Determination of Critical Period of Weed Competition in Faba bean (*Vicia faba* L.) at Haramaya, eastern Ethiopia

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Abstract

Weeds reduce the yield and quality of faba bean if they are left unmanaged. Therefore, a field experiment was conducted using the faba bean variety Gachena (EH91001-13-2) as a test crop under rain fed conditions at Haramaya, eastern Ethiopia, during 2017 main cropping season with the objective to determine the critical period of weed competition in faba bean. Twelve treatments in two sets, i.e. increasing duration of weedy and weed-free set each comprising weed competition and weed-free durations up to 15, 30, 45, 60 and 75 days after crop emergence (DAE) up to harvest, were laid out in a randomized complete block design with three replications. The data were collected on both weeds and the crop. The results of the study revealed that the maximum faba bean grain yield loss due to weedy check was 55.7% as compared to the grain yield from weed-free check (3,376 kg ha^{-1}). Thus, to prevent more than 5% yield loss of faba bean, the variety Gachena should be kept free of weeds from 237 to 669 growing degree Celsius days.

Keywords: Competition, critical period, *Vicia faba*, weeds, yield loss

Introduction

Faba bean (*Vicia faba* L.) is the first most important crop among the food legumes in Ethiopia. In the 2015/2016 cropping season, about 444,000 ha were cultivated with faba bean with the total production of 843,536 tons. The average yield obtained in the country was about 2 t ha^{-1} (CSA, 2016), which shows lower yield than the attainable yield of 5 t ha^{-1} (MoA, 2014). In West Hararghe Zone, faba bean was produced on total land area of about 540 ha with a total production of 550 t and yield of 1 t ha^{-1} during 2015/16 cropping season (CSA, 2016). Similarly, in East Hararghe Zone, faba bean accounted for a total production of about 5060 t. This low yield can be attributed to various biotic and abiotic stresses of which insect pests, plant diseases and weeds are the main biotic yield-limiting factors in its production (Torres *et al.* 2006; Zuhal *et al.* 2010). Among the biotic factors, the parasitic weed *Orobanche crenata*, which germinates in response to chemicals released from the faba bean causes losses of 50 to 80% (Gressel *et al.* 2004; Joel *et al.* 2007).

Weeds are plants that compete for nutrients, soil moisture, light and space, and exert a lot of harmful effects by reducing the quality as well as quantity of the crop, if not properly managed at a critical period (Halford *et al.* 2001; Kavaliauskaite & Bobinas 2006). Legume species generally have an open growth habit and a slow-growth rate in the early stages of the crop cycle, characteristics that favor the emergence and growth of weeds (Smitchger *et al.* 2012). It is estimated that 50% of all labor input into crop production in Sub-Saharan Africa (SSA) is expended on hand weeding (Akobndu 1991). Crop yield losses from weeds have been estimated at 10% in the less developed and 25% in the least developed countries (Akobndu 1991).

Identifying the critical period of weed management for a given crop/variety is essential for determining the appropriate timing of weed management and the efficient use of herbicides (Evans *et al.* 2003; Bukun 2004; Otto *et al.* 2009). Competition between the crop and weeds, and thus the critical period of weed control (CPWC), are dependent on site-specific factors, such as climatic conditions, management strategies, the composition of weed flora, weed density, and weed emergence time (Rajcan & Swanton 2001). Also, the critical period of weed control tends to vary widely with grain legume species (Mohammad *et al.* 2005; Fedoruk *et al.* 2011). Weeds differ in their ability to compete with the crop at similar density levels and the relative competitive ability of weeds for obtaining resources will depend on the weed species and the crop that is grown. This is primarily because of the difference in their growth habits as well as due to the allelopathic effects, which they may exert on the germination and growth of the crop. The degree of interference with the crop is affected by the relative competitive ability of the weeds. The competition often suppresses crop dry matter production and grain yield (Bhaskar & Vyas 1988).

Studying the critical period of weed competition also aids to plan appropriate and economic management strategies that are environmentally friendly with little or no residual effects on the crop by identifying the most favorable time periods for the optimum integrated weed management (IWM) program (Carvalho and Christoffoleti, 2008). Developing a suitable IWM system requires the precise study of weeds and their interference with crops (Cruse *et al.* 1995).

Weed growth prior to the beginning of the critical period of weed control does not affect yield because the crop and the weeds are too small or too far apart to negatively influence each other (Rajcan *et al.* 2004). Similarly, weeds that emerge after the end of the critical period of weed control do not appreciably affect yield because the crop has a high competitive ability. Idris (2001) reported that losses in faba bean yield due to weed infestation in the Sudan were 33 and 51% in 1999 and 2000, respectively. Alfonso *et al.* (2008) also indicated that the end of the CPWC of faba bean occurred at the early full-flowering stage when the canopy of each crop enclosed the inter row space. Moreover, the CPWC at a 5% yield loss level for faba bean ranged from 28 to 33 days in the Mediterranean basin. However, in Ethiopia, there is no information on critical period of weed competition in faba bean.

Thus, this study was undertaken to assess the effect of durations of weed competition on yield components and yield of faba bean; and to identify the critical period of weed competition in faba bean at Haramaya, eastern Ethiopia.

Materials and Methods

Description of the experimental site

A field experiment was conducted at the Haramaya University Research Farm in East Hararghe Zone in Oromia Regional State during 2017 main cropping season. The site lies at an altitude of 2022 meters above sea level, 9°26' north latitude and 42°3' east longitude. It receives an average annual rainfall of 780 mm; with mean annual minimum and maximum temperatures are 3.8 and 24.1 °C, respectively (Tekalign 2013). The experimental site during the cropping season of July to November in 2017 received total annual rainfall of 452.6 mm and mean air temperature of 25.6 °C (Figure 1). The soil of the study site is well-drained deep alluvial with organic matter content of 1.68%, total nitrogen of 0.15%, available phosphorus of 5.26 mg kg^{-1} , pH of 7.45 with sandy clay loam texture (Degefa 2015).

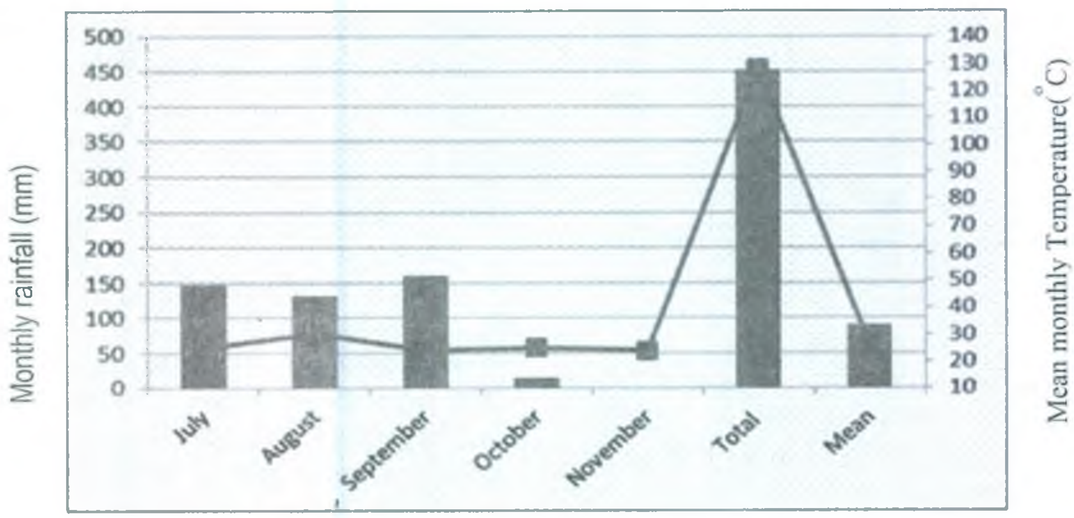


Figure 1. Mean annual rainfall and temperature of Haramaya during 2017 cropping season.

Treatments and experimental design

There were twelve treatments, including weedy up to 15 days after emergence (DAE); weedy up to 30 DAE; weedy up to 45 DAE; weedy up to 60 DAE; weedy up to 75 DAE; weedy up to harvest; and conversely weed-free up to 15 DAE; weed-free up to 30 DAE; weed-free up to

45 DAE; weed-free up to 60 DAE; weed-free up to 75 DAE; and weed-free up to harvest. The gross plot size was 2.4 m ×3 m (7.2 m^2). The design used was randomized complete block design with three replications. The distances between blocks and plots were 1 m and 0.5 m, respectively. Each plot consisted of six rows of 3 m length and the spacing between rows and plants was 40 and 10 cm, respectively. The net plot size was 1.6 m × 3 m = 4.8 m^2) comprised of four rows of 3 m length, excluding one row from each side of the plot as a border.

Management of the experimental field

The faba bean variety, called *Gachena* (EH91001-13-2), was used for the study. The variety was released by the Highland Pulses Research Program of Haramaya University in 2007. The variety has an indeterminate growth habit and is well adapted to the Hararghe highlands (MoARD 2008).

The experimental field was plowed and harrowed to a fine tilth using tractor. The seeds were sown on well-prepared seedbed in rows at the rate of two seeds per hill and later on thinned to one plant per hill. Diammonium phosphate (DAP) was applied at a rate of 100 kg ha^{-1} DAP (i.e. 18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}) at the time of planting as per the recommendation for the crop. Moreover, all other necessary field management practices were carried out as per the recommendation for the study area.

Data collected

The weed dry weight was determined for each plot during weed removal from the early competition and about 15 days before harvesting for late competition by placing a quadrat having an area of 0.25 m^2 and the weed species were grouped into grasses, broad leaved weeds and sedges and the samples were oven dried at 80 °C for 48 hours.

Crop data

Phenological and growth parameters

Days to 50% flowering was determined by counting the number of days from planting to the time when the first flowers appeared in 50% of the plants in a plot. Similarly, days to 90% physiological maturity was determined as the number of days from planting to the time when 90% of the faba bean plants started senescence of leaves (yellowing of the foliage) and pods started to turn yellow. The number of primary branches was determined by counting the total number of branches on five randomly pre-tagged plants in the net plot at physiological maturity and averaged on per plant basis and the plant height was measured at physiological maturity from the base to the tip of a plant for five randomly pre-tagged plants in harvestable rows using measuring taper (m) and averaged on a plant basis and expressed in centimeters.

Yield components and yield

The number of pods per plant was recorded from five pre-tagged plants in each net plot area at harvest and the average was taken as number of pods per plant. Likewise, the number of seeds per pod was determined by counting the number of seeds in the pods on five pre-tagged plants and then averaged on per pod basis. Hundred seed weight was determined by weighing 100 seeds randomly taken from the bulk of the harvest using a sensitive balance. The weight was adjusted to a moisture content of 10% and expressed in grams.

Grain yield was measured by harvesting the crop from the net plot area. The recorded grain yield of faba bean was adjusted to 10% moisture level and the final yield was expressed in kg ha^{-1}. From the yield data relative faba bean yield (%) was calculated as: relative faba bean yield

$$= \frac{Yield of faba bean in treatments}{Yield of the weed free check} \times 100.$$

Then, the maximum grain yield loss of faba bean due to weed interference was calculated as: maximum grain yield loss of faba bean =

$$1 - \frac{Yield of faba bean in weedy check}{Yield of the weed free check} \times 100.$$

Finally the growing degree days (GDDs) was calculated based mean monthly temperature of the growing season for the respective treatments which were in days after emergence.

$$GDDs = \frac{Maximum\ temprature - minimum\ temprature}{2} - base\ temprature$$

Data analysis

The collected weed and crop data were subjected to analysis of variance (ANOVA) using GenStat Release 16 software (GenStat, 2014). Mean comparison among the significant treatments was performed using Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

Weed flora of the experimental site

A total of 20 weed species belonging to 14 plant families were recorded in the experimental site. The highest proportion of weeds was found to be broad leaved weeds, followed by sedges, while grassy weeds were less frequent. Among the predominant weed species competing vigorously based on their density in faba bean were *Commelina benghalensis*, *Erucastrum arabicum*, *Argemone ochlereuca*, *Parthenium hysterophorus*, *Galinsago parviflora*, *Oxalis latifolia*, *Convolvulus arvensis* and *Plantago lanceolata* (Table 1).

Table 1. Weed flora with their families infesting faba bean in the experimental plots at Haramaya research site during 2017 main cropping season.

No.	Weed species	Family	Density	Life form
1	*Commelina benghalensis* L	Commelinaceae	78.7	Broad leaved (annual)
2	*Argemone ochlereuca* L.	Papaveraceae	44.0	Broad leaved (annual)
3	*Parthenium hysterophorus* L.	Asteraceae	42.7	Broad leaved (annual)
4	*Galinsoga parviflora* Cav.	Asteraceae	40.0	Broad leaved (annual)
5	*Oxalis latifolia* L.	Oxalidaceae	34.7	Broad leaved (annual)
6	*Convolvulus arvensis* L.	Convolvolaceae	26.7	Broad leaved (annual)
7	*Plantago lanceolata* L.	Plantaginaceae	24.0	Broad leaved (annual)
8	*Anagalis arvensis* L.	Primulaceae	22.7	Broad leaved (annual)
9	*Scorpiurus muricatus* L.	Fabaceae	18.7	Broad leaved (annual)
10	*Cyperus esculentus* L.	Cyperaceae	17.3	Sedge (perennial)
11	*Cyperus rotundus* L.	Cyperaceae	13.3	Sedge (perennial)
12	*Cynodon dactylon* L.	Poaceae	10.7	Grassy (perennials)
13	*Medicago polymorpha* L.	Fabaceae	10.7	Broad leaved (annual)
14	*Amaranthus hybridus* L.	Amaranthaceae	9.3	Broad leaved (annual)
15	*Guizotia scabra* L.	Asteraceae	9.3	Broad leaved (annual)
16	*Equisetum arvense* L.	Equisetaceae	9.3	Broad leaved (annual)
17	*Erucastrum arabicum* Fisch & mey.	Crucifereae	8.0	Broad leaved (annual)
18	*Nicandra physaloides* Scop.	Solanaceae	2.7	Broad leaved (annual)
19	*Datura stramonium* L.	Solanaceae	2.7	Broad leaved (annual)
20	*Avena fatua* L.	Poaceae	2.0	Broad leaved (annual)

Weed dry weight

Analysis of variance (ANOVA) indicated that weed dry weight was highly significantly ($p<0.01$) influenced by different time of weed competition. The highest weed dry weight (961.7 g m^{-2}) was recorded at weedy check, followed by a plot kept weedy up to 75 DAE with a value of 834.4 g m^{-2} in the increasing duration of weedy periods (IDWP), which was statistically similar with the value obtained at 15 DAE in the increasing duration of weed-free periods, whereas the minimum dry weight (2.7 g m^{-2}) was obtained at a plot kept weed-free up to 75 DAE without considering the value in a weed-free checks (Table 2).

In general, weed dry weight increased with increasing duration of the weedy period (IDWP) and decreased with the increasing duration of the weed-free period (IDWFP). In IDWP, the weeds might have exerted a severe competition and utilized the growth factors for a longer period, which resulted in accumulation of more dry matter, but in IDWFP, the weeds germinated and developed after the respective weed-free periods after the crop reached at higher competitive advantage, which suppressed weed growth by the crop. Thus, the newly emerged weeds and less competent under stress accumulated lower dry weight. In line with this result, Stagnari *et al*. (2011) and Smitchger *et al*. (2012) found that the density and dry weight of weeds were inversely proportional to the increase in weed removal periods. Similarly, Mengesha *et al*. (2013) reported for common bean that weed dry weight decreased as the weed-free period was prolonged but increased in the increasing duration of weed competition.

Crop parameters

Phenological and growth parameters

The results of the experiment indicated that days to 50% flowering were not significantly affected by the durations of weed interference although there was a small numerical difference among the treatments. In general, days to flowering ranged from 50.67 to 54.33 days. However, significant difference ($p<0.05$) was observed in days to 90% physiological maturity. The maximum days to 90% physiological maturity (108.3) was observed in the treatments, which were kept weed-free beyond 60 DAE, whereas the shortest duration (101 days) to reach 90% physiological maturity was observed in weedy check plots (Table 3). In general, with increasing duration of weedy period and decreasing duration of the weed-free period, the days required to attain physiological maturity decreased. This might be due to the severe competition of the weeds with the crop for the limited environmental resources when weeds were allowed to germinate and grow for prolonged periods. This, in turn, may aggravate the stress for the plant, which compels the crop towards physiological response for stressful environment that enables the crop to mature earlier to escape the stressful environment before drying.

Table 2. Effect of duration of weed–faba bean interference on weed dry weight at Hramaya during 2017 main cropping season.

Treatments	Broad leaved weeds	Sedge
IDWP (DAE):		
15	27.7 (5.25[d])	0.867 (1.058[bc])
30	240.5 (15.40[c])	2.314 (1.543[abc])
45	400.1 (20.00[b])	0 (0.707 [c])
60	708.8 (26.57[a])	1.928 (1.425[abc])
75	834.4 (28.60[a])	3.367 (1.873[ab])
WC	961.7 (30.70[a])	4.439 (2.120[a])
IDWFP (DAE):		
15	438.1 (20.90[b])	0.256 (0.847[c])
30	215.5 (14.69[c])	0.878 (1.060[bc])
45	135.3 (11.65[c])	0 (0.707[c])
60	19.7 (4.31[de])	0.459 (0.928[c])
75	2.7 (1.64[de])	0 (0.707[c])
WFC	0.0 (0.71[e])	0 (0.707[c])
LSD (0.05)	4.2730	0.8677
CV (%)	16.8	44.9

Where; DAE= days after emergence; IDWP=increasing duration of weedy period; IDWFP= increasing duration of weed-free period; WC= weedy check; WFC= weed-free check; Values in parenthesis are square root transformed values, while out of parentheses are original values; Means followed by the same letters in the same column are not significantly different from each other at 5% significance level

The current result is in agreement with the observation of Desclaux and Roumet (1996) who reported that limited water supply triggers a signal to cause an early switching of plant development from the vegetative to reproductive phase. Similarly, in soybean (*Glycine max* L.), drought during grain filling hastened physiological maturity but yield was reduced due to smaller grains. Furthermore, Prasad *et al.* (2008) reported that moderate drought diminishes the length of time from flowering to anthesis (i.e. drought escape); however, it might be increased under severe water stress. In contrast, Mitiku *et al.* (2012) reported that with increase in the dry weight of *Parthenium hysterophorus*, the duration required by the common bean plants to reach physiological maturity was delayed.

Number of primary branches per plant was highly significantly ($p<0.01$) affected by the different periods of weed-crop competition. A weed-free check plot had the maximum number of branches per plant (4.33) in the increasing duration of weed-free period, followed by a plot that was kept weedy up to 15 DAE with the value of 4.0 in the increasing duration of weedy period, while the lowest number of branches per plant (1.09) was recorded from weedy check, followed by the treatments kept weedy up to 75 DAE (Table 3). The number of primary branches per plant increased as the duration of weed interference was shortened or it increased when the faba bean crop was kept free of weeds for longer periods. This might be due to when weeds were left unweeded for longer time, environmental factors became limited, which brought resource scarcity and finally prevented crop branching.

In line with the current result, Almarie (2017) obtained that the increase of soybean branches continued significantly between weed removal treatments until five weeks of removal, and then no significant increase was obtained. Singh *et al.* (2015) also described that number of primary branches per plant in field pea increased when the weed-free days were prolonged.

The result of the experiment showed significant ($p<0.05$) differences among the treatments for plant height. The highest plant height (157.8 cm) was obtained in weedy check and plots remained weedy for 75 DAE (156.7 cm) under the increasing duration of weedy period, whereas significantly the shortest plant height was recorded in plots which were free of weeds for 75 DAE, followed by weed-free checks (Table 4). In general, with increasing duration of weedy period and decreasing duration of weed free period, plant height increased, which could be due to weeds that were left to grow for longer periods; the weed plant population per unit area tended to increase, which resulted in severe competition between crop and weed for light and space. The current result is in agreement with the investigation of Singh *et al.* (2015) who reported that the field pea plant height increased with increase in duration of weed interference and decreased with increase in weed-free periods.

Yield components and yield

Number of Pods per plant

Significant ($p<0.05$) differences were observed in the number of pods per plant due to duration of weed competition. The least number of pods per plant (9.07) was obtained from the weedy check, which was at statistical parity with the number of pods per plant in plots kept weedy up to 75 DAE. On the other hand, the maximum number of pods per plant (17.6) was recorded at weed-free check, which was at statistical parity with the value obtained from the plot kept weed-free for 45, 60 and 75 DAE (Table 4). Generally, the trend from the treatment means revealed that the number of pods per plant increased with decrease in weed interference period which could be due to decreased weed dry weight.

Table 3. Effect of duration of weed-faba bean interference on days to 90% physiological maturity, number of primary branches per plant and plant height of faba bean at Haramaya during 2017 main cropping season.

Treatments	Days to 90% PM	NPBPP	PH (cm)
IDWP (DAE)			
15	104.7[ab]	4.00[ab]	153.4[abcde]
30	102.3[ab]	2.60[de]	154.3[abc]
45	102.3[ab]	2.07[def]	154.6[abc]
60	101.3[b]	1.40[fg]	155.1[abc]
75	101.3[b]	1.13[g]	156.7[ab]
WC	101.0[b]	1.09[g]	157.8[a]
IDWFP (DAE)			
15	103.0[ab]	1.87[efg]	154.9[abc]
30	104.7[ab]	2.73[cd]	153.7[abcd]
45	106.3[ab]	2.73[cd]	142.3[bcde]
60	108.3a	3.47[bc]	141.5[cde]
75	108.3[a]	3.93[ab]	139.1[e]
WFC	108.3[a]	4.33[a]	139.3[de]
LSD (0.05)	6.1070	0.7852	14.4800
CV (%)	3.5	17.7	5.7

Where; DAE= days after crop emergence; IDWP= increasing duration of weedy periods; WC= weedy checks; IDWFP= increasing duration of weed-free periods; WFC= weed-free check; PM= days to physiological maturity; NPBPP= number of primary branches per plant; PH = plant height; Means followed by the same letters in the same column are not significantly different from each other at 5% significance level.

Similarly, Mengesha *et al*. (2013) reported in common bean that the number of pods per plant significantly increased with the increase in duration of weed-free period and decreased with increase in durations of weedy period. Furthermore, Almarie (2017) also indicated that the total number of pods per plant of soybean was affected by weed removal period; where removing weeds through the first week after emergence did not show any improvement of the total number of pods per plant.

Number of seeds per pod

Significant ($p<0.05$) differences were obtained in number of seeds per pod due to the duration of weed competition. The highest number of seeds per pod (3.69) was recorded in weed-free checks which were statistically at par with the treatments kept weed-free beyond 45 DAE under the increasing duration of weed-free period and in the the plots left unweeded up 15 and 30 DAE in increasing duration of weedy periods. On the other hand, the least number of seeds per pod (2.26) was obtained from the weedy check plots, which was statistically similar with the value obtained in the plot when weeds were allowed to interfere with the crop beyond 45 DAE and when weeds were removed up to 15 DAE (Table 4). Generally, the number of seeds per pod was inversely related to the length of weedy periods, whereas it was directly proportional to the length of weed-free durations.

In line with the current result, Singh *et al.* (2015) reported that yield and yield attributes, including number of seeds per pod of field pea increased with increase in weed-free duration and decreased with increase in weedy period. Similarly, Nano and Sharma (2017) reported the maximum number of seeds per pod of faba bean from the weed-free checks, followed by a plot treated with S-metolachlor at a rate of 1.0 kg ha^{-1} supplied with one hand weeding five weeks after emergence, whereas the minimum was from the weedy check plot under different weed management systems.

Table 4. Effect of duration of weed- faba bean competition on yield components and yield of faba bean at Haramaya during 2017 main cropping season.

DAE	NPPP	NSPP	100 SW (g)	GY (kg ha^{-1})
IDWP				
15	14.87^{bcd}	3.49^{ab}	78.50^{abc}	3315^{ab}
30	13.27^{cde}	3.16^{abc}	77.67^{abc}	3019^{b}
45	11.80^{ef}	2.82^{cde}	70.74^{bcd}	2291^{c}
60	10.27^{fg}	2.47^{de}	68.48^{cd}	1643^{d}
75	9.20^{g}	2.40^{de}	59.32^{d}	1532^{d}
WC	9.07^{g}	2.26^{e}	59.56^{d}	1495^{d}
IDWFP				
15	13.00^{de}	2.40^{de}	67.59^{cd}	1788^{d}
30	14.33^{bcd}	3.00^{bcd}	70.36^{cd}	2240^{c}
45	15.47^{abc}	3.27^{abc}	76.41^{abc}	3166^{ab}
60	16.20^{ab}	3.34^{abc}	78.24^{abc}	3298^{ab}
75	17.20^{a}	3.61^{ab}	84.17^{ab}	3345^{ab}
WFC	17.60^{a}	3.69^{a}	84.76^{a}	3376^{a}
LSD (0.05)	2.277	0.64	13.81	332.45
CV (%)	9.9	12.6	11.2	7.7

DAE= days after crop emergence; IDWP= increasing duration of weedy periods; WC= weedy checks; IDWFP= increasing duration of weed-free periods; WFC= weed-free checks; NPPP= number of pods per plant; NSPP= number of seeds per pod; 100 SW=100 seed weight; AGDB= aboveground dry biomass; GY= grain yield; Means followed by the same letters in the same column are not significantly different from each other at 5% significance level.

Hundred seed weight (g)

Hundred seed weight was highly significantly ($p<0.01$) influenced by the duration of weed competition. The maximum hundred seed weight (84.76 g) was obtained from weed-free check plots, which was not significantly different from treatments kept weed-free beyond 30 DAE and the lowest 100 seed weight (59.56 g) was found in weedy checks, which was statistically at par with the value obtained at the treatments that remained weedy beyond 45 DAE in the increasing duration of weedy period (Table 3). In general, 100 seed weight of faba bean was inversely related to the increase in the duration of weedy period and directly proportional to the increase in weed-free periods. The highest 100 seed weight in the increasing duration of weed-free period might be due to the accumulation of adequate dry matter by the crop through the utilization of available aboveground and belowground growth resources by the crop.

Similarly, Singh *et al.* (2015) stated that yield attributes, including 100 seed weight of field pea increased with increase in weed-free duration and decrease in weedy periods. They also reported that the yield attributes were highest in season-long weed-free period and at par with weed-free for initial 40 days or plots kept weedy only for initial 20 days.

Grain yield (kg ha^{-1})

Regarding the grain yield of faba bean, it was highly significantly ($p \leq 0.01$) affected by the duration of weed/crop interference. The highest grain yield of faba bean (3376 kg ha^{-1}) was recorded from the weed-free check, which was in statistical party with the yield of faba bean obtained from the treatments when plots were kept free of weeds beyond 45 DAE and when weeds were allowed to compete for the initial 15 DAE only. On the other hand, the weedy check plots had the lowest grain yield (1,495 kg ha^{-1}), which was statistically similar with treatments when weeds were left uncontrolled for more than 60 DAE and when weeds were removed for the initial 15 DAE only (Table 3).

The grain yield of faba bean was increased with the increasing duration of weed-free periods and decreased when the crop was left unweeded. The highest yield in season long weed-free treatment could be due to the contributing effect of yield attributes, like branches per plant, pods per plant, seeds per pod and 100 seed weight, which resulted from the efficient utilization of growth resources, such as nutrients, soil moisture and light. In conformity with this result, Zühal and Ufuk (2010) reported that the yield of faba bean significantly varied when weeds were allowed to grow for different durations and about 46% yield loss was recorded from the weedy check plot. Similarly, Knezevic and Datta (2015) stated that the removal of weeds, in the early stages of growth of leguminous crops, definitely led to a significant increase in economic yield.

The result of this study revealed that the faba bean grain yield loss in the weedy check plots due to weed interference throughout the entire life span of the crop was 55.7% as compared to the weed-free check plot. This observation is in agreement with the finding of Idris (2001) who reported that the grain yield losses in faba bean due to weed infestation in the Sudan were estimated at 33 and 51% in 1999 and 2000, respectively. Moreover, Zuhal *et al.* (2010) reported 46% grain yield loss accrued from uncontrolled weed growth throughout the life span of faba bean.

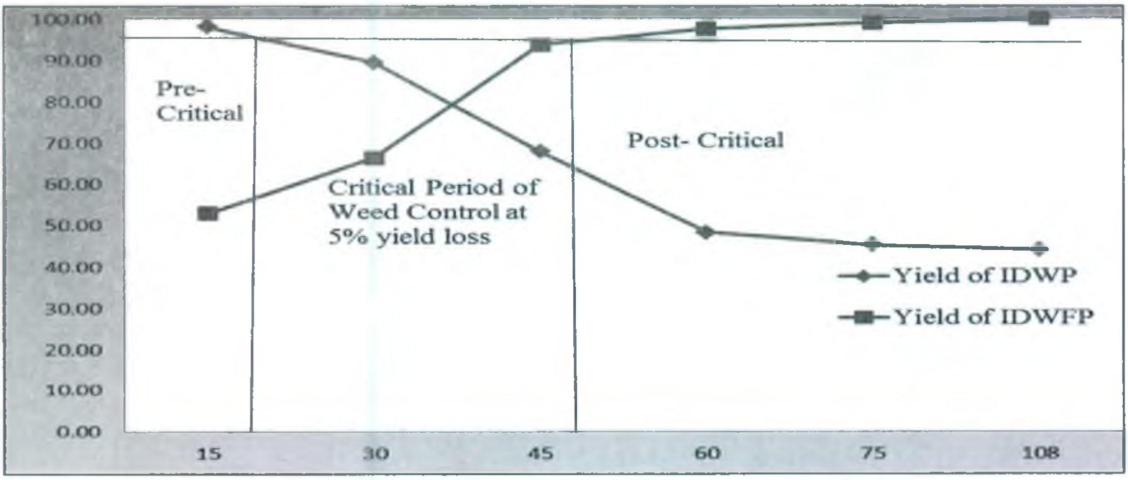
Critical period of weed control

The critical period of weed control was estimated based on the relative yields of faba bean with 5% acceptable yield loss. The starting of the critical periods of weed competition was obtained from the late weed-crop (from the increasing duration of weedy periods) competition, while the end of the critical periods of weed control was obtained from the early crop weed competition (from the increasing duration of weed-free periods (Figure 2). The growth degree celisus days (GDDs) were calculated for the respective number of days of each treatment starting from the average date of emergence. Based on the current result, the critical period of weed control for faba bean ranged from 237 to

669 GDDs. Thus, the weeds have to be managed during these periods through appropriate methods to prevent more than 5% yield loss of the crop. The current result was in conformity with the finding of Zuhal *et al.* (2010) who reported that the critical period of weed control in faba bean started at 30 and ends 45 days after crop emergence at 10% acceptable yield loss.

On the other hand, the critical periods of weed control in this study was wider than the result of Alfonso *et al.* (2008) who reported that the critical periods of weed control for faba bean ranged from 28 to 33 days after crop sowing to obtain 95% of faba bean yield in the Mediterranean basin. This wider critical period of weed control in the current study might be due the existence of early emerging, faster growing and regeneration capacity and more competitive weed species with the highest weed density. According to Knezevic *et al.* (2002), critical period of weed control varied with weed species composition, weed emergence pattern, weed density and intensity, ecological variations, climatic conditions, frequency of tillage operation and soil type of the area. Besides, Lehoczky *et al.* (2014) indicated that the length of the critical periods of weed control was influencedby the diversity and cover of weed species. Moreover, Everman *et al.* (2008) demonstrated that the duration of the critical periods of weed control was affected by the relative competitive ability of different weed species. Mohammad *et al.* (2005) also found that the critical periods of weed control tended to vary widely within a grain legume species.

Based on the current results, the critical period of weed control started in its early growth stage of the crop at about 17 days after faba bean emergence, the observation of which is in agreement with the investigation of Smitchger *et al.* (2012) who reported that the legume species generally have an open growth habit and a slow-growth rate in the early stages of the crop cycle, the characteristics of which favors the emergence and growth of several weed species and that lead to restriction of the development of the crop.



Days after emergence of faba bean

Figure 2. The graph showing the critical periods of weed competition of faba bean at 5% acceptable yield loss

Conclusions

The present study revealed that with increasing duration of weed-free periods, the number of days required to attain physiological maturity, number of pods per plant, seeds per pod, hundred seed weight, and grain yield of faba bean were significantly increased, while the reverse was true in case of increasing duration of weed. The maximum faba bean yield loss due to weed interference was 55.7% as compared to the weed-free check plots. To achieve more than 95% yield of faba bean, it has to be weed-free between 237 to 669 GDDs, which lies between 17 to 48 days after crop emergence at Haramaya.

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