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Determination of Critical Period of Weed Competition in Vernonia (*Vernonia galamensis* Cass. Less) at Wondo Genet, Southern Ethiopia

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Abstract: Vernonia is a new industrial biofuel crop, which is potentially grown for its seed oil. However, its production has been greatly challenged by diverse constraints like abiotic and biotic (Diseases, insect pests, and weed) factors. The weed effect is one of the important limiting factors for crop growth and productivity in agricultural crop production. But there is little information on the type of weed affecting the crop and the critical time of weed competition for the production of *Vernonia galamensis*. Hence, this study was conducted at Wondo Genet to determine the critical weed competition period for growth, yield, and yield components of the vernonia plant. The experiment was laid out by RCBD with fourteen treatments of weeding regimes in three replications. The data on the growth, yield components, and yield parameters of vernonia were collected, analyzed, and discussed accordingly. The weed competition duration had a significant influence on the plant height, the number of primary branches per plant, thousand seed weights, seed yield weight per plant, and seed yield weight per hectare. Hence, the highest seed yield was obtained from the weed-free check (2.84 t ha^{-1}), weed-free for 90 (2.66 t ha^{-1}) and 75 (2.63 t ha^{-1}) whereas the lowest was from the weedy-check (0.88 t ha^{-1}). The yield loss of *Vernonia galamensis* was estimated based on seed yield weight per hectare. Thus, the highest yield loss of seed yield was recorded in the weedy check (69.22%) 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 at 5% and 10% acceptable yield loss levels were used. Therefore, to reduce the yield losses by more than 10% and to obtain a higher economic return, weeds must be kept free within WF75 to WF90 to reduce the risk of economic yield losses as it has been found to be the critical period.

Keywords: Crop-Weed Competition, Seed Yield, Weed Species, Yield Losses

1. Introduction

Vernonia (*Vernonia galamensis* Cass. Less) is an annual herb that belongs to the family of Asteraceae and is widely distributed in the wild form in Eastern Africa including Eritrea, Ethiopia, Malawi, Tanzania, and Kenya [1]. Most vernonia species occur in South America but more than 300 species from Africa have been described with most occurring in Ethiopia and Madagascar [2]. The genus vernonia comprises more than a thousand species, which vary from annual herbs and shrubs to perennial trees [3].

Vernonia is a new industrial crop, which is potentially grown for seed oil making it an interesting crop nowadays both economically and ecologically for the growers and users [4]. The seed oil is rich in vernolic acid (used as raw material for manufacturing paints and coatings with low or no volatile organic compounds), which contents are ranges from 42% to 80% considerably higher than any selection of *Vernonia anthelmintica* originating from India [5]. Even though Vernonia is a potential oil crop, it has been considered a weed plant in different areas [6]. However, the seed oil of vernonia can be used in the chemical (glue paint and plastics), pharmaceutical and agricultural- industries [5]. It was tested as a component of low volatile organic-solvent paints in the paint industry. The component of heated-baked films and coatings, provides outstanding adhesion, flexibility and chipping resistance, and good resistance to alkaline, acid, and non-polar solvents [7]. It can also be used as a plasticizer of PVC and as a structural component of polymers in plastics.

However, like other crops, various constraints pose serious problems to vernonia plant growth and productivities like agro-climatic variation, insufficient requirement of nutrients and water, genotypes characteristics, absence of diseases, insect pests, and weed management are fewer from the lists. Thus, the losses caused by weeds are reported to exceed the highest losses from any other category of agricultural pests such as insects, diseases, nematodes, and rodents. Among the total annual losses of agricultural products from various pests, weed accounts for 45%, insects for 30%, a disease for 20%, and other pests for 5% [8]. Weed competes with crops for growth resources like sunlight, moisture, and nutrients that can affect the plant growth and quality seed production if not properly managed at a critical period [9, 10]. The period of crop growth, when it is most susceptible to weed interference has been regarded as the critical period of weed competition [11]. Hence, the impact of weeds on yields of crops varies with the characteristics of the crop, the weed species, weed density, the environment, the stage of crop growth, and the duration of crop exposure to the weeds [12].

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 periods for the optimum integrated weed management (IWM) program [13]. Thus, developing a suitable IWM system requires the precise study of weeds and their interference with crops [14]. The weed growth before the beginning of the critical period of weed control does not affect the yield of the plant because the crop and the weeds are too small or far apart to negatively influence each other [15]. Similarly, the weeds that emerge after the end of the critical period of weed control do not appreciably affect yield because the crop has a highly competitive ability.

Weed control is one of the main yield-limiting factors for the vernonia plant. Thus, weeds should be controlled and eliminated before competing with vernonia plants for growth resources (nutrients, light, and water). However, in Ethiopia, there is no studied report and information on the critical period of weed competition in the vernonia plant. Therefore, this study was proposed to determine the effect of duration of weed competition on growth, yield components, and yield of vernonia and to identify the critical period of weed competition in vernonia at Wondo Genet, Southern Ethiopia.

2. Materials and Methods

The experiment was conducted at Wondo Genet Agricultural Research Center (WGARC) during the main cropping seasons of 2017 to 2018 in Southern Ethiopia. The WGARC is located at 7° 192′ N latitude and 38° 382′ E longitudes with an altitude of 1780 meters above sea level. The site receives a mean annual rainfall of 1000 mm with minimum and maximum temperatures of 10 and 30°C, respectively. The soil textural class is clay loam with an average pH of 6.4 [16].

A Randomized Complete Block Design (RCBD) was used, with fourteen treatments of weeding regimes in three replications. The best performing genotypes of vernonia seeds were sown by direct sowing method on specified rows of well-prepared plots which have 2.80 m in length and 3.60 m in width with 60 cm x 40 cm between rows and plants, respectively. The distance between plot and block was maintained at 1.50 m and 2.00 m, respectively. Fourteen weeding regimes of treatments (WF15–WIO) (Table 1) were devised to examine the effects of differing periods of weed control and interference and were similar to those of [11] and [17].

Table 1. *The treatments arrangement for determination of the critical period of weed competition in Vernonia at Wondo Genet, for the 2017/2018 cropping season trial.*

Treatment Arrangements			
Nº.	**IDWFP at DAS**	**Nº.**	**IDWP at DAS**
1.	WF15: Weed-free until 15	8.	WI15: Weedy until 15
2.	WF30: Weed-free until 30	9.	WI30: Weedy until 30
3.	WF45: Weed-free until 45	10.	WI45: Weedy until 45
4.	WF60: Weed-free until 60	11.	WI60: Weedy until 60
5.	WF75: Weed-free until 75	12.	WI75: Weedy until 75
6.	WF90: Weed-free until 90	13.	WI90: Weedy until 90
7.	WF0: Weedy check	14.	WI0: Weed-free check

IDWFP=Increased Duration Weed-Free Period, IDWP=Increased Duration Weedy Period, DAS=Days After Sowing.

Weed growth was controlled in the required periods for each of the above treatments, and hand weeding was applied weekly as needed. The term ‘‘weed-free’’ in the treatments, therefore, indicates the period during which weeds were removed at weekly intervals.

Data Collection and Statistical Analysis

A quadrant measuring 0.5 m x 0.5 m (0.25 m^2) was thrown randomly at four spots in each plot to determine the major weed species grown in association with vernonia plants. The sampled weeds were separated into broad leaves and grass, and then the number of weeds was counted to determine the weed density in each plot. Above-ground biomass of the mixed weed, the population was harvested and oven-dried until a constant reading was maintained to measure the above-ground weed dry weight. Also, the growth parameters like plant height (cm), primary branch numbers per plant as well as the yield and yield component parameters like 1000 seed weight (g), seed weight per plant (g), and seed weight per hectare (kg) were recorded from six sampled plants and converted in to appropriate unit accordingly in both years.

The critical period of weed control is also computed as the percentage of relative yields of vernonia [18]. Thus, dividing the yield of vernonia in each treatment by the yield of the weed-free check as follows:

$$\text{Relative yield} = \frac{\textit{Vernonia galemensis } f(\text{a}) \text{ yield in treatment}}{\textit{Vernonoia galemensis } \text{f(a) yield in weed free check}} \text{x100}$$

The Yield losses of vernonia to the highest level due to weed competition were also calculated as:

$$\text{Yield loss \%} = \frac{[1 - \textit{vernonia galemensis } \text{f(a)in each yield treatmenet}]}{\textit{Vernonoia galemensis } \text{f(a) yield in weed free check}} \text{x100}$$

Data recorded on growth, yield components, and yield parameters were subjected to analysis of variances (ANOVA) to test the significant effects of the single factor with the collected data using the General Linear Model (GLM) of the Statistical Analysis System (SAS) software version 9.3. LSD test at 5% probability was used for mean separation when analysis of variance indicated the presence of significant differences.

3. Results and Discussions

3.1. Weed Data

3.1.1. Weed Species

During the two years of experimentation, 13 main weed species belonging to 10 families were identified in which a greater number of broadleaved species were found than grass and sedge weeds. The main weed species found in the experiment were: *Bidens pilosa* L., *Commelina benghalensis* L., *Guizotia scabra* L., *Amaranthus hybridus* L., *Galinsoga parviflora* L., *Plantago lanceolate* L., *Cyperus esculentus* L., *Datura stramonium* L., *Xanthium strumarium* L., *Digitaria ternate* L., *Oxalis corniculate* L., *Gortulaca olerace* L., *and Nicandra physalodes* L. By grouping weeds according to their methods of reproduction, dispersal method and determining their life cycle, the following groups were distinguished as annual (grasses, broadleaved species, and sedges) and perennials (grasses, broadleaved species, and sedges) (Table 2). Thus, the annuals were the weeds that complete their life cycle within one year or less and were categorized as the most common group during the two years of study, while the perennials were found as the second type of weeds grouped in the area. Most of the weed species identified in the present study were in line with Adjun [19], Mahadevan, *et al.* [20] and Ahmed and Salaheldeen [21] who were reported that the weed species composed of a wide range of annual, biennial, and perennial broad-leaved, grasses and sieges weeds.

Table 2. *Lists of the main weed species found in the determination of the critical period of weed competition in Vernonia at Wondo Genet, for the 2017/2018 cropping season trial.*

No	Scientific name	Family name	Category	Life cycle
1	*Bidens pilosa* L.	Asteraceae	Broadleaf	Perennial
2	*Commelina benghalensis* L.	Commelinaceae	Broadleaf	Perennial
3	*Guizotia scabra* L.	Asteraceae	Broadleaf	Perennial
4	*Amaranthus hybridus* L.	Amaranthaceae	Broadleaf	Annual
5	*Galinsoga parviflora* L.	Poaceae	Grass	Perennial
6	*Plantago lanceolate* L.	Plantaginaceae	Broadleaf	Perennial
7	*Cyperus esculentus* L.	Cyperaceae	Sege	Perennial
8	*Datura stramonium* L.	Solanaceae	Broadleaf	Annual
9	*Xanthium strumarium* L.	Asteraceae	Broadleaf	Annual
10	*Digitaria ternate* L.	Poaceae	Grass	Annual
11	*Oxalis corniculate* L.	Oxalidaceae	Broadleaf	Annual
12	*Gortulaca olerace* L.	Portulacaceae	Broadleaf	Annual
13	*Nicandra physalodes* L.	Solanaceae	Broadleaf	Annual

3.1.2. Weed Density

The study results revealed that the total weed density increased significantly ($P<0.05$) with the increase in competition duration and the increase was significant at each increase in duration period (Table 3). The maximum (51.50) and minimum (0.95) total weed densities were obtained in plots with weed-infested season long (weedy check) and weed-free season long (weed-free check), respectively. This might be due to the availability of a longer period for free germination and continued growth throughout the study period which agreed with the study of Tunio *et al.* [22]. On the other hand, the weed-free plot showed a minimum density of weeds due to repeated hand hoeing that affects the germination and continuous growth of weeds.

3.1.3. Weed Biomass

The dry weight of weed species was increased significantly ($P<0.05$) with the increase in the competition period, being a maximum (193.72 g) in the weedy check and a minimum (0.25 g) was in the weed-free check (Table 3). As a result, 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 dry matter increment of weeds in the weedy period like in the weedy check might be due to the presence of a higher density of weeds and a longer growth period which resulted in more utilization of photo assimilate 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, newly emerged weeds and less competent under stress accumulated lower dry weight. In agreement with this result, [23] Stagnari *et al*. [23] and Smitchger *et al*. [24] reported that the weight of dry weeds and weed density was inversely proportional to the increase in weed removal periods. Similarly, Akhtar *et al.* [25] reported that increasing weed crop competition duration increased weed biomass.

Table 3. *The effect of weed biomass and density on vernonia growth and development at Wondo Genet, southern Ethiopia in the 2017/2018 cropping season.*

Treatment	Weed biomass (g)	Weed density (N^o.)
WF15	157.54^{b}	51.88^{a}
WF30	116.75^{c}	49.50^{a}
WF45	3.58^{fg}	4.50^{c}
WF60	2.50^{fg}	2.83^{c}
WF75	2.08^{fg}	1.83^{c}
WF90	1.75^{fg}	1.00^{c}
WF0	193.72^{a}	51.50^{a}
WI15	16.06^{ef}	31.75^{b}
WI30	19.51^{e}	22.88^{b}
WI45	42.16^{d}	25.63^{b}
WI60	52.53^{d}	25.25^{b}
WI75	122.41^{c}	27.75^{b}
WI90	152.87^{b}	22.92^{b}
WI0	0.25^{g}	0.95^{c}
Mean	63.12	22.80
CV (%)	14.05	25.12

3.2. Crop Data

3.2.1. Plant Height

There were significant (P<0.05) differences in plant height between the various weed-competition periods in the 2017 and 2018 cropping seasons and the pooled mean. From the pooled mean analysis, the tallest plant height per plant (185.09 cm) was recorded from the weedy check and the lowest (149.55 cm) was at the weed-free check (Table 4). 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 in the increasing duration of the weedy- period reached the higher values. In agreement with the present study, Singh *et al.* [26] 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. Similarly, Freckle ton and Freckleton and Watkinson, [27] also reported the height of plants is often associated with their interspecific competitive ability.

3.2.2. Number of Primary Branches Per Plant

There was a significant (P<0.05) effect of weed-crop competition durations on the number of primary branches per plant in the 2017 and 2018 cropping seasons and pooled mean. As pooled mean analysis indicated that a gradual and progressive decrease in the number of primary branches per plant was recorded with increasing competition duration. The highest number of primary branches (49.50) per plant was found in weed-free checks followed by weed-free for 90 (41.67) and 75 (41.34) days after sowing while the lowest was in weedy-check (6.83) (Table 4). 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 the 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 Almarie [28] who obtained that the increase of soybean branches continued significantly between weed removals and changing the wording. Then, no significant increase was obtained. Similarly, Singh *et al.* [26] also described that the number of primary branches per plant in field pea increased when the weed-free days were prolonged.

Table 4. *The effect of weed Vernonia competition on plant height and primary branch number at Wondo Genet, southern Ethiopia in 2017/2018 cropping seasons.*

Treatment	Plant height (cm)			Primary number of branches per plant		
	2017	2018	pooled	2017	2018	pooled
WF15	155.83^{ab}	164.50^{abc}	160.17^{ab}	22^{cde}	18.67^{efg}	20.34^{cd}
WF30	181.58^{ab}	166.17^{abc}	173.88^{ab}	28.67^{bcd}	22.00^{def}	25.34^{c}
WF45	144.92^{b}	165.08^{abc}	155.00^{b}	35.33^{bc}	23.33^{de}	29.33^{b}
WF60	172.33^{ab}	165.00^{abc}	168.67^{ab}	38.33^{b}	26.00^{cd}	32.17^{b}
WF75	156.67^{ab}	154.25^{bc}	155.46^{b}	53^{a}	29.67^{bc}	41.34^{ab}
WF90	186.58^{ab}	153.00^{bc}	169.79^{ab}	49.67^{a}	33.67^{ab}	41.67^{ab}
WF0	188.25^{ab}	181.92^{a}	185.09^{a}	3.33^{f}	10.33^{j}	6.83^{g}
WI15	181.08^{ab}	164.92^{abc}	172.71^{ab}	18.33^{de}	17.33^{fgh}	17.83^{def}
WI30	171.25^{ab}	169.00^{abc}	170.13^{ab}	17^{def}	16.67^{ghi}	16.84^{ef}
WI45	156.33^{ab}	172.42^{ab}	164.38^{ab}	15.67^{def}	15.33^{ghij}	15.50^{ef}
WI60	175.42^{ab}	170.75^{ab}	173.08^{ab}	13.33^{ef}	12.33^{hij}	12.83^{fg}
WI75	174.5^{ab}	174.83^{ab}	174.67^{ab}	12.67^{ef}	10.67^{j}	11.67^{fg}
WI90	191.58^{a}	175.83^{ab}	183.17^{a}	11.67^{ef}	11.67^{ij}	11.67^{fg}
WI0	152.92^{ab}	146.17^{c}	149.55^{b}	61^{a}	38.00^{a}	49.50^{a}
Mean	170.66	165.99	168.27	27.14	20.41	23.77
CV (%)	15.24	8.64	9.97	12.75	15.44	10.30

3.2.3. Thousand Seed Weight

The obtained result revealed that thousand seed weight was significantly (P<0.01) influenced by the duration of weed competition in both years and pooled mean. From the pooled mean analysis, the maximum thousand seed weight (0.71 g) was recorded in weed-free check followed by treatments kept weed-free beyond 90 (0.69 g) and 75 (0.67 g) days after sowing while the minimum was (0.23g) in weedy-check (Table 5). In general, 1000 seed weight of vernonia 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 content by the crop through the utilization of available above and belowground growth resources (nutrients and water) by the crop. Similarly, Singh *et al*. [26] stated that yield attributes, including 1000 seed weight of field pea increased with an increase in weed-free duration and decrease in weedy periods.

3.2.4. Seed Yield Weight

The data pertaining to seed yield of vernonia revealed that seed yield was significantly (P<0.01) affected by weed-crop competition durations in both years and pooled mean. From pooled mean analysis, a linear decrease in seed yield was observed by increasing the duration of the weed-crop competition. The maximum seed yield per plant (1.02 g) and per hectare (2.84 t ha^{-1}) were recorded where there was a weed-free check and it was statistically at par with competition duration of 90, (0.97 g) and (2.67 t ha^{-1}) and 75 (0.96 g) and (2.63 t ha^{-1}) DAS with significantly higher than all the other treatments. The minimum seed yield per plant (0.23g) and per hectare (0.88 r ha^{-1}) was recorded in weedy-check (Table 5). The decrease in seed yield with increasing weed-crop competition duration was due to the decrease in the yield components like the number of branches per plant and 1000 seed weight, which resulted from the efficient utilization of growth resources, such as nutrients, and soil moisture, and light. In conformity with this result, Zuhal and Ufuk [29] 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, Ahmad and Shaikh [30] and Welsh *et al.* [31] found that wheat yield decreased as the weed-infested duration increased.

Table 5. *The effect of weed vernonia competition on thousand seed and seed yield weight at Wondo Genet, southern Ethiopia in 2017/2018 cropping seasons.*

Treatments	1000 seed weight (g)			Seed weight per plant (g)			Seed weight (t ha^{-1})		
	2017	2018	pooled	2017	2018	pooled	2017	2018	pooled
WF15	0.33^{de}	0.52^{abc}	0.42^{ef}	0.43^{cde}	0.67^{def}	0.54^{cde}	11.82^{cde}	1.87^{def}	1.57^{ed}
WF30	0.42^{cd}	0.55^{abc}	0.49^{de}	0.49^{cd}	0.76^{cde}	0.62^{cd}	13.60^{cd}	2.11^{cde}	1.78^{cd}
WF45	0.51^{bc}	0.55^{abc}	0.54^{cd}	0.55^{bc}	0.77^{cd}	0.66^{c}	15.35^{bc}	2.14^{cd}	1.88^{c}
WF60	0.59^{b}	0.59^{abc}	0.60^{bc}	0.69^{b}	0.86^{bc}	0.78^{b}	19.19^{b}	2.39^{bc}	2.19^{b}
WF75	0.72^{a}	0.60^{ab}	0.67^{ab}	0.99^{a}	0.91^{b}	0.96^{a}	27.50^{a}	2.53^{b}	2.63^{a}
WF90	0.74^{a}	0.61^{ab}	0.69^{ab}	0.96^{a}	0.95^{ab}	0.97^{a}	26.67^{a}	2.65^{ab}	2.66^{a}
WF0	0.12^{g}	0.36^{d}	0.23^{h}	0.15^{g}	0.45^{h}	0.29^{i}	4.05^{g}	1.24^{h}	0.88^{i}
WI15	0.27^{ef}	0.50^{bc}	0.38^{fg}	0.42^{cde}	0.67^{def}	0.54^{de}	11.63^{cde}	1.85^{def}	1.55^{def}
WI30	0.26^{ef}	0.50^{bc}	0.38^{fg}	0.41^{cde}	0.65^{defg}	0.53^{def}	11.47^{cde}	1.80^{defg}	1.52^{def}
WI45	0.21^{fg}	0.51^{bc}	0.35^{fg}	0.34^{def}	0.64^{efg}	0.48^{efg}	9.41^{def}	1.77^{efg}	1.41^{efg}
WI60	0.18^{fg}	0.48^{bcd}	0.33^{g}	0.24^{efg}	0.63^{fg}	0.42^{fgh}	6.67^{efg}	1.74^{fg}	1.27^{fgh}
WI75	0.15^{fg}	0.48^{bcd}	0.31^{gh}	0.19^{fg}	0.60^{fg}	0.38^{ghi}	5.35^{fg}	1.67^{fg}	1.17^{hi}
WI90	0.16^{fg}	0.46^{cd}	0.30^{gh}	0.18^{fg}	0.53^{gh}	0.35^{hi}	5.08^{fg}	1.47^{gh}	1.07^{hi}
WI0	0.74^{a}	0.65^{a}	0.71^{a}	0.98^{a}	1.05^{a}	1.02^{a}	27.09^{a}	2.93^{a}	2.84^{a}
Mean	0.39	0.53	0.46	0.50	0.72	0.61	13.92	1.87^{def}	1.57^{ed}
CV (%)	17.74	15.37	12.28	22.54	10.20	11.27	22.55	21.10^{cde}	17.85^{cd}

3.3. Critical Period of Weed Control

The critical period of weed control for vernonia was estimated based on the relative yields with 5% and 10% acceptable yield loss. A significant (P<0.01) variation was obtained in the relative yield of vernonia in that the highest relative yield was obtained in weed-free check (100), weed-free for 90 (95.11%) and 75 (92.76%) days after sowing. Likewise, the lowest was obtained from the weedy-check (30.785%). Based on the current result, the critical period of weed control for vernonia should have been kept weed-free from 75 to 90 days after sowing (Table 6). 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 Marnotte [32] located this critical period between 30 and 90 DAS for long-cycle crops (yams, cassava, sugarcane, etc.). Another finding by Zuhal *et al.* [29] reported that the critical period of weed control in faba bean started at 30 days and ends 45 days after crop emergence at 10% acceptable yield loss. However, according to Knezevic *et al.* [33], 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.

3.4. 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 treatment and significantly varied (P<0.01). The results in losses indicated that the pooled mean of seed yield per hectare was higher beyond 60 weedy days after sowing including weedy-check compared to the WI0 (Table 5). The pooled mean seed yield per hectare losses ranged from (45.26 to 69.22%) in increased duration of weedy periods while (0.00 - 44.45%) increased duration of weed-free periods (Table 6). Thus, the losses come through the results of weed-crop competitions regarding the nearby resources utilization during 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.

Table 6. *Effect of increasing duration of weedy and weed-free periods on relative yield and yield loss of vernonia at Wondo genet southern Ethiopia, in 2017/2018 cropping seasons.*

Treatment	Relative yield (%)	Yield loss (%)
WF15	55.55^{cde}	44.45^{ef}
WF30	62.83^{cd}	37.17^{fg}
WF45	65.85^{c}	34.15^{g}
WF60	77.47^{b}	22.53^{h}
WF75	92.76^{a}	7.24^{i}
WF90	95.11^{a}	4.89^{i}
WF0	30.78^{h}	69.22^{a}
WI15	54.74^{de}	45.26^{ef}
WI30	53.34^{de}	46.66^{de}
WI45	49.85^{ef}	50.15^{cde}
WI60	44.78^{efg}	55.22^{bcd}
WI75	41.39^{fgh}	58.61^{bc}
WI90	37.82^{gh}	62.18^{ab}
WI0	100^{a}	0.00^{i}
Mean	61.59	38.41
CV (%)	9.12	14.62

4. Conclusions

There was an overall sensitivity of vernonia crops to the presence of 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. It can be concluded from the results that for obtaining a better yield more than 90% yield of vernonia, it has to be weed-free which lies between 75 to 90 days after emergence of the crop as it is found to be the critical period of weed crop competition at Wondo Genet and to other similar agro-ecological areas.

Conflict of Interest

The authors declare that they have no competing interests.

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