



## Field Evaluation of Cassava Effluent, Hoe Weeding, and Pendimethalin on Weed Growth and Okra (*Abelmoschus esculentus* L. Moench) Performance

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### Abstract

This study investigated the impact of different weed control methods on okra crop yield. Field trials were conducted during the rainy seasons of 2017 and 2018 at the Institute of Agricultural Research and Training, Ibadan. Eight weed management methods and two controls were implemented at sowing, 3, and 5 weeks after sowing (WAS). The methods included Pendimethalin at sowing, Cassava effluent at 3 WAS, Hoe-weeding at 3 WAS, Cassava effluent at 3 WAS combined with Hoe-weeding at 5 WAS, Hoe-weeding at 3 and 5 WAS, Cassava effluent at 3 and 5 WAS, Pendimethalin combined with Cassava effluent at 5 WAS, and Pendimethalin combined with Hoe-weeding at 5 WAS. The experiment followed a Randomised Complete Block Design with three replications. Data on okra and weed growth parameters were collected at 5 and 9 WAS, while yield-related parameters were evaluated from 9 WAS. Analysis of variance showed varying weed control efficiencies, ranging from -48.0% (Pendimethalin, 2017 trial) to 94.3% (Hoe-weeding at 3 and 5 WAS, 2018). Pendimethalin enhanced okra growth at 5 WAS in the 2017 trial, similar to Pendimethalin combined with Hoe-weeding at 5 WAS and Hoe-weeding at 3 and 5 WAS at 9 WAS in the 2017 and 2018 trials, respectively. The highest and lowest okra fruit weights ( $\text{gm}^{-2}$ ) were recorded from Hoe-weeding at 3 and 5 WAS (572.9, 2018) and Cassava effluent at 3 and 5 WAS (23.9, 2018), respectively. While one-off weed control treatments did not provide season-long effects, Pendimethalin combined with Hoe-weeding at 5 WAS and Hoe-weeding at 3 and 5 WAS treatments effectively enhanced okra yield and maintained weed control throughout the season. These treatments are recommended for efficient weed management in okra production.

### Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a fruit vegetable widely cultivated in Nigeria on approximately two million hectares annually (Haruna and Jabil, 2017). However, its growth and yield are severely hindered by the presence of weeds, with reports of 100% loss during uncontrolled weed infestations in okra production (Adejonwo *et al.*, 1991). Efficient weed management is thus indispensable to achieve high yields in okra cultivation.

The critical period of weed competition in

okra has been identified as between two and six weeks after sowing (Dhivya *et al.*, 2021). Consequently, early weeding, preferably within the first two to three weeks after sowing, has been recommended to avoid yield losses (Dada and Fayinminnu, 2010).

In the rainforest agro-ecological zone of Nigeria, maintaining a weed-free condition throughout the crop cycle is advised for optimal okra yields (Law-Ogbomo *et al.*, 2013). To achieve this, Nigerian farmers predominantly employ mulching, manual weeding, and herbicide application as their primary weed control measures (Ayodele, 2021). Manual weeding has shown effectiveness in controlling weeds in okra, with studies reporting 97.67%

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weed control efficiency when hand weeding was conducted at 30 and 60 days after sowing (Baraiya et al., 2017). However, manual weeding is laborious, time-consuming, and costly (Daramola, 2021). The timing and frequency of manual weeding are also critical factors influencing successful crop protection, as observed in studies showing significant yield increase with one-time weeding at 3 weeks after sowing (WAS) compared to twice at 6 and 9 WAS (Osundare, 2009).

Pendimethalin, a widely used dinitro-aniline herbicide, has demonstrated effective pre-emergence weed control in okra, resulting in improved yields (Smith, 2006). However, the herbicide is associated with drawbacks such as weed resistance, underground water contamination, changes in soil microbial communities, and potential crop injury (Smith, 2006; Chen *et al.*, 2017; Chen *et al.*, 2021). Consequently, alternative weed control techniques are being explored to address these issues when necessary. For instance, Chompoo *et al.* (2019) reported that allelopathic water extract from French marigold stem (*Tagetes patula*) at 5% concentration displayed growth inhibition efficiency comparable to pendimethalin on weeds like *Bidens pilosa* and *Tridax procumbens*.

In recent studies, phytochemicals have shown potential for weed control, with cassava effluent being investigated as a suppressant for weeds in cowpea (Fayinminnu, 2014). The yield of cowpea treated with cassava effluent was significantly higher compared to weedy plots and comparable to hand-weeded plots. However, the weed control efficiency of cassava effluent for various crops remains under-researched, warranting further investigation given the negative impact of weeds on crops and the abundance of cassava effluent in many processing centers at no cost.

Due to the limitations of some one-off weed management techniques in providing season-long protection for crops, supplementary weeding has become essential during crop

production. Integrated weed management approaches that involve combining multiple techniques have shown promising results in enhancing yields (Ayodele and Aluko, 2017). Studies have recommended the use of pendimethalin-based integrated herbicide management systems over pendimethalin alone, while others have suggested improved okra yields with pre-emergence pendimethalin application alongside supplementary hoe-weeding (Smith *et al.*, 2009; Bagudo *et al.*, 2016).

Although the effectiveness of hoe-weeding and pendimethalin for weed control in okra has been investigated, information on integrated weed management involving phytochemicals remains scarce. As such, this study aims to evaluate the sole and combined use of hoe weeding, milled cassava effluent, and pendimethalin for weed management in okra, focusing on their influence on okra growth and yield. By exploring these integrated strategies, valuable insights can be gained to optimize weed control practices and enhance okra productivity.

## Materials and Methods

### Experimental Site

The field trials were conducted at the research farm of the Institute of Agricultural Research and Training Ibadan (7°38' N 3°84' E) in southwestern Nigeria, situated in the rainforest-savanna transition agroecology. The site had been fallowed for one year and was dominated by vegetation such as *Mimosa pudica*, *Panicum maximum*, and *Mitracapus villosus*. The trials were carried out during the rainy seasons of 2017 and 2018, with total rainfall recorded as 770 mm and 610 mm, respectively. The soil at the experimental site was ploughed and harrowed before sowing. Prior to the first trial, soil samples were collected from 0 to 15 cm depth and analyzed for their physicochemical properties, revealing acidic clay loam soil (Table 1). The site was divided into 2 m x 2 m plots with 50 cm and 100 cm spacing between plots and blocks, respectively

**Table 1:** Chemical properties and particle size distribution of soil on the experimental site

pH (H <sub>2</sub> O)	OC	Total N	Available P	Ca	Mg	K	Na	Sand	Silt	Clay
	(g/kg)		(mg/kg)	(Cmol/ kg)				(g/kg)		
4.9	18	1.5	11.4	1.9	1.3	11.4	0.2	328	239	383

## Experimental Materials

Okra seeds (v. 35) were obtained from the Seed Store of the Institute of Agricultural Research and Training, Ibadan. Pendimethalin (Missile<sup>®</sup>) in a water-soluble concentrate form was obtained from a reliable agrochemical store. Freshly milled cassava effluent was collected from the cassava processing unit of the International Institute of Tropical Agriculture, Ibadan, and its cyanide concentration was determined using the Ninhydrin-based spectrophotometric method described by Surleva *et al.* (2013). Application of cassava effluent was done at the rate of 24 g cyanide (CN) ha<sup>-1</sup>, prorated based on plot size.

## Experimental Treatments and Design

The experimental treatments included weedy check and weed-free as experimental controls, along with eight weed management approaches, which are:

- i. Pendimethalin at sowing (P)
- ii. Cassava effluent applied at 3 weeks after sowing (CE @3 WAS)
- iii. Hoe-weeding at 3 weeks after sowing (HW @3 WAS)
- iv. Hoe-weeding at 3 and 5 weeks after sowing (HW @3 & 5 WAS)
- v. CE at 3 weeks after sowing and hoe-weeding at 5 WAS (CE @3 WAS + HW @5WAS)
- vi. CE applied at 3 and 5 WAS (CE @3 & 5 WAS)
- vii. P and CE applied at 5 WAS (P + CE @5 WAS)
- viii. P and hoe-weeding at 5 WAS (P + HW @5 WAS)

The treatments were arranged in a randomised complete block design with three replications.

## Sowing of Okra Seeds

Three okra seeds were sown per hole (1 cm depth) on the flat with a spacing of 40 cm x 50 cm. Seedlings were later thinned to one plant per stand at 2 weeks after sowing (WAS).

## Data Collection

Data on weed density and weight were collected at 5 and 9 WAS using 25 cm x 25 cm

quadrats randomly placed within each plot. Weed samples were identified, counted, bulked, and weighed. The weed control efficiency (WCE) and weed index (WI) were calculated as follow:

$$WCE = \frac{a - b}{a} \times 100$$

$$WI = \frac{x - y}{x} \times 100$$

Where *a* = weed dry weight in weedy check, *b* = weed dry weight in treatment, *x* = yield from weed-free plots, *y* = yield from treatment.

The study involved measuring okra plant height, stem girth, number of leaves, and leaf area at 5 and 9 WAS. Additionally, okra fruits were harvested from tagged plants every three days between 9 and 12 WAS. The harvested fruits were then counted and weighed for each plot.

## Data Analysis

The collected data were subjected to Analysis of Variance (ANOVA), and significant means were separated using Duncan's multiple range test (DMRT) at a 5% level of probability with IBM SPSS Statistics 23 software.

## Results

### Effect of Weed Control Methods on Weeds and Okra at the Late Vegetative Stage (5 WAS)

In the 2017 trial, at 5 weeks after sowing (WAS), the weed control methods significantly influenced the growth parameters of okra (Table 2). Okra plants treated with pendimethalin exhibited the highest height (16.5 cm), which was comparable only to plants treated with CE @3 WAS (16.1 cm). However, HW @3 WAS resulted in the lowest height (12.9 cm), similar to weed-free and weedy-check plots (13.6 cm and 13.2 cm, respectively). The maximum number of leaves per okra plant (6.0) was observed in plots treated with HW @3 WAS, significantly comparable to plants treated with pendimethalin (5.7) and weed-free (5.8). Weedy-check plots had the fewest leaves (4.3).

**Table 2:** Effect of hoe weeding, cassava effluent and pendimethalin on growth parameters of okra and weeds at 5 weeks after sowing

Treatments	Okra					Weeds				
	Plant height (cm)	No of leaves (plant <sup>-1</sup> )	Stem girth (mm)	Leaf area (cm <sup>2</sup> )	Density (plant m <sup>-2</sup> )	Fresh weight (gm <sup>-2</sup> )	Dry weight (gm <sup>-2</sup> )	WCE (%)		
<b>2017</b>										
CF@3WAS	16.1a	4.9b	5.1a	81.7bc	120.0a	315.9	48.1a	-39.7b		
HW@3WAS	12.9b	6.0a	5.4a	108.2ab	61.3ab	25.1	10.3b	70.1a		
Pendimethalin (P)	16.5a	5.7a	5.2a	115.6a	53.3ab	286.2	28.4ab	17.4ab		
Weed-free	13.6b	5.8a	5.5a	116.3a	0.0b	0	0.0b	100.0a		
Weedy Check	13.2b	4.3c	4.2b	53.3c	104.0a	289	34.4a	0.0ab		
<b>2018</b>										
CF@3WAS	13.9	5.8	4	66.2	173.3ab	322.4b	64.3ab	36.4bc		
HW@3WAS	13.4	7.1	4.8	83.1	64.0bc	62.6b	9.6c	90.5a		
Pendimethalin (P)	15.9	6.3	4.8	109.8	144.0a-c	203.8b	43.7bc	56.7ab		
Weed-free	13.6	6.5	5	112.6	0.0c	0.0b	0.0c	100.0a		
Weedy Check	18.1	5.7	4.8	66.1	285.3a	656.2a	101.1a	0.0c		

Means in a column with the same letter under the same year are not significantly different based on DMRT ( $P = 0.05$ ). HW@3WAS: hoe weeding at 3 WAS; CF@3WAS: Cassava effluent of 24 g C/N/ha applied at 3 WAS; P: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing; Weed-free: No weed; Weedy check: No weeding treatment

Weed-free plots showed the widest stem girth (5.0 mm), significantly different from weedy-check plots (4.2 mm). Stem girth in weed-free plots was comparable to those in pendimethalin, CE @3 WAS, and HW @3 WAS plots (Table 2). Leaf area in weed-free plots was the largest (112.6 cm<sup>2</sup>), while weedy-check plots had the smallest (53.3 cm<sup>2</sup>). The leaf area of weed-free plots was comparable to that of pendimethalin and HW @3 WAS plots but significantly different from weedy-check and CE @3 WAS plots.

At 5 WAS in 2017, the fresh weights of weeds were comparable among all treatments. However, significant differences were observed in weed density and dry weight. (Table 2). CE @3 WAS had the highest weed density (120 plants m<sup>-2</sup>), comparable to other treatments except weed-free (0.0). Weed density in HW @3 WAS and pendimethalin treatments were similar to weed-free plots, which had the lowest density. Weed-free plots had the lowest weed dry weight (0.0 gm<sup>-2</sup>), not significantly different from HW @3 WAS (10.3 gm<sup>-2</sup>) and pendimethalin (28.4 gm<sup>-2</sup>) treatments. The highest weed dry weight (48.1 gm<sup>-2</sup>) was recorded in plots treated with CE @3 WAS, significantly different from weedy-check (34.4 gm<sup>-2</sup>). CE @3 WAS showed a negative weed control efficiency (-39.6), significantly lower than weed-free (100.0). On the other hand, HW @3 WAS (70.1) and pendimethalin (17.4) had positive weed control efficiencies, comparable to weed-free (100.0).

In the 2018 trial, at 5 WAS, the growth parameters of okra were not significantly influenced by the treatments (Table 2). However, significant variations were observed in weed density, fresh weight, dry weight, and weed control efficiency. The weed density ranged from 0 to 285.3 plants m<sup>-2</sup>, with weed-free plots having none and weedy-check plots having the highest density (285.3 plants m<sup>-2</sup>). HW @3 WAS (64.0 plants m<sup>-2</sup>) and pendimethalin (144.0 plants m<sup>-2</sup>) treatments had densities comparable to weed-free. Fresh weight of weeds in weedy-check plots was the highest (656 gm<sup>-2</sup>), significantly higher than other treatments. Other treatments had similar fresh weights, with weed-free plots having the least (0.0 gm<sup>-2</sup>). Dry weight of weeds in weed-free plots was the lowest (0.0 gm<sup>-2</sup>), significantly different from HW @3 WAS (9.6 gm<sup>-2</sup>) and pendimethalin (43.7 gm<sup>-2</sup>) treatments.

The highest weed dry weight (101 gm<sup>-2</sup>) was observed in plots treated with weedy check, significantly different from other treatments except CE @3 WAS.

### **Effect of Weed Control Methods on Okra and Weeds at Flowering Stage of Okra (9 WAS)**

In the 2017 trial at 9 WAS, the treatments significantly influenced all growth parameters of okra except plant height (Table 3). P + HW @5 WAS had the highest values for all recorded growth parameters of okra, significantly higher than the weedy check. Okra's lowest plant height was observed from HW @3 & 5WAS, while its smallest leaf area was recorded from CE @3 & 5 WAS. The weedy check plots exhibited the least stem girth and the lowest number of leaves among all the okra plants.

Throughout this trial, no significant differences were observed in the growth of okra plants between plots weeded once (HW @3 WAS) and twice (HW @3 & 5 WAS). Similarly, there were no significant variations in the stem girth and leaf area of okra plants among the CE @3 WAS, CE@3 WAS + HW @5 WAS, and CE @3 & 5 WAS plots (Table 3). These findings showed that follow-up hoe-weeding and cassava effluent treatments at 5 WAS, after CE @3 WAS, did not lead to a significant improvement in okra growth compared to the initial treatment. In contrast, okra plants treated with P + HW @5 WAS showed significantly higher growth compared to those treated with pendimethalin and P + CE @5 WAS, with the exception of plant height in pendimethalin and P + CE @5 WAS, as well as the number of leaves in P + CE @5 WAS.

During the flowering stage of okra in 2017 (9 WAS), the density and weight of weeds varied significantly among the treatments. The weed density on the field ranged from 0 to 312 plants/m<sup>2</sup>, with weed fresh and dry weights ranging between 0 and 1027.2 g/m<sup>2</sup> and 0 and 180.88 g/m<sup>2</sup>, respectively (Table 3). Plots treated with CE @3 & 5 WAS and pendimethalin exhibited the highest weed density and weed weights (fresh and dry), respectively. Comparatively, weed weights in pendimethalin plots significantly differed from other treatments, except for the fresh and dry weights of weeds in CE @3 & 5 WAS, P + CE @5 WAS, and the weedy check, as well as the dry weight of weeds in CE @3 WAS (Table 3).

**Table 3.** Effect of hoe weeding, cassava effluent, and pendimethalin on the growth of okra and weeds parameters at 9 weeks after sowing in 2017

Treatments	Okra					Weeds			
	Plant height (cm)	No of leaves (plant <sup>-1</sup> )	Stem Girth (mm)	Leaf area (cm <sup>2</sup> )	Density (plant m <sup>-2</sup> )	Fresh weight (gm <sup>2</sup> )	Dry weight (gm <sup>2</sup> )	WCE (%)	
CE@3WAS	24.8a-c	5.7c-c	5.4cd	96.8bc	136.0bc	527.4bc	113.1a-d	7.1b-c	
CE@3&5WAS	19.9cd	4.7d-f	4.4de	63.0c	312.0a	686.5ab	131.6a-c	-8.0c-e	
CE@3WAS + HW@5WAS	18.3d	7.7a-c	5.6c	101.1bc	80.0b-e	213.9c-e	38.8c-e	68.1a-c	
HW@3WAS	20.4b-d	5.9b-e	6.5bc	123.6b	112.0b-d	401.8b-d	73.5b-e	39.7a-d	
HW@3&5WAS	17.9d	8.0ab	6.8b	128.4b	58.7b-e	144.6de	29.4de	75.9ab	
Pendimethalin (P)	26.0ab	4.2ef	6.2bc	130.1b	48.0c-e	1027.2a	180.9a	-48.4e	
P+CE@5WAP	24.4a-c	6.2a-c	6.9b	131.2b	64.0b-c	672.9ab	141.6ab	-16.2dc	
P+HW@5WAS	28.2a	8.1a	8.1a	183.4a	16.0dc	117.5dc	14.8c	87.9a	
Weed-free	22.2b-d	6.9a-d	7.0ab	122.4b	0.0e	0.0e	0.0e	100.0a	
Weedy Check	18.0d	2.9f	4.2c	71.2c	157.3b	672.2ab	121.8a-d	0.0b-c	

Means in a column with the same letter are not significantly different based on DMRT ( $P < 0.05$ ). IIW@3WAS: hoe weeding at 3 WAS; IIW@3&5WAS: hoe weeding at 3 WAS and 5 WAS; CE@3WAS: Cassava effluent of 24 g CN/ha applied at 3 WAS; CE@3&5WAS: Cassava effluent of 24 g CN/ha applied at 3 WAS and hoe-weeding at 5 WAS; CE @3 & 5 WAS: Cassava effluent of 24 g CN/ha applied at 3 and 5 WAS; P: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing; P+IIW@5WAS: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and hoe-weeding at 5 WAS; P+CE@5WAS: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and Cassava effluent of 24 g CN/ha applied at 5 WAS; Weed-free: No weed; Weedy check: No weeding treatment

Okra plots that received HW @3 WAS and HW @3 & 5 WAS were not significantly different for all weed parameters (Table 3). Plots treated with pendimethalin, P + HW @5 WAS, and P + CE @5 WAS were not significantly different for weed density. However, P+HW @5 WAS had significantly fewer weed weights than the sole pendimethalin Treatment. The weed parameters recorded for plots that received supplementary hoe weeding were not significantly different from the weed-free treatment for all weed parameters. The highest WCE resulted from weed-free plots, and it was not significantly different from HW @3 WAS, HW @3 & 5WAS, CE @3 WAS + HW @5 WAS, and P + HW @5 WAS. In contrast, the least WCE was recorded from the pendimethalin treatment, and it was comparable to WCE from the weedy check, P+CE@5 WAS, CE @3 & 5 WAS, and CE @3 WAS.

In the 2018 trial, all the growth parameters of okra were significantly influenced by the treatments, except for plant height (Table 4). Plots that underwent hoe-weeding twice (HW @3 & 5 WAS) exhibited the highest number of leaves and leaf area, while those treated with CE twice (CE @3 & 5 WAS) showed the least growth parameters, comparable to the weedy check. The impact of plots weeded once (HW @3 WAS) and twice (HW @3 & 5 WAS) on okra growth was similar, with the exception of a significantly higher number of leaves in the plots weeded twice (Table 4).

Similarly, follow-up applications of hoe-weeding or CE at 5 WAS to CE @3 WAS or pendimethalin did not significantly improve the growth of okra compared to the initial treatments, except for a significantly increased stem girth recorded in P + CE @5 WAS. In other words, the growth of okra plants in plots treated with CE @3 WAS did not significantly differ from CE + HW @5 WAS and CE @3 & 5 WAS, just as okra plants in pendimethalin plots did not significantly differ from P + CE @5 WAS and P + HW@5 WAS, except for the significantly higher stem girth (17.7 cm) observed in P + CE @5 WAS plots (Table 4).

In the 2018 trial (Table 4), there were significant differences in weed density and weight at the flowering stage of okra (9 WAS) across the treatments. The weed density ranged between 0 and 245 plants m<sup>-2</sup>, resulting in weed

fresh and dry weight ranging from 0 to 1883.2 gm<sup>-2</sup> and 0 to 243.7 gm<sup>-2</sup>, respectively. The weedy check exhibited the highest weed density and weight, which were comparable to the CE @3 WAS and CE @3 & 5 WAS treatments for these parameters. On the other hand, the weed-free treatment had the least weed density and weight. However, this treatment did not differ significantly from the pendimethalin, HW @3 WAS, and supplementary hoe-weeding treatments (CE @3 WAS + HW @5 WAS, HW @3 & 5 WAS, and P + HW @5 WAS) in terms of weed density and weight.

Supplementary hoe-weeding in CE @3 WAS-treated plots (CE @3 & 5 WAS) resulted in a significant reduction in all weed parameters compared to CE @3 WAS-treated plots. However, the supplementary deployment of hoe-weeding in pendimethalin-treated plots (P + HW @5 WAS) had a similar effect on weed density and weight when compared to pendimethalin, HW @3 & 5 WAS, and CE @3 WAS + HW @5 WAS-treated plots. Additionally, the follow-up application of CE to plots initially treated with pendimethalin and CE did not significantly affect weed density and weight compared to the initial treatments.

### Effect of Weed Control Methods on Okra Yield

In 2017, the treatments significantly influenced the weight and number of okra fruits (Table 5). Okra plants in P + HW @5 WAS treated plots had the highest fruit weight (499 gm<sup>-2</sup>), comparable only to weed-free plots. The highest number of okra fruits (28.7 fruits/m<sup>2</sup>) was produced in weed-free plots, significantly different from other treatments except sole and supplementary hoe-weeded treatments. HW @3 WAS, HW @3 & 5 WAS, CE @3 WAS+ HW @5 WAS, and P + HW @5 WAS had comparable fruit weight and number with weed-free.

In the 2018 trial, the treatments significantly influenced the weight and number of okra fruits. HW @3 & 5WAS had the highest fruit weight and number of okra fruits per unit area, significantly different from other treatments. P + HW @5 WAS and HW @3 & 5WAS had the least weed index in 2017 and 2018, respectively. The weed index of weed-free plots was only significantly different from the weedy check in the 2017 trial

**Table 4:** Effect of hoe weeding, cassava effluence, and pendimethalin on the growth of okra and weeds at 9 weeks after sowing in 2018.

Treatments	Okra				Weeds			
	Plant height (cm)	No of leaves (plant <sup>-1</sup> )	Stem Girth (mm)	Leaf area (cm <sup>2</sup> )	Density (plant m <sup>-2</sup> )	Fresh weight (gm <sup>-2</sup> )	Dry weight (gm <sup>-2</sup> )	WCE (%)
CE@3WAS	34.3	4.8c	6.7b	97.3bc	210.7ab	1241.6ab	181.3ab	25.6cd
CE@3&5WAS	29.1	4.8c	5.7b	75.2c	242.7a	1325.9ab	166.7ab	31.6cd
CE@3WAS + HW@5WAS	24.6	7.0bc	6.3b	102.6bc	24.0cd	93.6d	14.1cd	94.2ab
HW@3WAS	34.4	8.6bc	9.2ab	157.8a-c	85.3b-d	536.5cd	65.1cd	73.3ab
HW@3&5WAS	40.1	13.73a	12.5ab	240.2a	26.7cd	111.5d	13.9cd	94.3ab
Pendimethalin (P)	34.4	7.1bc	8.5b	149.3a-c	136.0a-d	690.7b-d	97.6b-d	60.0a-c
P+CE@5WAP	38.3	8.0bc	17.7a	170.7a-c	152.0a-c	888.8bc	113.3bc	53.5bc
P+HW@5WAS	29.9	10.8ab	9.6ab	179.3a-c	82.7b-d	234.4cd	30.7cd	87.4ab
Weed-free	34.3	8.4bc	10.6ab	193.0ab	0.0d	0.0d	0.0d	100.0a
Weedy Check	40.2	6.0bc	6.5b	91.7bc	245.3a	1883.2a	243.7a	0.0d

Means in a column with the same letter are not significantly different based on DMRT ( $P = 0.05$ ). HW@3WAS; hoe weeding at 3 WAS; HW@3&5WAS; = hoe-weeding at 3 WAS and 5 WAS; CE@3WAS; Cassava effluent of 24 g CN/ha applied at 3 WAS; CE@3&5WAS; Cassava effluent of 24 g CN/ha applied at 3 and 5 WAS; P; Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing; P+HW@5WAS; Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and hoe-weeding at 5 WAS; P+CE@5WAS; Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and Cassava effluent of 24 g CN/ha applied at 5 WAS; Weed-free; No weed; Weedy check; No weeding treatment

**Table 5:** Effect of hoe weeding, cassava effluent, and pendimethalin on the yield of okra in 2017 and 2018

Treatments	2017			2018		
	Pod weight (gm <sup>-2</sup> )	No of pods (pods m <sup>-2</sup> )	Weed Index (%)	Pod weight (gm <sup>-2</sup> )	No of pods (pods m <sup>-2</sup> )	Weed Index (%)
CE@3WAS	84.3c	10.5c	78.8a	108.5b	7.7b	55.4a
CE@3&5WAS	63.0c	10.5c	84.2a	23.9b	2.1b	90.2a
CE@3WAS + HW@5WAS	224.4bc	21.0a-c	43.6ab	76.0b	6.3b	68.8a
HW@3WAS	256.8bc	20.3a-c	35.4ab	153.7b	10.5b	36.9a
HW@3&5WAS	239.7bc	18.2a-c	39.8ab	572.9a	28.7a	-135.3b
Pendimethalin (P)	149.1bc	15.4bc	62.5ab	151.0b	11.9b	38.0a
P+CE@5WAP	181.0bc	16.1bc	54.5ab	290.8b	16.8ab	-19.4a
P+HW@5WAS	499.0a	25.9ab	-25.4c	247.8b	9.8b	-1.8a
Weed-free	397.8ab	28.7a	0.0bc	243.5b	12.6b	0.0a
Weedy Check	47.0c	9.8c	88.2a	70.7b	7.0b	71.0a

Means in a column with the same letter are not significantly different based on DMRT ( $P = 0.05$ ). 1 hoe-weeding: hoe weeding at 3 WAS; 2 hoe weedings: hoe-weeding at 3 WAS and 5 WAS; CE=: Cassava effluent of 24 g CN/ha applied at 3 WAS; CE+ 1 hoe-weeding: Cassava effluent of 24 g CN/ha applied at 3 WAS and hoe-weeding at 5 WAS; CE + CE: Cassava effluent of 24 g CN/ha applied at sowing and hoe-weeding at 3 and 5 WAS; P: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing; P+1 hoe-weeding: pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and hoe-weeding at 5 WAS; P + CE: Pendimethalin of 1.2 kg a.i ha<sup>-1</sup> applied at sowing and cassava effluent of 24 g CN/ha applied at 5 WAS; Weed-free: No weed; Weedy check: No weeding treatment.

## Discussion

In the 2017 trial, during the late vegetative stage, the growth of okra varied significantly among different treatments, indicating that the weed control methods employed had varying degrees of success in mitigating the negative impact of weeds. The weedy check exhibited the most competitive weed scenario, resulting in okra plants with the fewest leaves, smaller leaf area, and reduced stem girth. Interestingly, the increased height of okra plants in plots treated with pendimethalin and CE compared to the weed-free treatment may be attributed to the phytotonic effect of these treatments. This finding aligns with the observations of Shylaja and Thomas (2004), who reported similar increased plant height in cocoa seedlings treated with pendimethalin due to its phytotonic effect. However, the comparable stem girth of okra plants in these treatments with those in the weed-free treatment challenges the assumption that the increased height is caused by competition for sunlight resulting in etiolation, as proposed by Oliveira *et al.* (2011).

During the late vegetative stage of the 2017 trial, HW @3 WAS and pendimethalin demonstrated higher effectiveness in weed control compared to CE @3 WAS. However, it was evident that the weed control effect of HW @3 WAS and pendimethalin diminished within 5 weeks after sowing (WAS), indicating that their one-off use might not provide adequate season-long weed control.

Remarkably, in 2018, weed competition had an insignificant effect on okra's growth during the late vegetative stage. This was evident from the similar growth observed between the weed-free and weedy check treatments, suggesting that environmental factors such as sufficient water availability (Pearson *et al.*, 2017), adequate sunlight exposure (Page *et al.*, 2010), and ample soil nutrients (Liebman and Davis, 2000) might have compensated weed competition during this season. Although there was less rainfall in 2018 compared to 2017, a shorter dry spell length was noted.

Pendimethalin (in both trials) and HW @3 WAS (only in 2018) failed to significantly lower weed density below the levels observed in the weedy check at the late vegetative stage. This observation highlights the importance of

supplementary weeding in combination with these treatments at approximately 5 WAS in okra cultivation. This finding supports previous submissions by authors such as Lagoke *et al.* (2014), Adigun *et al.* (2016), and Ojelade *et al.* (2018) on the necessity of supplementary weeding during crop production. Among the treatments at the late vegetative stage of okra, HW @3 WAS exhibited superiority over pendimethalin and CE @3 WAS due to its consistent reduction in weed dry weight compared to the weedy check.

During the flowering stage in the 2017 trial, the varied growth of okra across treatments could be attributed to inherent differences in weed densities among the plots. For instance, the most superior growth of okra was observed in P + HW @5 WAS plots with low weed density, whereas CE @3 & 5 WAS and weedy check treatments resulted in the least growth of okra due to the highest degree of weed growth in those plots. Pendimethalin's reported ability to provide a head start advantage to crops (Ahmed and Chauhan, 2015) is supported by these findings, indicating that combining its use with other weed control methods can extend the period of minimal weed competition and enhance crop growth. The common features of P + HW @5 WAS and HW @3 & 5 WAS, which showed superior growth of okra in the 2017 and 2018 trials, respectively, were weed parameters similar to weed-free and supplementary hoe weeding. The additional benefit of hoe-weeding in these treatments could be its ability to improve water infiltration into the soil (Wang *et al.*, 2017), further contributing to enhanced growth.

Comparing the treatments to the weed-free control, a noticeable reduction in the growth of okra by other treatments observed indicated their inefficiency in adequately averting the negative impact of weed interference on okra growth. The weedy check, pendimethalin, CE @3 WAS, CE @3 & 5 WAS, and CE @3 WAS + HW @5 WAS exhibited reduced growth at the flowering stage, further emphasizing their ineffectiveness. Cassava effluent's (CE) ineffectiveness for weed control in okra may be attributed to its inability to achieve similar weed density and dry weight as recorded in the weed-free treatment from the late vegetative to flowering stage.

The significant increase in weed density on CE @3 & 5 WAS plots over the weedy check suggests that the treatment likely promoted weed growth by breaking weed seed dormancy, consistent with the findings of Araújo (2019) reporting cassava effluent breaking seed dormancy in cabbage. Supplementary hoe-weeding helped achieve comparable weed weight and density in CE @3 WAS+HW@5WAS treatment to the weed-free control. However, the accompanying reduction in okra growth may have resulted from the initial poor performance of CE @3 WAS.

The similar growth of okra plants in HW @3 WAS and HW @3 & 5 WAS treatments at the flowering stage in 2017 could be attributed to the similarity in weed densities and weights on these plots. The comparable weed densities of HW @3 WAS and HW @3 & 5WAS treatments could be explained by the transiency of this weed control method, coupled with the absence of shading on the plots, promoting weed proliferation in a non-weedy environment. This may also account for the comparable weed densities of pendimethalin and P + HW @5 WAS. The efficacy of supplementary hoe-weeding in maintaining reduced weed density decreased over time due to the rapid emergence of weed flushes.

Supplementary weed control has proven to be an effective method in reducing crop exposure to weeds, thereby enhancing the growth of okra. In the 2017 trial, P + HW @5 WAS demonstrated superior performance compared to pendimethalin, leading to a noticeable reduction in weed weight and a subsequent increase in okra leaf area, stem girth, and the number of leaves. This finding is consistent with Adigun et al. (2018) which also highlighted the growth-enhancing effects of hoe-weeding in tomatoes after the application of herbicides. However, the impact of weed competition before the follow-up treatments may influence its effectiveness in improving okra growth. For instance, the follow-up deployment of hoe-weeding or CE to CE @3 WAS resulted in reduced plant height and fewer leaves, while P + HW @5 WAS exhibited an increase in stem girth, leaf area, and the number of leaves compared to pendimethalin.

The WCE of HW @3 WAS, HW @3 & 5WAS, CE @3 WAS+HW5@WAS, and P+HW5@WAS were comparable to the weed-

free control at the flowering stage of okra, qualifying these weed control treatments as efficient. However, it is pertinent to consider the performance of these weed control treatments before the flowering stage since effectively managing weeds only at the flowering stage may not necessarily influence crop yield (Erazo-Barradas et al., 2017). Similarly, pendimethalin, CE @3 WAS, P + CE @5 WAS, and CE @3 & 5 WAS may be deemed ineffective as these treatments showed comparable WCE with the weedy check.

In both trials, the weedy check and CE @3 & 5 WAS treatments failed to effectively control weed competition, leading to a poor yield of okra. On the other hand, in the 2017 trial, the high efficiency of P + HW @5 WAS and weed-free treatments in mitigating weed competition resulted in superior growth of okra plants, with P + HW @5 WAS yielding the highest weight of okra fruits and the weed-free treatment producing the highest number of okra fruits.

Similarly, in the 2018 trial, HW @3 & 5WAS treatment also demonstrated high efficiency in mitigating weed competition, resulting in the highest weight and number of okra fruits. However, the comparable yield of okra from HW @3 WAS and HW @3 & 5WAS treatments in the 2017 trial, as well as the superior yield of okra in HW @3 & 5WAS over HW @3 WAS in the 2018 trial, suggests that HW @3 & 5WAS may not consistently yield better okra results compared to HW @3 WAS. This variability could be attributed to differences in weed flora composition, rainfall distribution, and water infiltration between the two seasons of evaluation.

In the 2017 trial, the inability of supplementary weeding through hoeing or application of CE to improve the yield of okra in CE-treated plots indicates that the initial CE treatment allowed weed competition during the critical weed-free period of okra (Isik and Akca, 2018), and the subsequent follow-up treatment was insufficient to recover crop yield. The yield disparity between CE @3 WAS and weed-free justifies this observation. However, the higher fruit weight of okra from P+HW @3 WAS plots over pendimethalin-treated plots in the 2017 trial suggests that significant weed competition extended beyond the period in which

pendimethalin's persistence typically protects okra production. Effective supplementary weeding through hoeing mitigated the effects of subsequent weed competition and increased yield.

The significant difference in yield between the weed-free and weedy check treatments in the 2017 trial can be attributed to the notable differences in okra growth parameters during the late vegetative stage. This head-start in plant growth helped mitigate the effects of weed competition on the yield of okra (Singh et al., 2018). However, in the 2018 trial, the comparable yield of okra from the weed-free and weedy check treatments could be due to the minimal impact of weeds in the weedy check. Furthermore, the improved yield of HW @3 & 5 WAS over the weed-free treatment in the 2018 trial indicates that this treatment has additional yield-promoting attributes besides its weed control efficacy.

## Conclusion

Weeds can significantly reduce the yield of okra in the field. One-off weed control treatments such as HW @3 WAS and pendimethalin were found to be inadequate in providing season-long weed control. Similarly, CE @3 WAS also did not effectively manage weeds. However, incorporating supplementary hoeing proved to be beneficial in enhancing both the yield of okra and the weed control efficiency of one-off weed control treatments. Notably, P + HW @5 WAS and HW @3 & 5WAS treatments demonstrated effective weed control, preventing potential yield losses caused by weed interference. As a result, we highly recommend these treatments for weed management in okra production.

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