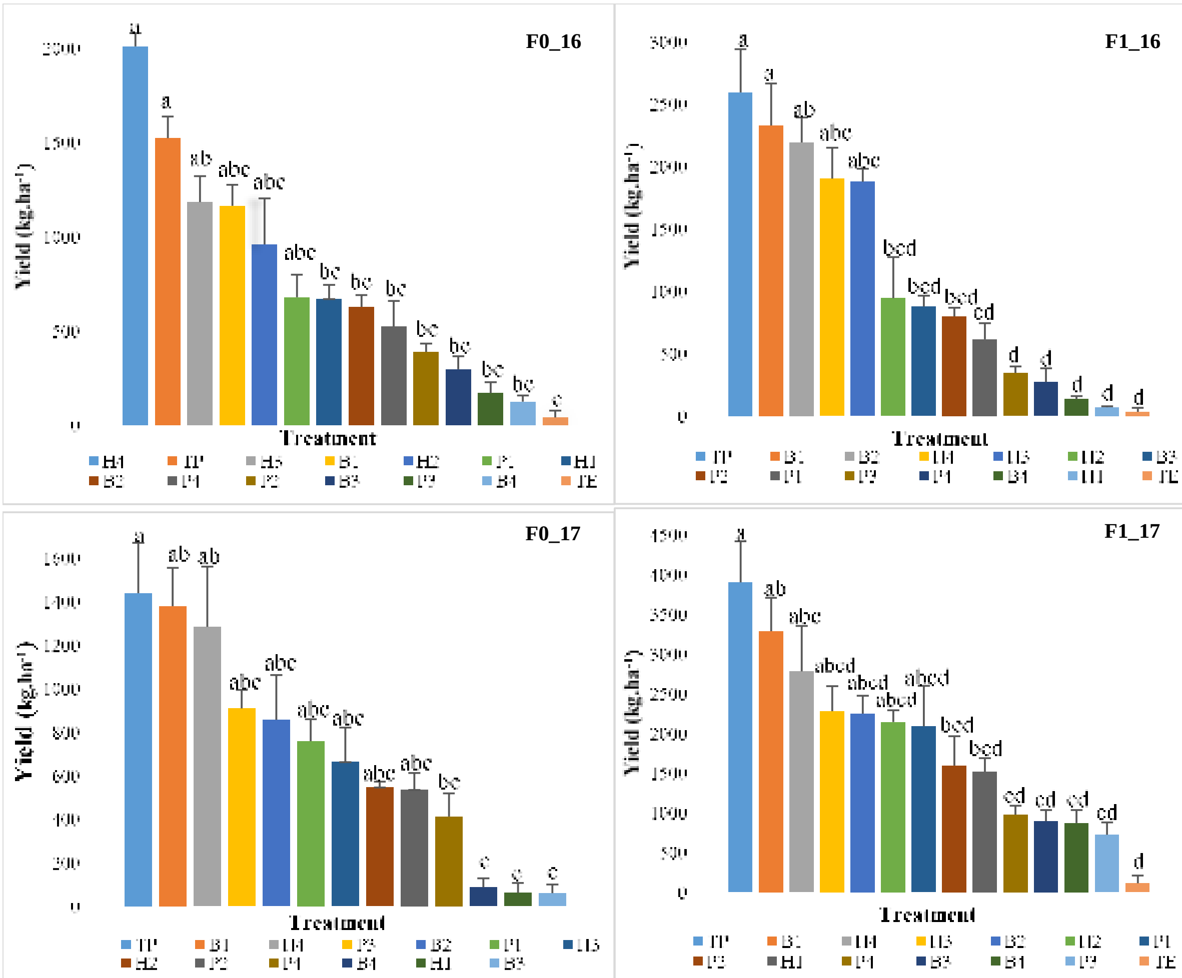
Grain yield were significantly affected by the weeding interval treatments (Figure 1).

In 2016, under unfertilized conditions, among the treatments, the highest yields were obtained in W4 and WFC treatments while the WC treatment recorded the lowest yield. In 2017, the WF control gave the best yield followed by W4 and WF1. The lowest grain yields were recorded in treatments WF4, W1 and WF3.

Under mineral fertilization, the highest grain yield (2.6 ton hectare^{-1}) was found in weed free control treatment and significantly higher to rest of the treatment in 2016. It was followed by WF1, WF2 and W4 where the yield recorded was respectively 2.3, 2.2 and 1.9 tons per hectare. The lowest grain yield was found in treatment WC (32 kg ha^{-1}), W1 (70 kg ha^{-1}) and WF4 (134 kg ha^{-1}). In 2017, the best grain yield was obtained in treatments WFC (3.9 tons ha^{-1}), WF1 (3.2 ton ha^{-1}) and W4 (2.7 ton ha^{-1}) while grain yield recorded in treatments WC (0.1 ton ha^{-1}), P3 (0.7 ton ha^{-1}) and WF4 (0.9 ton ha^{-1}) remained the lowest. Mathieu (2005) observed that weed competition affects the nitrogen nutrition index, which tends to decrease with increasing weed recovery and this negatively impacts the number of grains per panicle and panicles per plant.

Determination of the critical period of weed-sorghum competition

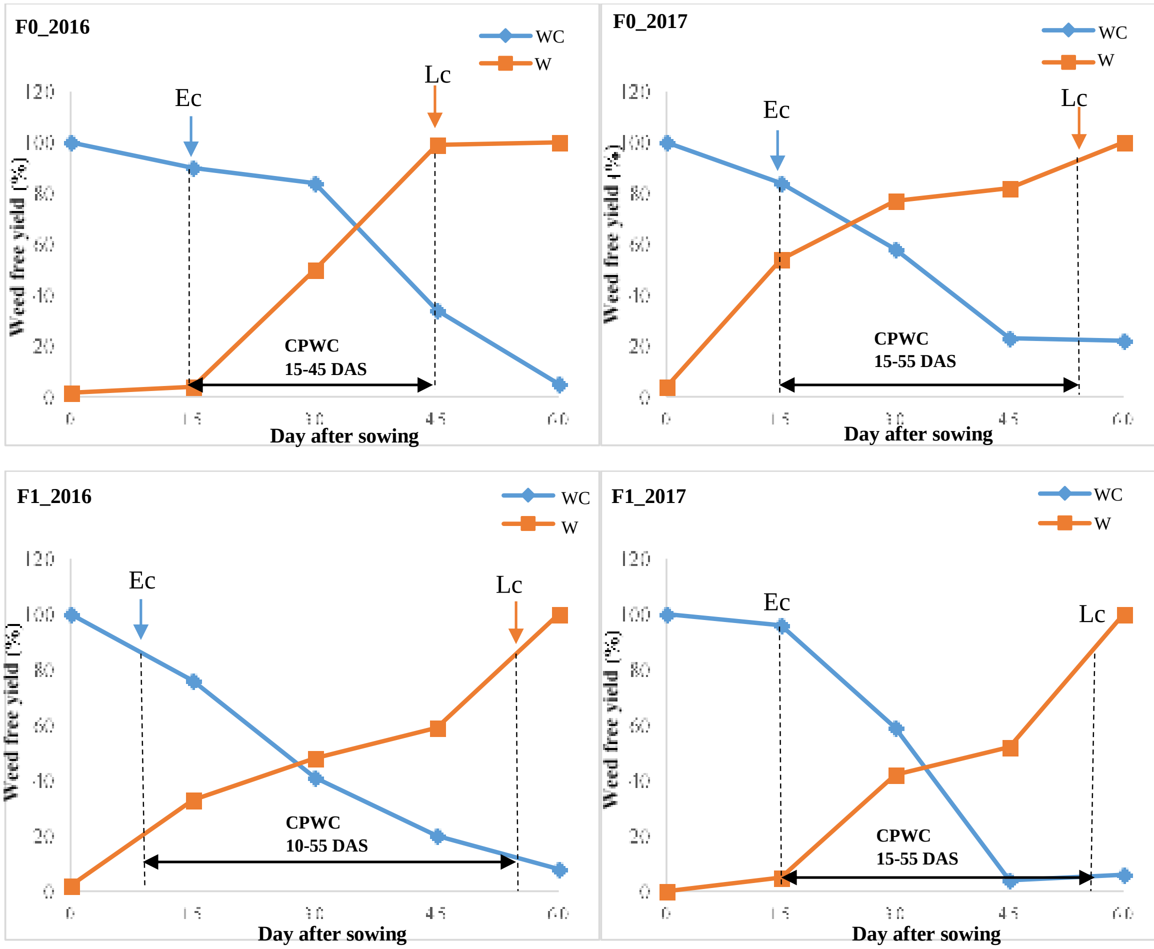
Our findings indicated that weed control measures in sudanian zone of Senegal begin 15 days after sowing till 45 and 55 days after sowing under traditional cropping system and 10-55 days after sowing under conventional system (Figure 2). During this critical period of weed control, sorghum should be kept weed free to avoid losses that can range from 10 to 96% of grain yield.



F0= unfertilized; F1= fertilized

Figure 1. Effect of time of weed removal on sorghum grain yields.

Similar findings have been recorded by Duary and Hazra (2013) in sesame, Bassène (2014) in corn, and it was noticed that the period of weed critical period in tropical and subtropical zone of Africa never exceed 60 days after sowing (Le Bourgeois et Marnotte, 2002; Noba, 2002; Mbaye, 2013) despite variations due to several factors such as rainfall, crop, weed dynamic and structure. Therefore, a critical period of crop-weed competition (CPWC) cannot be generalized but adapted according the cropping systems, management practices, etc. (Le Bourgeois and Marnotte, 2002). The early competition threshold and the late competition threshold found in this study correspond respectively to the formation of seminal roots and to the implementation of the physiological mechanisms of panicle initiation stages. Several studies reported the vulnerability of sorghum against weeds, water, temperature, diseases, insects etc. during these phases (House, 1987; Sène, 1995; Chantereau et al. 2013). Sorghum plant has a low competitive ability against weeds at early growth stages therefore critical period would start sooner mainly under N fertilizer conditions. As showed by Tursun et al. (2015), application of N fertilizer delayed the beginning of the CPWC because Nitrogen fertilization could break dormancy of many weed species; which may directly affect weed infestation (Blackshaw et al. 2003). Furthermore, structural variability of the weed community, density, rainfall and some other environmental factors, such as mean annual temperature may also affect the variability of the CPWC.



CPWC= critical period of weed competition; Ec= early competition; Lc= late competition; WC= weed control; WF= weed free control

Figure 2. Critical period of weed competition in sorghum under fertilized (F1) and unfertilized (F0) conditions.

Conclusion

In Senegal, manual and hand weeding are the major methods of weed control in rainy cropping system mainly for sorghum growers. The highest plant height, dry matter and yield were recorded in weed free treatment followed by weed free up to 60 days after sowing and weedy up to 15 days after sowing. The result also showed that plant height, biomass and yield decreased significantly with each increase in competition period. Therefore the lowest growth parameters and yield were noticed in weedy check treatment followed by weedy up to 60 days after sowing and weed free up to 15 days after sowing. The maximum competition between crop and weed was between 15 and 45-55 days after sowing under unfertilized conditions and 10 and 55 days after sowing under fertilized conditions, which can be considered as critical period of crop-weed competition. Yield recorded in agronomic practices are generally low, less than 1 ton per hectare both in fertilized and unfertilized conditions. Based on this study, it can be concluded that higher dry matter and yield may be obtained by controlling the weeds during this period despite variations due to several factors such as rainfall, temperature etc.

Conflicts of Interest

Authors declare no conflicts of interest for this study.

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