American Journal of Plant Biology
2022; 7(2): 95-102
http://www.sciencepublishinggroup.com/j/ajpb
doi: 10.11648/j.ajpb.20220702.12
ISSN: 2578-8329 (Print); ISSN: 2578-8337 (Online)

Determination of Critical Weed Competition Period in Roselle (*Hibiscus sabdariffa* L.) Production at Wondo Genet, Southern Ethiopia

Ano Wariyo[1], Desta Abayechaw[2, *], Negasu Guteta[3]

[1]Department of Pathology, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
[2]Department of Agronomy, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
[3]Department of Entomology, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Email address:
destab09@gmail.com (D. Abayechaw)
[*]Corresponding author

To cite this article:
Ano Wariyo, Desta Abayechaw, Negasu Guteta. Determination of Critical Weed Competition Period in Roselle (*Hibiscus sabdariffa* L.) Production at Wondo Genet, Southern Ethiopia. *American Journal of Plant Biology.* Vol. 7, No. 2, 2022, pp. 95-102.
doi: 10.11648/j.ajpb.20220702.12

Received: March 1, 2022; **Accepted**: April 6, 2022; **Published**: April 14, 2022

Abstract: Among the biotic factors, weeds caused significant effects on the yield of roselle and play the greatest role in the production system. With this in mind, the study was carried out at Wondo Genet Rift Valley of Ethiopia to determine the critical weed competition period for growth, yield, and yield components of roselle under rainfed conditions. The experimental treatments consisted of a quantitative series of both the increasing duration of weedy periods and the length of the weed-free periods using Randomized Complete Block Design (RCBD) with three replications. Data of growth and yield-related parameters were timely collected following their respective standard methods and procedures and further subjected to analysis of variance (ANOVA) using SAS computer software version 9.4. The results analyzed showed that the weed competition duration had a significant influence on the number of primary branches per plant, the number of capsules /plants, fresh and dry calyx yield/plant, thousand seed weight, and seed yield kg ha^{-1}. The highest fresh and dry calyx yield was recorded from the weed-free check (15348.60kg ha^{-1}) and (1389.42 kg ha^{-1}) whereas the lowest was from the weedy-check (1009.70 kg ha^{-1}) and weedy for 75DACE (Days After Crop Emergence) (242.57 kg ha^{-1}), respectively. The highest seed yield was recorded from the weed-free check (39.03 kg ha^{-1}) whereas the lowest was from the weedy check (4.76 kg ha^{-1}). The yield losses of roselle were estimated based on fresh and dry calyx yield. Thus, the highest yield loss of fresh and dry calyx yield was recorded in the weedy-check (93.42%) and weedy for 90 (82.54%) DACE whereas the lowest was in the weed-free check (0.00%), respectively. To determine the beginning and the end of the critical period of crop-weed competition 5 and 10% acceptable yield loss levels were used. Therefore, to reduce the yield losses by more than 10% and higher economic return, plants must be kept weeds-free within 60 to 90DACE to reduce the risk of economic yield losses as it is the critical period of weed-crop competition in roselle plants.

Keywords: Critical Period, Roselle, Weed Species, Yield Losses

1. Introduction

Roselle commonly known as roselle belongs to the Malvaceae family and is one of the common flower plants grown worldwide. It is cultivated in tropical and subtropical regions of different worlds [2, 9]. But African countries like Benin, Sudan, Cote D'Ivoire, Ghana, Niger, Burkina Faso, and Nigeria were reported as major areas of roselle cultivation [27]. Roselle is a versatile plant found in almost all warm countries [18]. The calyx is one of the most economical parts of the plant that is obtained by removing the petals of the flower from its capsule containing the seeds. It is high in calcium, niacin, riboflavin, and iron. It contains three and nine times more vitamin C than blackcurrant (Ribes nigrum L) and citrus (Citrus sinesis L) fruit, respectively [18]. They are used as valuable food products; wine, jelly, beverages, jam, color, and flavour ingredients [18]. Non-food products include the pharmaceutical use of flowers and fruits to treat cases of bronchitis and cough, hypertension, diarrhea, and many other diseases [11, 16].

Roselle plant is mainly used to produce healthy juice and herbal tea full of flavor and tartness, due to its high contents of vitamin C and anthocyanins that are found in the calyces in Ethiopia. It is predominantly produced by small-scale farmers in their homestead gardens. Ethiopia has a suitable environment for the production of roselle plants. Besides, the country has a diverse agro-ecology that can be growing various medicinal crops with a vast impending for roselle production as well both in rainfed and irrigation conditions. Also, have a huge potential in internal and external markets possibly produce by the farming communities in the country. Despite these potentials and economic importance, the overall yield and quality are lowered both in farmer and private farms mainly due to biotic and abiotic factors. These factors included increased pressure of insects, diseases, and weeds and, in addition, poor cultural practices and harvest constraints during the growing periods. Among the biotic factors, weeds caused significant effects on the yield of roselle and play the greatest role in the production system [4]. About 10 and 25% of crop yield losses from weed competition have been estimated in the less developed and least developed countries, respectively [6].

To determine appropriate time and methods of weed management including the efficient uses of herbicide for a given crop, identification of critical period is essential in the growing period of the crops; it helps determine the crop growth stages most sensitive to weed competition [14, 26]. The critical period defined by [17, 20] is several weeks after crop emergence during which a crop must be weed-free to prevent yield losses greater than 5%. Thus, the timing of weed control measures is important to maintain optimum crop yield. A critical period for weed control (CPWC) is a fundamental constituent of any management strategies in weed control options. This determining the critical period of weed completion could help decrease yield losses due to weed interference [21]. However, [28] reported that competition between crop and weeds, and thus CPWC, are dependent on on-site specific factors: climatic conditions, management strategies, the composition of weed flora, and weed emergence time. At the same time, CPWC tends to might tend to be varying widely from other crops. [12] suggested that the development of an appropriate IWM system demands the precise study of weeds and their interference with the crop grown. Similarly, [4, 35] reported that losses in economic yield of roselle due to weed infestation in Sudan were ranged from 45.00 to 90.17%. [37] who reported that delayed weeding until late stages could result in irreversible damage to the crop due to weed competition.

Despite being an important biotic factor in the reduction of economic yield of roselle in the study areas due to weed infestation, there has been no detailed empirical research on the actual effects resulting in causing significant yield loss were studied. That are no studies were committed to finding out the critical period for weed control concerning this crop in our country. Identification and determining effective critical weed competition periods are the initial steps in tailoring responses for the management of the weeds. Therefore, the objectives of this study were to determine the effect of weed competition periods on growth and yield performance and the critical period of crop-weed competition and yield losses in roselle at Wondo Genet, Southern Ethiopia.

2. Materials and Methods

The experiment was carried out at Wondo Genet Agricultural Research Center experimental site in Southern Ethiopia during the 2017 to 2018 cropping seasons. Wondo Genet is located between 7°19' N latitude and 38°38' E longitude which is found at an altitude of 1780 m.a.s.l (meter above sea level). It receives a mean annual rainfall of 1128 mm with minimum and maximum temperatures of 11°C and 26°C, respectively. The soil textural class is sandy loam with a PH of 6.4 [1]. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having plot sizes measuring 3.6 × 3.6 m. The crop was sown in June 2017 and 2018 with 60cm*60cm space between rows and plants, respectively. Plant to plant distance was maintained by thinning extra plants at an early growth stage and WG-Hibiscus-Sudan, genotype was used. The experimental treatments consisted of a quantitative series of both the increasing duration of weedy periods and the length of the weed-free periods. The timing of weed removal was based on the number of days after crop emergence. Weeds were removed manually with a hand hoe from respective plots after the prescribed duration and kept weed-free till harvest.

To determine the beginning of the CPWC, the first component, Increasing Duration of Weed Free period (IDWFP), was established by maintaining weed-free conditions for 15, 30, 45, 60, 75, and 90DACE (referred to as weed-free plots) before allowing subsequent emerging weeds to compete for the remainder of the growing season. To evaluate the end of the critical period of the CPWC, the second component, Increasing Duration of Weedy Period (IDWP), was established by allowing the weeds to compete with the roselle for 15, 30, 45, 60, 75, and 90DACE (referred to as weedy plots) after which, plots were maintained weed-free until harvest. In addition, weedy check (WC) and weed-free check (WFC) were included as a control.

Weed flora: Data on weed flora present in the experimental plots were recorded during the experimental period. The weed species found within the sample quadrats were identified and classified into their respective groups. Weed density: The weed density was recorded by throwing a quadrat (0.25 m×0.25 m) randomly at four places in each plot at the time of weed removal for early competition and about 10 days interval before the expected harvest time in the case of late competition to avoid possible foliage and seed shading. The weed species found within the sampling quadrat were identified, counted, and expressed in m^{-2}. Weed aboveground dry biomass (g): For aboveground weed dry biomass, the weeds falling within the quadrat were cut near the soil surface immediately after recording data on weed count and placed into paper bags separately treatment-wise. The samples were sun-dried for 3-4 days and thereafter were placed into an oven at 65°C. temperatures till a constant weight and, subsequently, their dry weight was measured. The dry weight was expressed in g m^{-2}. Four plants per plot were selected at random to record plant height, branch number per plant, number of capsules per plant, fresh and dry weight of calyx per plant, the weight of seed per plant, and number of seeds per plant. Thousand seed weights were taken from the yield of each treatment and were weighed separately using an electric balance. The weight of seed yields was recorded per plant basis and was converted to kg ha^{-1}. Data collected on growth and yield parameters of the crop were analyzed statistically by using Fisher's analysis of variance technique. The least significant difference (LSD) test at 0.05 probability levels was employed to compare the treatment means [33]. On the other hand, to analyze the critical period of weed control, the relative roselle yields (Y) of each treatment were computed as followed.

$$Y = H.\ sabdarif \text{ L. } fa \text{ yield in treatment } / H.\ sabdarif \text{ L. } fa \text{ yield in weed-free check x 100}$$

3. Results and Discussion

3.1. Weed Data

During the 2 years of experimentation, 24 main weed species belonging to 10 families were identified with which the greater number was broadleaf species with lower numbers of grass and sedge weeds. By grouping weeds according to their methods of reproduction and dispersal determining their life cycle, the following groups were distinguished as annual (grasses, broadleaved species, and sedges) and perennial (grasses, broadleaved species, and sedges) (Table 1). Thus, the annual weeds that complete their life cycle within one year or less were the most common group during the two years of study while perennial weeds were found as the second group. Most of the weed species identified in the present study were in line with [10] who reported that the weed species were composed of a wide range of annual, biennial, and perennial broad-leaved, grasses, and sedges weeds with differences in frequency, abundance, and dominance.

The present result revealed that total weed density increased significantly with the increase in competition duration and the increase was significant at each increase in duration period. The maximum (211.19) and minimum (18.73) total weed density was obtained in plots with weed-infested season long (weedy check) and weed-free season long (weed-free check), respectively (Figure 1). A weedy check showed the maximum weed density because there was a longer period available for weeds to germinate and weeds continued to germinate throughout the growth period. These results agree with [34]. Weed-free plots showed minimum density because weeds were eradicated by repeated hand hoeing (Figure 1).

The dry weight of weed species was increased with the increase in competition period, being a maximum (116.87g) in weedy check and a minimum (7.49g) was in weed-free check (Figure 1). In general, the weight of dry weeds increased as the duration of the weedy period increased while decreased as the duration of the weed-free period increased. The maximum dry weight of weeds in increasing weedy period including weedy check might have been due to higher weed density (Figure 1) and longer growth period resulting in more accumulation of photosynthates and a greater biomass. But in increasing weed-free periods, the weeds germinated and developed after the respective weed-free periods after the crop reached a 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 agreement with this result, [32; and 31] reported that the weight of dry weeds and weed density was inversely proportional to the increase in weed removal periods. Similarly, [6] found that increasing weed crop competition duration increased weed biomass.

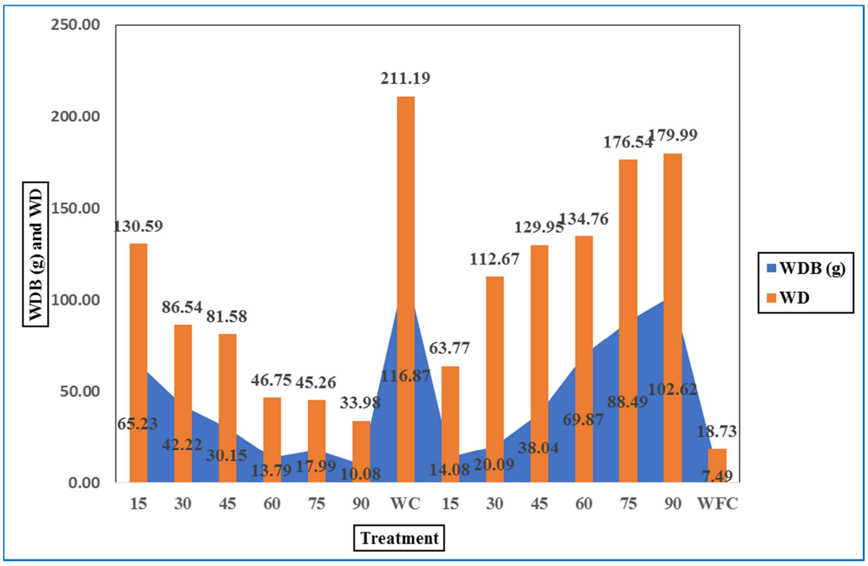

Figure 1. *The effect of weed dry biomass (WDB) and weed density (WD) on roselle plants.*

Table 1. *Major weed species of roselle during the main cropping seasons of 2017 and 2018.*

S/N	Scientific name	Family name	Category	Life cycle
1	*Bidens pilosa* L.	Asteraceae	Broadleaf	Perennial
2	*Commelina benghalensis* L.	Commelinaceae	Broadleaf	Perennial
3	*Commelina latifolia* Hochst.	Commelinaceae	Broadleaf	Perennial
4	*Guizotia scabra* (Vis.) Chiov	Asteraceae	Broadleaf	Perennial
5	*Ageratum conyzoides* L.	Asteraceae	Broadleaf	Annual
6	*Amaranthus hybridus* L.	Amaranthaceae	Broadleaf	Annual
7	*Amaranthus spinosus,* Khmer	Amaranthaceae	Broadleaf	Annual
8	*Galinsoga parviflora* Cav.	Asteraceae	Grass	Perennial
9	*Plantago lanceolate* L.	Plantaginaceae	Broadleaf	Perennial
10	*Cyperus esculentus* L.	Cyperaceae	Sedge	Perennial
11	*Datura stramonium* L.	Solanaceae	Broadleaf	Annual
12	*Xanthium strumarium* L.	Asteraceae	Broadleaf	Annual
13	*Xanthium spinosum* L.	Asteraceae	Broadleaf	Annual
14	*Solanum anguivi* L.	Solanaceae	Broadleaf	Perennial
15	*Parthenium hysterophorus L.*	Asteraceae	Broadleaf	Annual
16	*Biden pachyloma* L.	Asteraceae	Broadleaf	Annual
17	*Phalaris paradax* L.	Poaceae	Grass	Annual
18	*Digitaria abyssinica (A. Rich.) stapf*	Poaceae	Grass	Annual
19	*Oxalis anthelmintic A. Rich*	Oxalidaceae	Broadleaf	Annual
20	*Tribulus terresteris* L.	Zygophyllaceae	Broadleaf	Annual
21	*Portulaca oleracea* –Gourmet Sleuth	Portulacaceae	Broadleaf	Annual
22	*Nicandra physaloides* (L) Gaerth	Solanaceae	Broadleaf	Annual
23	*Rottboallia cochinchinesis* (Lour.) Clayton	Poaceae	Grass	Annual
24	*Anagallis arvensis* var. caerulea (L.) Gouan	Primulaceae	Grass	Perennial

3.2. Crop Data

The present results revealed that the effect of different weed-crop competition durations on plant height was significantly (P = 0.28) varied. With the increased duration of weedy periods, the plant height becomes higher while in the increased duration of weed-free periods becomes decreased (Table 2). This could be due to weeds that were left to grow for longer periods and the weed plant population per unit area tended to increase which resulted in severe competition between crop and weed for light and space. Overall, in increasing weed-free periods, plant heights reached lower values while increasing the duration of weedy periods reached higher values. In agreement with the present study, [30] reported that the field pea plant height increased with an increase in the duration of weed interference and decreased with an increase in weed-free periods.

There is a significant (P<0.0001) effect of weed-crop competition duration on the number of primary branches per plant. A gradual and progressive decrease in the number of primary branches per plant was recorded with increasing competition duration. The maximum number of primary branches (29.50) per plant was found in weed-free check followed by competition duration of 90, 75, and 60DACE and significantly different from the rest of the treatment (Table 2). This might be due to less time available for the competition of resources between the crop and weeds in a short competition duration for the higher number of primary branches per plant. Because weeds were removed and plants achieved a good growth rate and maximum assimilates may be formed which allowed good vegetative growth and a higher number of branches per plant in return while a minimum number of branches per plant was probably due to longer competition duration between crop and weeds and resources were not fully utilized by the crop. The results are in accordance with the findings of [7] who obtained that the increase of soybean branches continued significantly between weed removal and then no significant increase was obtained. Similarly, [30] also described that the number of primary branches per plant in field pea increased when the weed-free days were prolonged.

The result revealed that there is a significant (P<0.0001) effect of weed-crop competition durations on the number of capsules per plant. Weed-free check, weed-free for 90 and 75DACE produce the maximum number of capsules per plant (186.50), (184.50), and (177.33), respectively (Table 2). The minimum number of capsules per plant (10.00) was recorded in plots where competition was throughout the growing season (Table 2). The absence of weeds in the weed-free check might have been enabled the crop to make the best use of growth resources resulting in a greater number of capsules per plant. In conformity with [24] who reported in a common bean that the number of pods per plant significantly increased with the increase in the duration of the weed-free period and decreased with the increase in the duration of the weedy period.

The results of the experiment indicated that days to 50% flowering was increased significantly with the increase in competition duration and the increase was significant (P<0.0001) at each increase in duration period. The longest days of 50% flowering were recorded from the weedy-check (157.50) which was statistically at par with competition duration weedy for 60DACE and significantly varied from other treatments while the shortest was from the weed-free for 90DACE (119.17) (Table 2). As the weedy period duration increased, the days required to attain 50% flowering was increased while in weed-free duration increase the days to attain 50% flowering was decreased (Table 2). 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 to a stressful environment that enables the crop to mature earlier to escape the stressful environment before drying. This is in line with the observation of [13] who reported that limited water supply triggers a signal to cause an early switching of plant development from the vegetative to reproductive phase.

Table 2. *Effect of weed competition on yield components of roselle plants.*

Treatment	PH (cm)	NPBPP	NCPP	50% FD
IDWFP at DACE				
15	131.83^{abc}	9.67^{fg}	39.50^{de}	144.00^{e}
30	128.83^{abc}	12.33^{e}	51.00^{d}	133.83^{f}
45	133.5^{abc}	17.83^{c}	81.17^{c}	128.67^{fg}
60	122.00^{bc}	19.83^{b}	123.00^{b}	125.00^{gh}
75	122.83^{bc}	26.67^{b}	177.33^{a}	124.33^{gh}
90	120.50^{c}	26.50^{b}	184.50^{a}	119.17^{h}
WC	145^{a}	6.00^{h}	10.00^{g}	157.50^{a}
IDWP at DACE				
15	133.83^{abc}	10.00^{ef}	42.67^{d}	149.67^{bcde}
30	141.5^{ab}	15.00^{d}	52.17^{d}	146.17^{de}
45	131.67^{abc}	9.33^{fg}	27.67^{ef}	147.67^{cde}
60	137.17^{abc}	9.00^{fg}	25.50^{f}	154.83^{ab}
75	127.33^{abc}	7.50^{fgh}	19.33^{fg}	154.00^{abc}
90	141.33^{ab}	7.17^{gh}	16.00^{fg}	152.33^{abcd}
WFC	124.83^{bc}	29.50^{a}	186.50^{a}	130.33^{fg}
$lsd_{0.05}$	19.74	2.66	13.71	6.48
CV%	12.96	15.63	16.00	3.98

PH= Plant Height, NPBPP=Number of Primary Branches Per Plant, NCPP=Number of Capsules Per Plant, 50% FD= 50% Flowering date.

The weight of fresh and dry calyx yield per plant was significantly (P<0.0001) influenced by the duration of weed competition. The maximum fresh calyx yield per plant (552.55g) was found in the weed-free check. This was statistically on par with competition duration of 90, 75, and 60 days after crop emergence and significantly different from the rest of the treatments (Table 3). The maximum dry calyx yield per plant (50.02g) was recorded in the weed-free check followed by the weed-free for 90DACE (47.76g) and 75 (46.51g) while the minimum was in the weedy for 75DACE (8.73g) (Table 3). Likewise, the highest total fresh and dry calyx yield per hectare was also recorded from the weed-free check (15348.60 kg ha^{-1}) and (1389.42 kg ha^{-1}) while the lowest was from the weedy check (1009.70 kg ha^{-1}) and weedy for 75DACE (242.57 kg ha^{-1}), respectively (Table 3). In general, in the increasing duration of the weedy period fresh and dry calyx yield was decreased but in the increasing duration of the weed-free period, the fresh and dry calyx yield increased. This could be due to the fact that the increased duration of weed-free periods is attributed to the increase in fresh and dry calyx yield per given unit. This result is in line with, *[30]* who reported that the yield attributes were highest in the season-long weed-free period and on par with weed-free for the initial 40days or plots kept weedy only for the initial 20days.

The study revealed that thousand seed weight was significantly (P<0.0001) influenced by the duration of weed competition. The maximum thousand seed weight (28.14g) was recorded in the weed-free check followed by treatments kept weed-free beyond 75DACE while the minimum was (6.12g) in the weedy check (Table 3). It was found that 1000 seed weight of roselle was inversely related to the increase in the duration of the weedy period and directly proportional to the increase in the duration of weed-free periods. The highest 1000 seed weight in the increasing duration of the weed-free period might be due to the accumulation of adequate dry matter by the crop through the utilization of available above and belowground growth resources by the crop. Similarly, [30] stated that yield attributes, including 1000 seed weight of field pea increased with an increase in weed-free duration and decrease in weedy periods.

The data about the seed yield of roselle revealed that seed yield was significantly (P<0.0001) affected by weed-crop competition durations. A linear decrease in seed yield was observed by increasing the duration of the weed-crop competition. The maximum seed yield of (39.03 kg ha^{-1}) was recorded where there was a weed-free check and it was statistically on par with the competition duration of 90DACE (37.63 kg ha^{-1}) significantly higher than all the other treatments (Table 3). The minimum seed yield (4.76 kg ha^{-1}) was recorded in the weedy-check (Table 3). The decrease in seed yield with increasing weed-crop competition duration was due to the decrease in the yield components like several branches per plant, the number of capsules per plant, and 1000 seed weight, which resulted from the efficient utilization of growth resources, such as nutrients, soil moisture, and light. In conformity with this result, [38] 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 weedy check plots. Similarly, [4, 36] found that wheat yield decreased as the weed-infested duration increased.

Table 3. *Effect of weed competition on yield and components of roselle plants.*

Treatment	WFCYPP (g)	WDCYPP (g)	WFCY (kg ha^{-1})	WDCY (kg ha^{-1})	TSW	WSY (kg ha^{-1})
IDWFP at DACE						
15	188.58^{d}	12.87^{ef}	5238.20^{d}	357.36^{ef}	18.74^{cd}	11.44^{ef}
30	237.29^{c}	18.41^{d}	6591.30^{c}	511.36^{d}	20.85^{c}	12.88^{e}
45	327.84^{b}	31.82^{c}	9106.70^{b}	884.03^{c}	23.72^{b}	19.79^{c}
60	521.08^{a}	45.36^{b}	14474.40^{a}	1259.81^{b}	24.57^{b}	35.61^{b}
75	530.47^{a}	46.51^{ab}	14735.30^{a}	1291.96^{ab}	25.04^{b}	35.87^{b}
90	546.09^{a}	47.76^{ab}	15169.20^{a}	1326.76^{ab}	25.52^{b}	37.63^{ab}
WC IDWP at DACE	36.75^{f}	9.84^{efg}	1009.70^{f}	273.37^{efg}	6.12^{g}	4.76^{h}
15	246.94^{c}	12.93^{e}	6859.40^{c}	359.03^{e}	16.93^{d}	10.45^{efg}
30	250.63^{c}	13.61^{e}	6961.90^{c}	378.10^{e}	18.07^{d}	16.27^{d}
45	134.53^{e}	12.05^{efg}	3737.00^{e}	334.65^{efg}	14.37e	11.07^{ef}
60	142.64^{e}	10.93^{efg}	3962.30^{e}	303.57^{efg}	12.86^{e}	7.81^{g}
75	118.04^{e}	8.73^{g}	3278.90^{e}	242.57^{g}	10.08^{f}	8.05^{g}
90	115.96^{e}	8.91^{f}	3220.90^{e}	247.38^{fg}	9.73^{f}	9.50^{fg}
WFC	552.55^{a}	50.02^{a}	15348.60^{a}	1389.42^{a}	28.14^{a}	39.03^{a}
$lsd_{0.05}$	35.34	4.00	981.62	111.19	2.45	2.74
CV%	10.82	14.68	10.82	14.68	11.62	12.72

WFCYPP=Weight of Fresh Calyx Yield Per Plant, WFCY = Weight of Fresh Calyx Yield, WDCYPP=Weight of Dry Calyx Yield Per Plant, WDCYPH=Weight of Dry Calyx Yield, TSW= Thousand seed weight, WSY=Weight of Seed Yield

3.3. Yield Losses

The losses that were shown due to each of the different weed competition periods were considered relative to the yield of weed-free checks compared with each of the treatments. The data in losses indicated that the fresh calyx yield per hectare was higher beyond weedy for 45DACE including weedy-check compared to the WFC. The fresh calyx yield per hectare losses ranged from (54.64 to 93.42%) in increased duration of weedy periods while (0.00 – 65.87%) in increased duration of weed-free periods (Figure 2). Likewise, dry calyx yield losses were higher in the weedy for 75 and 90DACE followed by WC as compared to the WFC. In this case, the dry calyx yield per hectare losses ranged from (72.79 to 82.54%) in the increased duration of weedy periods while the increased duration of weed-free periods ranged from (0.00 to 74.28%) (Figure 2). Thus, the losses come through the results of weed-crop competition regarding the nearby resources utilize in the growing period. The prolonged crop-weed competition resulted in reduced dry biomass accumulation which ultimately rendered the yields of parameters considered and higher yield losses for them.

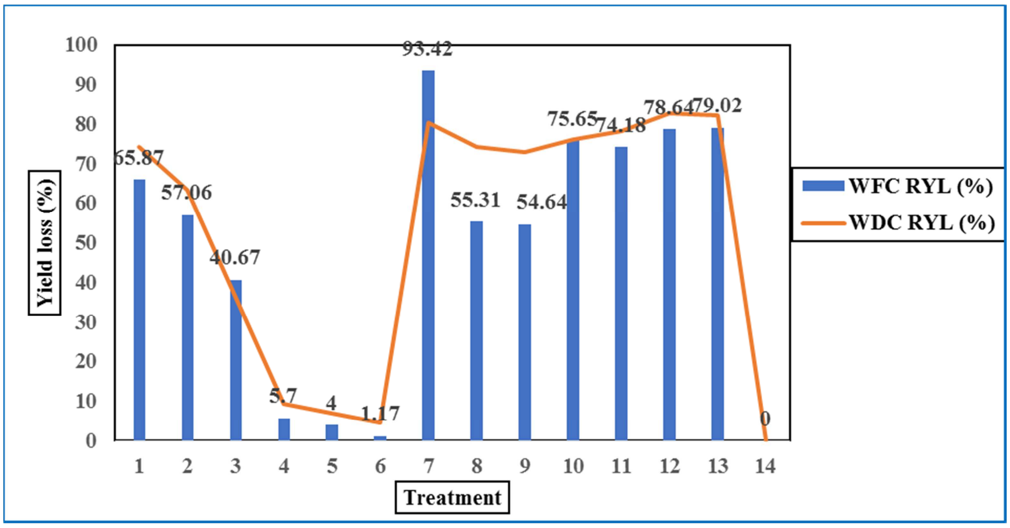

Figure 2. *The effect of weeds competition on the yield loss of roselle plants.*

3.4. Critical Period of Weed Control

The critical period of weed control for roselle was estimated based on the relative yields with between 5% and 10% as acceptable yield loss. The beginning 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). Based on the current result, the critical period of weed control for roselle should be kept weed-free from 60 to 90DACE. Thus, the weeds have to be managed during these periods through appropriate methods to prevent more than 10% yield loss of the crop. This critical period of weed control follows previous studies. Le Bourgeois and [22] located this critical period between 30 and 90 DAS for long-cycle crops (yams, cassava, sugarcane, etc.). Another finding by [38 reported that the critical period of weed control in faba bean started at 30days and ends at 45days after crop emergence with a 10% acceptable yield loss. However, according to [21], critical periods 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.

4. Conclusion

There was an overall sensitivity of roselle to infestation by weeds, which demonstrates the need for weed control techniques. The highest weed biomass and density at harvest seemed to be associated with the lowest values of seed yield and yield components. From this study it can be concluded that to obtain a better yield of more than 90% yield, roselle has to be weed-free. This period is between 60 to 90 days after the emergence of the crop as it is found to be the critical period of weed crop competition at the Wondo Genet Agricultural Research Center experimental site and is similar to the other agro-ecology. Hence, in Integrated Weed Management (IWM) strategies, the determination of the critical weed competition period is paramount to take the appropriate management of weeds control in one of the IWM components. Thus, when the critical period of weed competition was determined for one crop, economically feasible, environmentally friendly, and sustainable methods of IWM components to be developed properly.

Acknowledgements

The authors are grateful to Wondo Genet Agricultural Research Center and the Ethiopian Institute of Agricultural Research for the support of the research fund and vehicles. Our gratitude also extends to field assistants for their support during the study.

References

[1] Abayneh E, Demeke T, Ashenafi A (2006). Soils of Wondo Genet Agricultural Research Center. National Soil Research Center, 67 pp.

[2] Abu-Tarboush HM, Ahmed SAB and Al Kahtani HA (1997). Some nutritional and functional properties of karkade (Hibiscus sabdariffa) seed products. Cereal chemistry 74: 352-355.

[3] Adjun JA (2003). Effect of Intra row spacing and weed control on growth and yield of Roselle (*Hibiscus sabdariffa* L.). Agriculture and Environment 3: 91-98.

[4] Ahmed MEN, Salaheldeen EA (2010). Effect of Weeding Frequencies on Growth and Yield of Two Roselle (Hibiscus sabdariffa L) Varieties under Rain Fed. Australian Journal of Basic and Applied Sciences 4 (9): 4250-4255.

[5] Ahmad R, Sheikh AS (2003). Common weeds of wheat and their control. Pakistan Journal of Water Resource 7: 73-74.

[6] Akhtar M, Mahmood A, Ahmad J, Iqbal K (2000). Nitrogen uptake efficiency in wheat (Triticum aestivum L.) as influenced by nitrogen level and weed crop competition duration. Pakistan Journal of Biological Science 3: 1002-1003.

[7] Almarie A (2017). The Critical Period for Weed Competition in Soybean [Glycine max (L.) Merr.] under Iraqi Irrigated Areas. Journal of Agricultural and Biological Science 12 (14): 128-132.

[8] Akobundu IO (1991). Weeds in Human Affairs in Sub-Saharan Africa: Implications for Sustainable Food Production. Weed Technology 5 (3): 680 - 690.

[9] Babatunde FE and Mofoke ALE (2006). Performance of Roselle (Hibiscus sabdariffa L) as Influenced by Irrigation Schedules. Pakistan Journal of Nutrition 5: 363-367.

[10] Bayisa NG and Hundesa N (2017). Assessment and identification of weed flora associated to medicinal and aromatic plants at Wondo Genet District, Ethiopia. International Journal of Agricultural and Bioscience 6 (3): 136-140. www.ijagbio.com.

[11] Chewonarin T, Kinouchi T, Kataoka K, Arimochi H, Kuwahara T, Vinitketkumnuen, U and Ohnishi Y (1999). Effects of roselle (Hibiscus sabdariffa Linn.), a Thai medicinal plant, on the mutagenicity of various known mutagens in Salmonella typhimurium and on the formation of aberrant crypt foci induced by the colon carcinogens azoxymethane and 2amino-1-methyl-6-phenylimidazo [4, 5-b] pyridine in F344 rats. Food and chemical toxicology 37: 591-601.

[12] Cruser D, Ampony N, Labrada R, Merago A (1995). Weed management in legume crops: bean, soybean, and cowpea. In: Labrada R. (ed). 2003. Weed management for developing countries. FAO crop production and protection paper 120 add. 1. ISBN 92-5-105019-8, ISSN 0259-2517.

[13] Desclaux D, Roumet P (1996). Impact of drought stress on the phenology of two soybeans (Glysine max L. Merr) cultivars. Journal of Field Crop Research 46 (1-3): 61-70.

[14] Evans SP, Knezevic SZ, Lindquist JL, Shapiro CA, Blankenship EE (2003). Nitrogen application influences the critical period for weed control in corn. Weed Science 51 (3): 408–417.

[15] Freckleton RP, Watkinson AR (2001). Predicting competition coefficients for plant mixture: reciprocity, transitivity, and correlations with life-history traits. Ecology of Letter 4: 348–357. doi: 10.1046/j.14610248.2001. 00231.x.

[16] Haji Faraji, M and Haji Tarkhani AH (1999). The effect of sour tea (Hibiscus sabdariffa) on essential hypertension. Journal of Ethnopharmacology 65: 231-236.

[17] Hall MR, Swanton CJ, Anderson GJ (1992). The critical period of weed control in grain corn. Weed Science 40: 441–447.

[18] Ismail A, Ikram EHK and Nazri HSM (2008). Roselle (*Hibiscus sabdariffa* L.) Seeds GÇô Nutritional Composition, Protein Quality and Health Benefits.

[19] Kells JJ (1999). Weed competition in corn. Illinois Crop Protect. Conference Proceeding pp. 63-64.

[20] Knezevic SZ, Weise SF, Swanton CJ (1994). Interference of redroot pigweed (Amaranthus retroflexus) in corn (Zea mays). Weed Science 42: 568 – 573.

[21] Knezevic SZ, Evans SP, Blankenship EF, Van Acker RC, Lindquist JL (2002). The critical period for weed control: the concept and data analysis. Weed Science Journal 50 (6): 773-786.

[22] Le Bourgeois T, Marnotte P (2002). La lutte contre les mauvaises herbes. In: Mémento de l'Agronome. CIRAD-GRET, Ministère des Affaires Etrangères, Paris pp. 663–684.

[23] Mahadevan N, Shivali and Pradeep K (2009). *Hibiscus sabdariffa* L. An overview. Natural Product Radiance 8: 77-83.

[24] Mengesha K, Sharma JJ, Lisanework N (2013). Influence of Weed Dynamics on the productivity of Common Bean (Phaseolus vulgaris L.) in Eastern Ethiopia. East African Journal of Sciences 7 (2): 109-120.

[25] Morton FJ (1987). Roselle (Hibiscus sabdariffa L). In: Morton JF, Ed. Fruit of Warm Climates. Creative Resources Systems, Increased Miami, Florida pp: 281-286.

[26] Otto S, Masin R, Lindquist J, Casari G, Zanin G (2008). Weed-corm competition on parameters in late winter sowing in northern Italy. Weed Science 57: 194-201.

[27] Oyewole CI and Mera M (2010). Response of roselle (*Hibiscus sabdariffa* L.) to rates of inorganic and farmyard fertilizers in the Sudan savanna ecological zone of Nigeria. African Journal of Agricultural Research 5: 2305-2309.

[28] Rajcan I, Swanton CJ (2001). Understanding maize-weed competition: competition, light quality, and the whole crop. Field Crops Research Journal 71: 139-150.

[29] Shad RA (1987). Status of Weed Science in Pakistan. Program Farming 7: 10-16.

[30] Singh M, Kumar R, Kumar S, Kumar V (2015). The critical period for weed control in field pea. Legume Research 39 (1): 86-90.

[31] Smitchger JA, Burke IC and Yenish JP (2012). The critical period for weed control in lentils. Weed Management Journals 24 (2): 89: 96.

[32] Stagnari F, Pisante M (2011). The Critical period for weed competition in French bean (Phaseolus vulgaris L.) in Mediterranean areas. Crop Protection Journal 30 (2): 179-184.

[33] Steel RGD, Torrie JH and Dickey DA (1997). Principles and Procedures of Statistics. A biometrical approach 3rd Ed. McGraw Hill Book Cooperation Increased, New York pp. 400-428.

[34] Tunio SD, Kake SN, Jarwar AD and Wagan MR (2004). Effect of integrated weed management practices on wheat yield. Pakistan Journal Agricultural Engineering and Veterinary Science 20: 5-10.

[35] Upadhyay RK, Baksh H, Patra DD, et al (2011). Integrated weed management of medicinal crops in India. International Journal of Medicinal and Aromatic Crops 1 (2): 51−56.

[36] Welsh JP, Bulson HAJ, Stopes CE, Froud-Williams RJ, Murdoch AJ (1999). The critical weed-free duration has grown winter wheat. Annual Applied Biology 134: 315-320.

[37] Zimdahl RL (1987). The concept and application of the critical weed-free period. In: Altieri MA, Liebman M. (eds). Weed management in agroecosystems: ecological approaches. Florida, USA, CRC Press, Increased pp. 145–156.

[38] Zuhal KI, Ufuk, Kagan N, Adil B (2010). Determining Critical Period of Weed -Crop Competition in Faba Bean (Vicia faba L.). International Journal of Agricultural and Biology 156: 181-187.