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Determination of Critical Weed Competition Period in Basil (*Ocimum basilicum* L.) Production at Mid Altitude of Wondo Genet and Alage, Southern Ethiopia

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Abstract

Weed is one of the most important enemies of basil production. Therefore, this study aimed to determine the critical weed competition period on growth, yield, and yield components of the basil plant at Wondo Genet and Alage site during the 2017 to 2018 cropping seasons. The experiment was laid out in a randomized complete block design with three replications consisted the treatments of 10, 20, 30, 40,50, and 60 Days After Crop Emergence (DACE), and season-long weedy and weed-free checks were included as a control. In both locations, the yield losses of basil were estimated based on fresh and dried herbage, and essential oil yield. The highest fresh and dry herbage yield of 2,829.10kg/ha and 1,193.06kg/ha from Wondo Genet and 3,101.87kg/ha and 1,148.78kg/ha from Alage were recorded from the weed-free for 60DACE, respectively. Also, the maximum essential oil content and yield of (1.05v/w) and (12.66kg/ha) from Wondo Genet and (1.27v/w) and (14.58kg/ha) from Alage were recorded from the weed-free check, respectively. Based on the estimated value of yield losses the beginning and the end of the critical period of crop-weed competition at 5 and 10% acceptable yield loss levels were determined. Thus, to reduce the yield losses by more than 10%, plants must be kept weed-free within 50 to 60 and 40 to 60DACE at Wondo genet and Alage site, respectively as it is the critical period of weed-crop competition in basil plants.

Keywords

Basil, Critical Period, Weed Species, Yield Losses

1. Introduction

Basil is an important group of aromatic and medicinal plants belonging to Lamiaceae family. Which includes about 200 genera and 3,200 species of annuals and non-woody perennials widely distributed almost all-over the temperate and tropical regions of the world [1, 2, 3]. The extract of the herb is used in preventing cardiovascular diseases through improved diet and several antioxidant compounds display a high antioxidant power [4]. It has been used as a folk remedy for an enormous number of ailments including boredom, cancer, convulsion, deafness, diarrhea, epilepsy, gout, hiccup, impotency, insanity, nausea, sore throat, toothaches and whooping cough, insect repellent, anti-viral, anti-microbial, antioxidant, and anti-cancer properties of the oils [3].

As with all commonly grown crops, also in medicinal and aromatic plants, weeds function as crop competitors, create problems for mechanized harvest, and may alter the end quality when mixed with the harvested product. The well-known interference of weeds takes additional relevance for medicinal and aromatic plants for several reasons.

Firstly, the synthesis of secondary metabolites in plants is linked to many genetic and environmental factors [3]. Buyers often grade such plants according to their specific quality features, which are primarily determined by their content in essential oils or other secondary metabolites, which in their turn can be reduced in presence of weeds [6]. Some experiments carried out on the suitability of medicinal and aromatic plants to field conditions have confirmed the importance of weed competition; [7] demonstrated that on coriander, especially under poor soil conditions, weeding had a greater effect than did N fertilization.

In Ethiopia, where basil is found in cultivation as well as in the wild in most regions, it is a commonly cultivated herb. Either fresh or dried plant parts are for sale on almost every Ethiopian market and small-scale cultivation near houses is widespread. However, [8] reported that Ethiopia has exported 68,786 kg of basil essential oil to Sudan and the USA from which a total foreign currency of $ 54,991.20 and 746.00, respectively was obtained in 2009. The export volume accounted for 19.77% in 2006-2009 and exhibit 0.15 and 0.14% both volume and value share of the total spice export. But this indicates that the productivity of basil is much below its potential. The limiting factors could be lack of high yield, pest and biotic stress, resistant variety, lack of improved agronomic practices, lack of knowledge, and systematic oil analyzing laboratory. Among these, poor weed management at the appropriate time was considered a critical problem of basil production in Ethiopia. There is no crucial period during which weed infestation is particularly harmful to the basil plant. Thus, for sound integrated weed management in basil cropping, it is necessary to determine when basil plants will be the most and least affected by weeds.

The concept of critical periods of weed competition, during which weeds have the greatest impact on crop growth, was verified by [9]. It is a specific minimum period during which the crop must be free of weeds to prevent loss in yield and represents the overlap of two separate components [10]. The first component is the length of time weeds can remain in a crop before interference begins. The second component is the length of time that weed emergence must be prevented so that subsequent weed growth does not reduce crop yield. The critical period is the prime period most suitable for conducting weeding operations considering the following factors: the environment (climate and soil), the period of weed infestation in the field, the weed species, the cultural practices including crop rotation, fertilization, density, and methods of seeding (broadcast, hill seeding or transplanting), and the relative growth rates of the crop and its associated weeds.

Despite diverse potential uses of basil plants, the increasing interest of farmers and investors in its cultivation in Ethiopia, and the existence of diverse ecological conditions, there exists scanty information about the weed management system at the appropriate time. Because of the differences in climatic conditions and weed populations, the result of studies conducted in different environments or on different crops may not apply to other systems [11, 12, 13, 14]. The critical period for weed control in basil plants has not been determined in our country. This could help basil producers to improve the efficacy of their current weed management systems and reduce yield loss resulting from weed competition. Therefore, this study aimed to determine the critical crop-weed competition period and to investigate the effect of weed interferences on basil yield.

2. Materials and Methods

The experiment was laid out at Wondo Genet and Alage site during the 2017 to 2018 cropping seasons. Wondo Genet is located at 7° 192′ N latitude and 38° 382′ E longitudes with an altitude of (1780m.a.s.l). The site receives a mean annual rainfall of 1,000 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 [15]. Alage is located at a longitude of 38^{o} 30'East and a latitude of 7^{o}30' North, with an altitude of (1600 m.a.s.l). The site is characterized by mild tropical weather with a minimum and maximum temperature ranging from 11°C to 29°C and experiences a bimodal rainfall distribution with an annual average of 800m [16]. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having a net plot size measuring 2.4m × 3.6 m with 60cm*40cm space between rows and plants, respectively. The crop was sown in June 2017 and 2018 and the basil-05, genotype was used. 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 a prescribed duration and kept weed-free till harvest.

To determine the beginning of the CPWC (Critical Period of Weed Control), the first component, (IDWFP) Increasing Duration of Weed Free Period, was established by maintaining weed-free conditions for 10, 20, 30, 40, 50, and 60DACE 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, (IDWP) Increasing Duration of Weedy Period, was established by allowing the weeds to compete with the basil for 10, 20, 30, 40, 50, and 60DACE after which, plots were maintained weed-free until harvest. In addition, season-long weedy and weed-free checks were included as a control.

Weed flora: Data on weed flora present in the experimental fields 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 quadrate (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 before the expected harvest time in the case of late competition to avoid possible foliage and seed shading. The weed species found within the sample quadrate were identified, counted, and expressed in m^{-2}. Weed aboveground dry biomass (g): For aboveground weed dry biomass, the weeds falling within the quadrate 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. Four plants were selected at random to record plant height, the number of primary branches per plant, fresh stem yield per plant, fresh and dry herbage yield per plant and hectare, essential oil content, and yield per hectare. 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. On the other hand, to analyze the critical period of weed control, the relative basil yields (Y) of each treatment were computed as followed.

Y = Ocimum basilicum L. fayield in treatment / Ocimum basilicum L. fa yield in weed-free check x 100.

3. Results and Discussion

3.1. Weed Data

There were 23 and 12 main weed species belonging to 7 families that were identified in which a greater number was broadleaf species with lower numbers of grass and sedge weeds in both Wondo genet and Alage sites, respectively (Tables 1 and 2). 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 [17] who reported that the weed species were composed of a wide range of annual, biennial, and perennial broad-leaved, grasses, and sieges weeds with differed in frequency, abundance, and dominance.

Table 1. Major weed species at Wondo Genet site

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

Table 2. Major weed species at Alage site

S/N	Scientific name	Family name	Category	Life cycle
1	*Commelina benghalensis* L.	Commelinaceae	Broadleaf	Perennial
2	*Cyperus rotundus* L.	Cyperaceae	Sedge	Perennial
3	*Guizotia scabra* (Vis.) Chiov.	Asteraceae	Broadleaf	Perennial
4	*Ageratum conyzoides* L.	Asteraceae	Broadleaf	Annual
5	*Amaranthus hybridus* L.	Amaranthaceae	Broadleaf	Annual
6	*Galinsoga parviflora L.*	Asteraceae	Grass	Perennial
7	*Plantago lanceolate L.*	Plantaginaceae	Broadleaf	Perennial
8	*Bidens pilosa* L.	Asteraceae	Broad leaf	Perennial
9	*Cynodon dactylon* L.	Poaceae	Grass	Annual
10	*Datura stramonium* L.	Solanaceae	Broad leaf	Annual
11	*Digitariasanguinalis (L.) Scop.*	Poaceae	Grass	Annual
12	*Nicandra physaloides* (L) Gaerth	Solanaceae	Broad leaf	Annual

In both locations, the total weed density increased significantly with the increase in competition duration and the increase was significant at each increase in duration period. At Wondo genet, the maximum (147.00) and minimum (0.00) total weed density was obtained in plots with the weedy check and weed-free check, respectively (Figure 1) while at Alage the maximum (148.67) and minimum (2.00) were obtained in plots with the weedy for 60DACE and weed-free check, respectively (Figure 2). Weedy check and weedy for 60DACE 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 [18] who reported that weed-free plots showed minimum density because weeds were eradicated by repeated hand hoeing.

The dry weight of aboveground weed biomass was increased with the increase in the competition period, being the maximum (125.67g) in the weedy check and the minimum (0.00g) in the weed-free check (Figure 1). The maximum dry weight of aboveground weed biomass in the 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. Thus, the result clearly showed that the weed-free condition at the early crop growth stage is more important than the weed-free condition at the later one. The result further indicated that the weeds emerging at the later growth stages offer less competition to crops as it accumulates lower weed biomass [18]. Similarly, [19] found that increasing weed crop competition duration increased weed biomass.

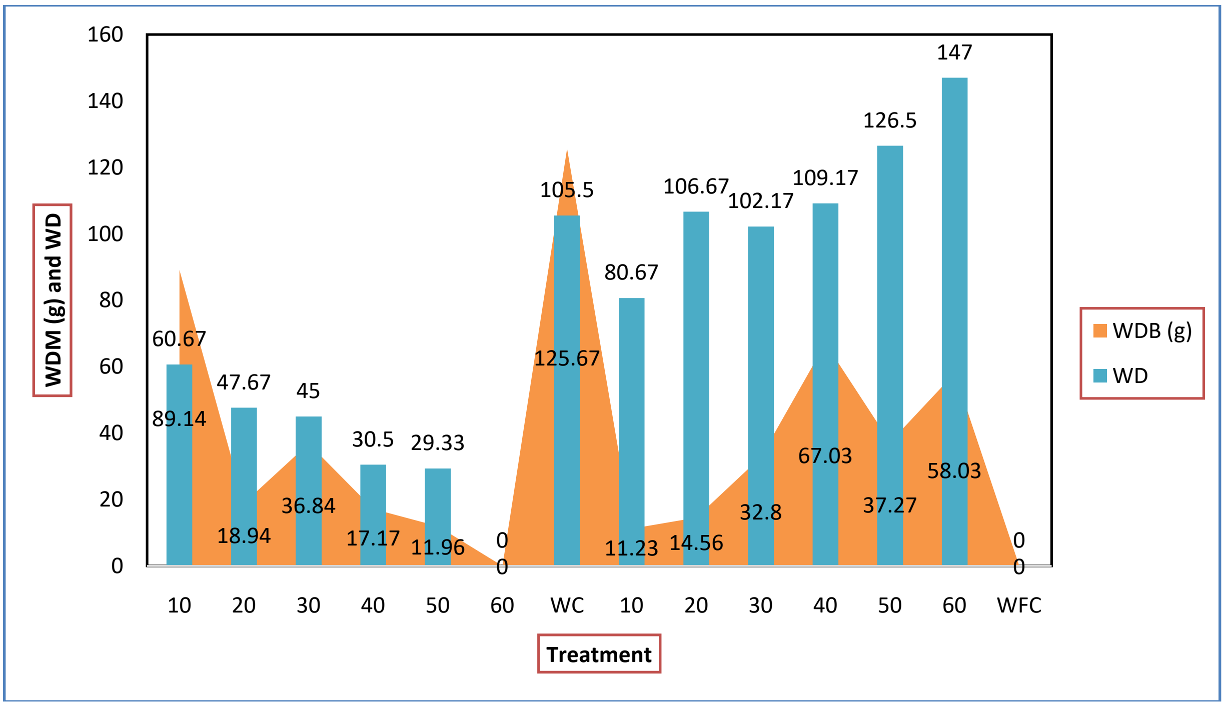

Figure 1. The effect of weed dry biomass (WDB) and weed density (WD) on basil plants at Wondogenet site.

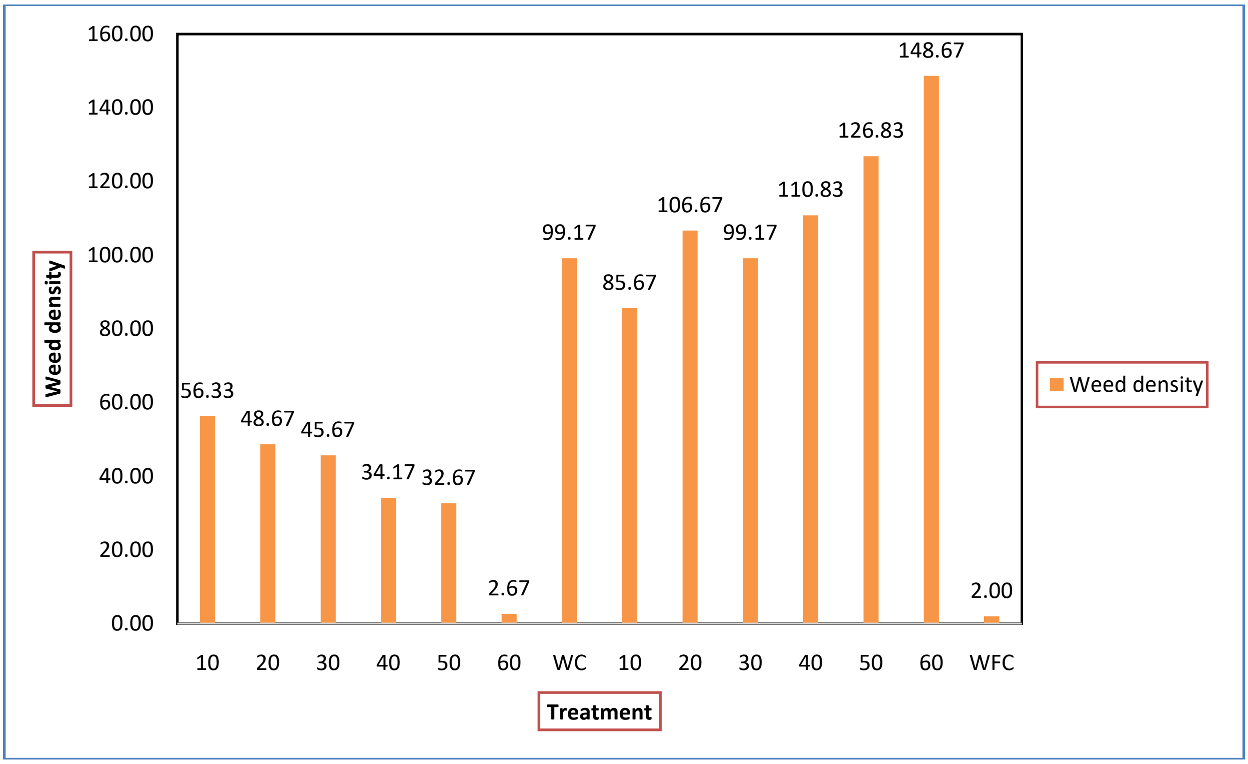

Figure 2. The effect of weed density on basil plants at Alage site.

3.2. Crop data

The plant height of basil was significantly (P<0.0001) influenced by the weed competition period, increased the length of weed interference, and caused the shortest plant in both locations. At the Wondo genetsite, the tallest plant height was found in the weed-free check (47.13cm) while the weedy-check (32.54cm) plots resulted in the shortest plant height (Table 3). Likewise, at the Alage site, the tallest plant height was found in the weed-free for 50DACE (55.12cm) while the weedy for 60DACE (21.10cm) plots resulted in the shortest plant height (Table 4). The present study revealed a significant reduction in plant height might be due to high weed density. The height of basil plants increased with the prolonged weed-free conditions and decreased with the extended weed-infested period. The results are from the previous research, where the taller rice plants were found in all weed-free treatments [20].

The result revealed that a significant (P<0.0001) difference was observed in the number of primary branches per plant at different crop-weed competition periods (Table 3) in both locations. At the Wondo genet and Alage site, the highest number of primary branches (21.21) and (21.50 per plant was found in the weed-free check, respectively. This was statistically on par with competition duration of 50 and 60DACE and significantly different from the rest of the treatments at both locations (Tables 3 and 4). A gradual and progressive decrease in the number of primary branches per plant was recorded with increasing competition duration. The probable reason for the higher number of primary branches per plant in short competition durations was the less time available for the competition of resources between crops and weeds. 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 [21] who also described that number of primary branches per plant in field pea increased when the weed-free days were prolonged.

The present study indicated a significant (P<0.0001) effect of weed-crop competition durations on a fresh stem and fresh and dry herbage yield at both locations. At Wondo genet site, weed-free check and weed-free for 60DACE produce maximum fresh stem weight per plant (163.02g) and (159.38g), respectively; while the minimum (20.80g) was in plots where competition was throughout the growing season (Table 3). The highest fresh (67.90g) and dry herbage (28.63g) yield per plant was recorded in the weed-free check. This was statistically on par with competition duration of 60 and 50DACE and significantly different from the rest of the treatments. The lowest fresh and dry herbage yield per plant was in the weedy-check (11.73g) and (7.87g), respectively (Table 3). The highest fresh (2,829.10kg/ha) and dry herbage (1,193.06 kg/ha) yield per hectare was recorded in the weed-free check which was on parity with competition durations of 60 and 50DACE and significantly different from the rest of the treatments; while the lowest was in the weedy-check (488.60kg/ha) and (328.00kg/ha), respectively (Table 3).

At Alage site, weed-free check, weed-free for 60 and 50DACE produce maximum fresh stem weight per plant (265.20g), (258.69g), and (256.03g), respectively; while the minimum (2.72g) was in plots where competition was throughout the growing season (Table 7). The highest fresh (74.45g) and dry herbage (27.57g) yield per plant was recorded in the weed-free check. This was statistically on par with competition duration of 60, 50 and 40DACE and significantly different from the rest of the treatments. The lowest fresh and dry herbage yield per plant was in the weedy-check (22.81g) and weedy for 60DACE (9.04g), respectively (Table 4). The highest fresh (3,101.87 kg/ha) and dry herbage (1,148.78kg/ha) yield per hectare was recorded in weed-free check which was on parity with competition durations of 60, 50 and 40DACE and significantly different from the rest of the treatments; while the lowest was in the weedy-check (950.29kg/ha) and (376.60kg/ha), respectively (Table 4).

Overall, in increasing weed competition periods, the weeds might have exerted severe competition and utilized the environmental resources for a longer period which led to little or minimum amount of dry biomass accumulation for the yield components. But, in increasing weed-free periods the likely reasons for the higher weight for each parameter could be the relatively better control of weeds and favorable conditions during the growing season for the crop, which might have persuaded more accruement of available dry biomass. Similarly, [21] reported that the yield attributes were highest in the season-long weed-free period and on par with weed-free for initial the 40days or plots kept weedy only for initial the 20days.

Essential oil content and yield were significantly ($P<0.0001$) influenced by the duration of weed competition. At the Wondo genet site, the maximum essential oil content (1.05v/w) and yield (12.66kg/ha) were obtained from the weed-free check. This was on parity with the treatments kept weed-free for 60 and 50DACE and significantly varied from the other treatments. The minimum essential oil content (0.19v/w) and yield (0.63kg/ha) were recorded in the weedy-check (Table 4). At the Alage site, the maximum essential oil content (1.27v/w) and yield (14.58kg/ha) were obtained from the weed-free check. This was on parity with the treatments kept weed-free for 60, 50 and 40DACE and significantly varied from the other treatments. The minimum essential oil content (0.07v/w) and yield (0.24kg/ha) were recorded in the weedy-check (Table 5). The highest essential oil content and yield 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 aboveground and belowground growth resources by the crop. The decrease in essential oil content and yield with increasing weed-crop competition duration was due to a decrease in the yield components like the number of branches per plant, and fresh and dry herbage unit areas. In general, the essential oil content and yield of basil were inversely related to the increase in the duration of weedy periods and directly proportional to the increase in weed-free periods. In conformity with this result, [22] 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.

Table 3. The effect of weed competition periods on basil yield components at Wondo genet site

Treatment	PH (cm)	NPBPP	FSWPP(g)	FHYPP(g)	DHYPP(g)
IDWFP at DACE					
10	39.21^{bcd}	9.75^{efg}	57.32^{ef}	27.78^{de}	14.19^{e}
20	39.00^{bcd}	13.13^{d}	103.10^{d}	33.10^{d}	18.64^{d}
30	40.92^{bcd}	16.64^{c}	129.17^{c}	42.57^{c}	21.93^{c}
40	41.88^{a-d}	18.60^{bc}	135.51^{bc}	51.74^{b}	25.09^{b}
50	42.38^{abc}	19.67^{ab}	143.12^{b}	67.41^{a}	28.15^{a}
60	43.13^{ab}	20.03^{ab}	159.38^{a}	67.51^{a}	28.36^{a}
WC	32.54^{e}	6.20^{h}	20.80^{h}	11.73^{g}	7.87^{h}
IDWP at DACE					
10	36.63^{de}	11.25^{de}	65.09^{e}	27.82^{de}	17.05^{d}
20	37.17^{cde}	10.88^{ef}	47.19^{f}	20.86^{ef}	14.25^{e}
30	38.42^{bcd}	9.02^{fg}	32.98^{g}	19.11^{f}	13.27^{ef}
40	39.08^{bcd}	8.91^{fg}	28.14^{gh}	17.93^{fg}	12.44^{efg}
50	40.79^{bcd}	8.18^{gh}	28.05^{gh}	17.84^{fg}	11.87^{fg}
60	38.75^{bcd}	6.37^{h}	25.95^{gh}	13.77^{fg}	10.66^{g}
WFC	47.13^{a}	21.21^{a}	163.02^{a}	67.90^{a}	28.63^{a}
$Lsd_{0.05}$	5.65	2.02	11.15	7.25	2.07
CV (%)	12.27	13.58	11.84	18.01	9.90

PH = Plant Height, NPBPP = Number of Primary Branches Per Plant, FSWPP= Fresh Stem Weight Per Plant, FHYPP = Fresh herbage Yield Per Plant, DHYPP= Dried Herbage Yield Per Plant.

Table 4. The effect of weed competition periods on basil yield components at Alage site

Treatment	PH (cm)	NPB	FSWPP(g)	TFHPP(g)	TDHPP(g)
IDWFP at DACE					
10	42.85^{d}	9.17^{d}	176.83^{d}	46.35^{c}	17.29^{d}
20	47.89^{bcd}	13.67^{c}	230.10^{c}	60.60^{b}	19.65^{c}
30	45.38^{cd}	13.67^{c}	236.30^{bc}	63.92^{b}	22.82^{b}
40	50.02^{abc}	17.00^{b}	247.88^{abc}	73.16^{a}	26.43^{a}
50	55.12^{a}	20.33^{a}	256.03^{ab}	73.03^{a}	27.44^{a}
60	54.00^{ab}	21.17^{a}	258.69^{ab}	74.34^{a}	27.35^{a}
WC	23.95^{fg}	1.67^{g}	2.72^{h}	22.81^{g}	11.34^{fg}
IDWP at DACE					
10	50.62^{abc}	9.33^{d}	157.56^{de}	44.29^{cd}	16.74^{de}
20	46.24^{cd}	8.67^{d}	152.13^{e}	41.51^{d}	15.37^{e}
30	34.29^{e}	5.83^{e}	81.76^{f}	33.98^{e}	13.10^{f}
40	28.28^{ef}	3.00^{f}	30.59^{g}	31.06^{e}	11.87^{fg}
50	22.53^{fg}	2.00^{fg}	4.60^{h}	27.06^{f}	10.25^{gh}
60	21.10^{g}	1.33^{g}	5.06^{h}	24.67^{fg}	9.04^{h}
WFC	49.18^{abc}	21.50^{a}	265.20^{a}	74.45^{a}	27.57^{a}
$Lsd_{0.05}$	6.23	1.30	22.65	3.80	1.80
CV (%)	13.19	10.52	13.01	6.67	8.48

Table 5. The effect of weed competition periods on basil yield and yield components at Wondo genet site

Treatment	TFHY (kg/ha)	TDHY (kg/ha)	EOC (v/w)	EOY (kg/ha)
IDWFP at DACE				
10	1,157.60^{de}	591.43^{e}	0.41^{e}	2.38^{ef}
20	1,379.30^{d}	776.56^{d}	0.60^{d}	4.65^{d}
30	1,773.60^{c}	913.59^{c}	0.76^{c}	6.95^{c}
40	2,155.70^{b}	1,045.28^{b}	0.90^{b}	9.43^{b}
50	2808.70^{a}	1,172.79^{a}	0.96^{ab}	11.30^{a}
60	2,813.00^{a}	1,181.49^{a}	1.01^{ab}	12.06^{a}
WC	488.60^{g}	328.00^{h}	0.19^{g}	0.63^{g}
IDWP at DACE				
10	1,158.90^{de}	710.50^{d}	0.53^{d}	3.81^{de}
20	869.10^{ef}	593.74^{e}	0.40^{e}	2.36^{ef}
30	796.10^{f}	552.86^{ef}	0.33^{ef}	1.79^{fg}
40	747.00^{fg}	518.32^{efg}	0.24^{fg}	1.27^{fg}
50	743.30^{fg}	494.75^{fg}	0.22^{fg}	1.19^{fg}
60	573.70^{fg}	444.14^{g}	0.24^{fg}	1.11^{fg}
WFC	2,829.10^{a}	1,193.06^{a}	1.05^{a}	12.66^{a}
$Lsd_{0.05}$	302.15	86.02	0.12	1.48
CV (%)	18.01	9.90	18.87	25.07

TFHY=Total Fresh Herbage Yield, TDHY=Total Dried Herbage, EOC=Essential Oil Content, EOY=Essential Oil Yield

Table 6. The effect of weed competition periods on basil yield and yield components at Alage

Treatment	FHY (kg/ha)	DHY (kg/ha)	EOC(v/w)	EOY (kg/ha)
IDWFP at DACE				
10	1,931.15[c]	720.52[d]	0.73[c]	5.29[d]
20	2,525.17[b]	818.66[c]	0.80[c]	6.60[c]
30	2,663.13[b]	951.00[b]	0.90[b]	8.63[b]
40	3,048.28[a]	1,101.24[a]	1.25[a]	13.82[a]
50	3,042.94[a]	1,143.32[a]	1.25[a]	14.38[a]
60	3,097.33[a]	1,139.43[a]	1.26[a]	14.46[a]
WC	950.29[g]	472.60[fg]	0.13[fg]	0.63[f]
IDWP at DACE				
10	1,845.18[cd]	697.41[de]	0.64[d]	4.46[d]
20	1,729.68[d]	640.46[e]	0.48[e]	3.10[e]
30	1,415.83[e]	545.84[f]	0.52[e]	2.87[e]
40	1,294.10[e]	494.49[fg]	0.18[f]	0.90[f]
50	1,127.64[f]	427.14[gh]	0.14[fg]	0.61[f]
60	1,027.70[fg]	376.60[h]	0.07[g]	0.24[f]
WFC	3,101.87 [a]	1,148.78[a]	1.27[a]	14.58[a]
$Lsd_{0.05}$	158.94	74.82	0.08	0.96
CV (%)	6.67	8.48	10.52	12.82

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 at both locations. The results in losses indicated that the fresh and dry herbage, and essential oil yield were higher in the increased duration of the weedy period than in the increased duration of weed-free periods. At the Wondo genet site, the fresh herbage yield losses ranged from (59.04%-82.73%) in increased duration of weedy periods while (0.00-59.08%) in increased duration of weed-free periods (Figure 3). Likewise, the dry herbage yield losses ranged from (40.45%-72.51%) in increased duration of weedy periods while in increased duration of weed-free periods ranged from (0.00 to 50.43%) (Figure 3). For essential oil yield, the maximum losses were found in the weedycheck (95.02%) while the minimum was in the weed-free check (0.00%) Figure 3. At the Alage site, the fresh herbage yield losses ranged from (40.51%-69.36%) in increased duration of weedy periods while (0.00-37.74%) in increased duration of weed-free periods (Figure 4). Likewise, the dry herbage yield losses ranged from (39.29%-67.22%) in increased duration of weedy periods while in increased duration of weed-free periods ranged from (0.00-37.28 %) (Figure 4). For essential oil yield, the maximum losses were found in the weedy for 60DACE (98.35%) while the minimum was in the weed-free check (0.00%) (Figure 4). 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.

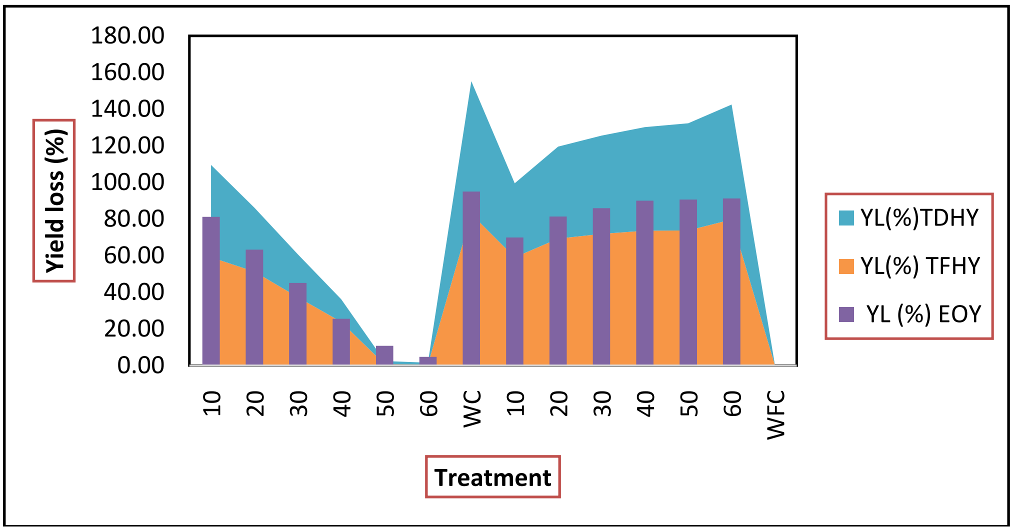

Figure 3. The effect of weed competition on the yield loss of basil plants at Wondo genet site.
YL%=Yield Loss in percent

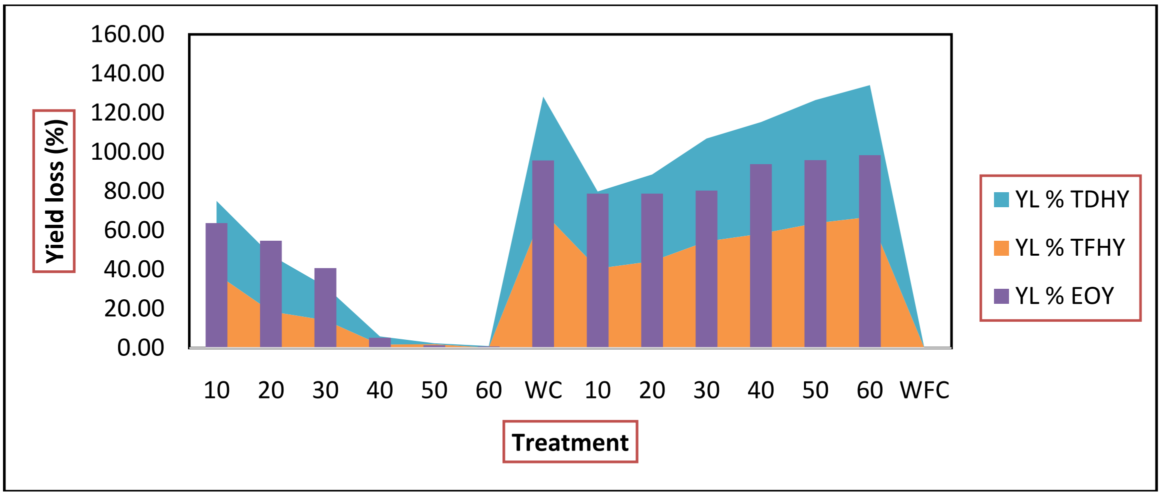

Figure 4. The effect of weed competition on the yield loss of basil plants at Alage site.

3.4. The critical period of weed control

The critical period of weed control for the basil plant was estimated based on the relative yields with between 5% and 10% at 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 of yield losses, the critical period of weed control for basil should be kept weed-free from 50 to 60 and 40 to 60DACE at Wondo genet and Alage site, respectively. 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 [23] who located this critical period between 30 and 90 DAS for long-cycle crops (yams, cassava, sugarcane, etc.). Similarly, this was in line with the finding of [22] who 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.

4. Conclusion

There was an overall sensitivity of basil crops 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 essential oil yield and yield-related components. From this study it can be concluded that to obtain a better yield of more than 90% yield, basil has to be weed-free. This period is between 50 to 60 and 40 to 60DACE of the crop as it is found to be the critical period of weed crop competition at Wondo Genet and Alage site and similar to the other agro-ecology areas. 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, environmentally friendly, and sustainable methods in IWM components to be developed properly.

Author Contributions

All the authors contributed to this work. N.G. initiated the concept, designed, and experimented. A. W. and D. A. conducted the experiment, structured and wrote the original draft, performed reviewing and editing of the manuscript, and prepared the final paper.

Conflict of Interest

The work described has not been published previously, nor is it under consideration for publication elsewhere. All authors approve publication, all sources of funding and reference are duly acknowledged, and no conflicts of interest are applicable.

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