Assessing the critical period of weed interference in Mango Ginger (*Curcuma amada* Roxb.) in Oyo and Ogun States, south western Nigeria.

Running Title: Weed interference period in mango ginger

Abstract

Assessing the critical period of weed interference will provide information on when crop is most sensitive to weed interference, and this will guide in developing weeding programme for the crop. Therefore, field trials were conducted in Ibadan, Oyo State and Ikenne, Ogun State to determine the critical period of weed interference in Mango ginger. In both locations, twelve weed interference periods were laid out in a randomized complete block design and replicated three times. Data collected on growth and yield of mango ginger, as well as weed dry matter were subjected to analysis of variance and treatment means were separated using Duncan's Multiple Rage Test at $P \leq 0.05$. Results revealed that growth and yield of mango ginger increased with length of weed free period and decreased with increase in weed infestation period. Conversely, weed dry matter production decreased with weed free period and increased with length of weed infestation. The highest yield gain of 51.9% and weed removal of 40.4% was observed between 4 and 8 weeks after planting (WAP). Weed infestation the first 12 weeks caused 84.7% reduction in mango ginger yield. Therefore, for optimum yield in mango ginger, weeding regime should be built around the first 12 weeks.

Keywords: Critical period, Mango ginger, weed removal, weeding regime and yield

Introduction

Mango ginger (*Curcuma amada* Roxb.) is a spice of great importance around the world, belonging to ginger family and closely associated to turmeric (Nayak, 2002; Sasikumar, 2005; Tepe *et al.*, 2006; Chandarana *et al.*, 2005). The rhizome has a combination of tastes, starting from being bitter, turning to a sweet and later sour aromatic sensation, used as a carminative, appetizer, digestive, diuretic, laxative, expectorant and antipyretic and useful in the treatment of dyspepsia, anorexia, flatulence, wounds, cough, bronchitis, skin diseases, ulcers, constipation, sprains and inflammations (Hussain *et al*., 1992; Warrier *et al*., 1994). Mango ginger has a typical exotic flavour of raw unripe mango. Therefore, it is used as a basic ingredient in pickles, preserves, candies, sauces, curries, salads and so on (Verghese 1990). The ethyl alcohol extract of mango ginger rhizome has antiinflammatory activity in acute and chronic administration in albino rats (Mujumdar et al. 2000). Mujumdar et al. (2000) also reported the presence of chemical compounds with hydroxyl, ester, carbonyl and olefin functional groups in ethyl alcohol extract. It was found to be significant at higher concentrations in acute carrageenan-induced rat paw oedema model. C. amada is reportedly used in various herbal preparations, including antiallergy formulations (Pushpangadan et al. 2006).

Weeds have been described to be the most common pests in crop production in the humid and subtropical tropics (Nedunchezhiyan et al. 2013). Weed infestation causes severe yield losses, which can reach 100% in the early stages (Ambe et al. 1992). Uncontrolled weed infestation in mango ginger had been reported to cause yield reduction, ranging between 85.1% to 92.9 (Osunleti et al., 2021a; 2021b; 2023). The critical period of weed interference is the time in the crop life cycle when weeds must be controlled in order to avoid unacceptable or economic yield loss (Zimdahl, 1988). Critical period of weed interference had been reported in several crops: in tumeric (Njoke et al., 2012), ginger (Kifelew et al., 2015), groundnut (Osunleti et al.,

2022), sweet pepper (Adigun et al. (1992) among others. But there is little or no information about critical period of weed interference in mango ginger, especially in South Western Nigeria. Therefore, the objective of this present work is to assess the critical period of weed interference in mango ginger in south west Nigeria.

Materials and Methods

The trials were conducted at the Teaching and Research farm, University of Ibadan, Ibadan Oyo state, Nigeria and Institute of Agricultural Research and Training, Ikenne Station during the early wet season.

The details of physic-chemical properties of the soil prior to the commencement of the trials in both locations are contained in Table 1. The result of the analysis showed that the soil was loamy sand in texture in both locations with soil pH of 6.2 and 5.9 in Ibadan and Ikenne, respectively (Table 1). The sites received a total rain fall of 1121 mm and 1202 mm in Ibadan and Ikenne, respectively (Table 2). Twelve treatments consisting of two sets of weed interference period. In the first set, mango ginger were kept weed-free, initially for 4, 8, 12, 16, 20 weeks after planting (WAP) and allowed to be subsequently weed infested until harvest. In the second set, the plots were left weed-infested initially for 4, 8, 12, 16, 20 weeks after planting (WAP) and thereafter, kept weed free by hoe-weeding until harvest. There were weed infested throughout plots and plots kept weed-free throughout the life cycle as control treatments. The treatments were arranged in a randomized complete block design and replicated three times.

In each location, the field was ploughed and harrowed at two-week intervals to ensure a well aerated and weed-free soil. After the removal of weed debris, field layout was done and beds of 3 m × 2 m were made manually with hoe. Mango ginger rhizome one per hole were planted per stand at 0.30 m × 0.25 m to give total plant population of 133,333 plants/ha.

Table 1: Physic-chemical properties of soil at the experimental sites

	Ibadan	Ikenne
pH (H_20) 1:2	6.2	5.9
Available P (mg/kg)	7	8
Org. Carbon (g/kg)	13.3	8.9
Total N (g/kg)	1.3	1.1
Exchangeable acidity (cmol/kg)	0.1	0.4
Bulk Density (g/cm^3)	1.42	1.74
Particle size (g/kg)		
Sand	780	810
Silt	126	120
Clay	94	70
Textural class (USDA)	Loamy sand	Loamy sand

Table 2: Monthly distribution and annual total rainfall, mean temperature and relative humidity of the experimental site

	Ibadan			Ikenne		
	Rainfall (mm)	Temperature	Relative Humidity	Rainfall (mm)	Temperature	Relative Humidity
Jan	8.0	27.0	76.0	25.8	27.5	74.0
Feb	23.0	28.0	71.0	0.0	28.5	76.0
Mar	76.0	28.5	75.0	131.0	28.0	78.0
April	125.0	28.0	78.0	120.2	28.0	84.0
May	145.0	27.0	83.0	145.9	27.0	82.0
June	163.0	25.5	86.0	185.1	25.5	86.0
July	132.0	24.5	88.0	132.0	25.5	88.0
Aug	74.0	24.0	87.0	106.0	25.0	87.0
Sep	170.0	25.5	86.0	171.4	25.5	88.0
Oct	152.0	26.0	84.0	152.0	26.0	86.0
Nov	43.0	27.0	81.0	23.5	27.5	80.0
Dec	10.0	27.0	79.0	8.7	27.0	76.0

Hoe weeding was carried out according to the treatment requirement using West African hand hoe. Weeding operation on each plot in both locations was preceded by collection of weed samples using systematic random sampling on the plots. Weed samples were collected from quadrat size of 0.5 × 0.5 m before every weeding according to the treatments. The samples collected from each plot were pulled together, weighed and recorded as weed dry matter production. The samples taken from each plots, at various weeding periods were cumulatively added to determine total weed dry matter.

Data collected on mango ginger include: crop vigour score, which is a visual rating from 1 – 5 (where 1 means poor growth and 5 means vigorous growth), plant height, stand count at harvest, rhizome length, number of rhizome and rhizome yield. Data collected on weed include: weed dry matter production and weed cover score, which is a visual rating from 10 to 100, according to Osunleti et al., 2021. Data collected were subjected to Analysis of Variance (ANOVA) according to the procedures of GENSTAT. Significant means were separated using Duncan's Multiple Rage Test at 5% level probability

Results

Plant Growth

Location in which the trial was carried out had no significant effect on crop vigour score, while weed interference period had significant effect of crop vigour score throughout the period of observation (Table 3). At 8 WAP, keeping mango ginger weed free for 8 weeks and more as well as those kept weed infestation for only 4 weeks resulted in significantly higher crop vigour than keeping mango ginger weed infested for 8 weeks and more. Weed free situation for only 4 WAP, resulted in significantly higher crop vigour than weed infestation periods for 8 weeks and more. At 12 WAP, plots kept weed free for 12 WAP and more and those weed infested for 4 WAP, produced significantly higher crop vigour than initial weed free situation for 4 and 8

Table 3: Effect of location and weed interference period on crop vigour score of mango ginger

Treatments	Crop Vigour Score			
	8 WAP	12 WAP	16 WAP	20 WAP
Location (L)				
Ibadan	2.6	3.0	3.0	3.0a
Ikenneh	2.6	3.0	3.0	2.8b
SE(±)	0.00982ns	0.01964ns	0.00982ns	0.00982
Weed Interference Period (W)				
Weed Free 4WAP	2.0a	1.0d	1.0e	1.0e
Weed Free 8WAP	4.0a	4.0b	4.0c	3.5c
Weed Free 12WAP	3.9a	4.9a	5.0a	5.0a
Weed Free 16WAP	4.0a	4.9a	4.9b	4.9b
Weed Free 20WAP	4.0a	5.0a	5.0a	5.0a
Weed Free Throughout	4.0a	5.0a	5.0a	5.0a
Weed Infested 4WAP	4.0a	5.0a	5.0a	5.0a
Weed Infested 8WAP	1.0d	2.0c	2.0d	1.5
Weed Infested 12WAP	1.0d	1.0d	1.0e	1.0e
Weed Infested 16WAP	1.0d	1.0d	1.0e	1.0e
Weed Infested 20WAP	1.0d	1.0d	1.0e	1.0e
Weed Infested Throughout	1.0d	1.0d	1.0e	1.0e
SE(±)	0.02406	0.03244	0.02406	0.02406
Interaction				
L x W	ns	ns	ns	0.09695

WAP, as well as weed infestation for 8 WAP and more. At 16 and 20 WAP, keeping plots weed free for 12 WAP and more as well as weed infestation for 4 WAP resulted in significantly higher crop vigour score than initial weed free for 4 and 8 WAP, as well as weed infestation for 8 WAP and more (Table 3). At 16 WAP in both locations, weed free periods for 12 WAP and beyond, as well as weed infestation for 4 WAP only resulted in significantly higher crop vigour score than weed infestation periods from 8 WAP and more in both locations (Figure 1).

Location and weed interference periods had significant effect on plant height throughout the period of observation (Table 4). Throughout the period, mango ginger planted in Ibadan are taller in height compared to those planted in Ikenne. At 8 WAP, plots kept weed free for 8 WAP and more produced taller plants than initial weed free situation for 4 WAP and weed infestation for 8 WAP and more. At 12 WAP, keeping weed free for 12 WAP and more produced taller plants than various weed infestation periods and initial weed free situation for up to 8 WAP. At 12 WAP, weed free situation for 12 WAP and more, produced taller plants than weed infestation for various periods. Also at 12 WAP, weed infestation for only 4 WAP, produced taller plants than weed infestation for other periods and weed free for 4 WAP. At 16 and 20 WAP, weed free situation for 20 WAP and more produced taller plants than various weed infestation period and those weed infested up to 8 WAP. At 20 WAP there was height reduction with increase in weed infestation periods, while the tallest plants was recorded on plots kept weed free throughout (Table 4). At 20 WAP, weed free periods for 8 WAP and beyond in Ibadan, as well as weed infestation for 4 WAP in Ibadan resulted in taller plants than weed infestation periods from 8 WAP and more in both locations as well as weed free period for 4 WAP in both location (Figure 2).

Taller plants observed in Ibadan could be attributed to more fertile soil in Ibadan compared to Ikenne as shown in the physic chemical properties of the soil. This implies that mango ginger thrives well in a well fertile soil. Uninterrupted weed infestation for the first 8 weeks in this

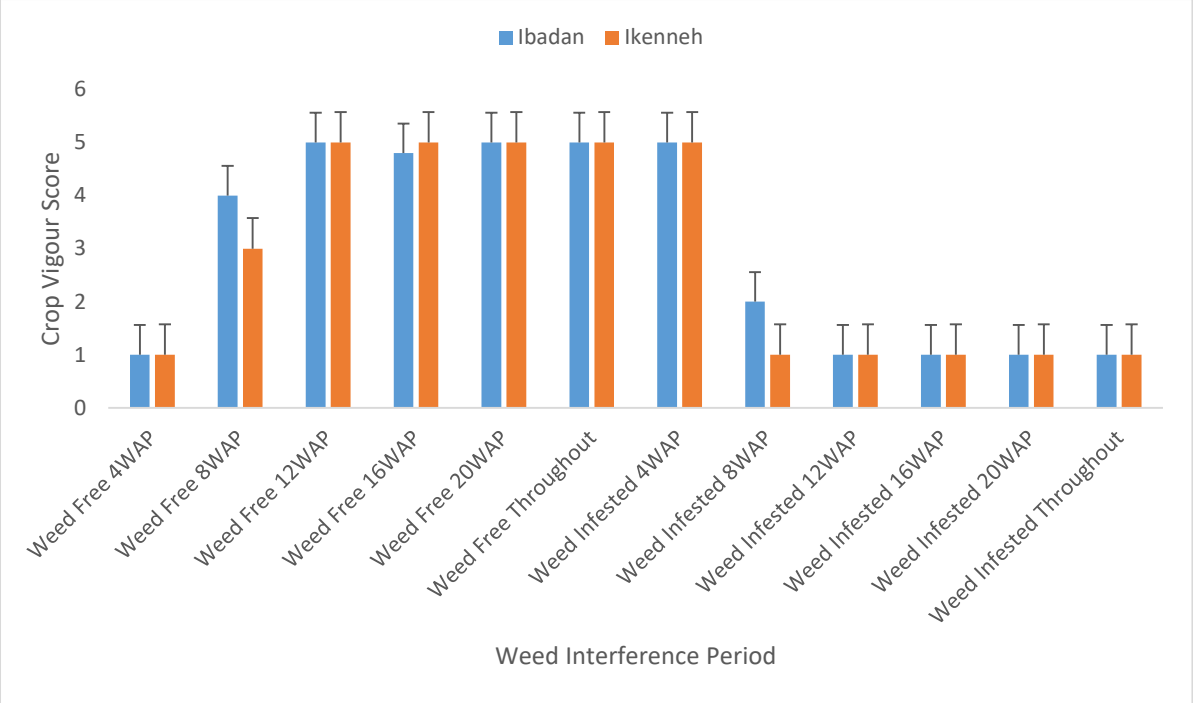

Figure 1: Interaction of location and weed interference period on crop vigour score at 16 WAP

Table 4: Effect of location and weed interference period on height of mango ginger

Treatments	Plant Height (cm) 8 WAP	12 WAP	16 WAP	20 WAP
Location (L)				
Ibadan	46.6a	58.3a	63.9a	66.8a
Ikenneh	31.0b	37.4b	44.0b	47.9b
SE(±)	0.285	0.352	0.091	0.0241
Weed Interference Period (W)				
Weed Free 4WAP	31.8c	46.1e	48.4e	50.8f
Weed Free 8WAP	51.8b	58.7d	65.0d	70.7e
Weed Free 12WAP	51.3b	64.5b	72.7b	76.8cd
Weed Free 16WAP	51.9b	64.9b	73.5b	77.3bc
Weed Free 20WAP	52.1b	64.8b	73.0b	77.6b
Weed Free Throughout	54.8a	66.7a	75.7a	81.5a
Weed Infested 4WAP	50.9b	62.3c	48.4e	76.3d
Weed Infested 8WAP	24.1d	37.2f	42.5f	44.9g
Weed Infested 12WAP	24.6d	28.2g	33.5g	35.9h
Weed Infested 16WAP	24.4d	28.1g	32.9g	34.7i
Weed Infested 20WAP	24.7d	27.4g	32.3g	33.9j
Weed Infested Throughout	23.5d	25.6h	27.3h	28.4k
SE(±)	0.413	0.478	0.412	0.2761
Interaction				
L x W	0.627	0.737	0.565	0.3747

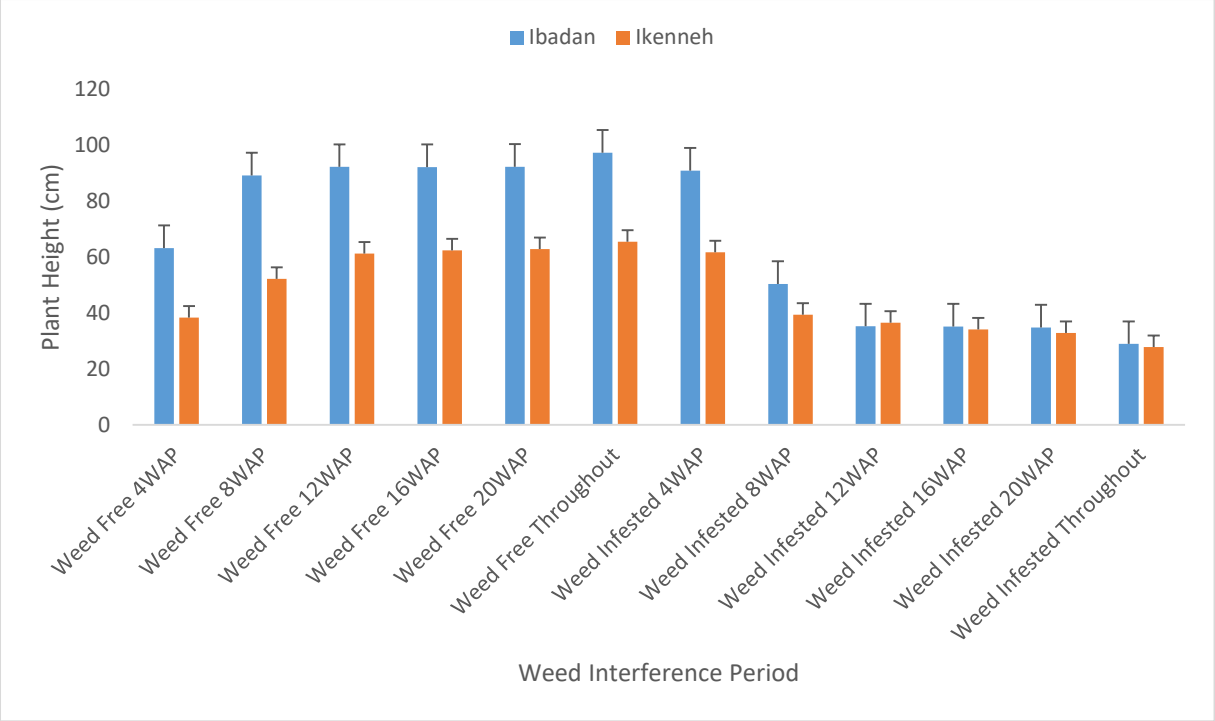

Figure 2: Interaction of location and weed interference period on plant height at 20 WAP

study caused significant reduction in mango ginger's vigour and height. Similarly, subsequent weed infestation, after the initial weed free for 8 weeks also reduced crop growth. This implies that mango ginger is very sensitive to weed infestation. Weed has been reported by several researchers to compete with crop for light, soil nutrients and moisture. Also, weed harbour insect pest, while some exhibit allelopatic effect thereby affecting the growth negatively (Osunleti et al., 2022; 2023; KAU 2006).

Harvest Parameters

At harvest, location had significant effect of stand count, number of rhizome per plant and rhizome yield with those planted in Ibadan having higher values. Weed interference period had significant effect on all the data collected at harvest. While the lowest stand count was recorded on plots left weed infested throughout, the highest number of stand count was recorded on the plots kept weed free throughout, followed by weed free situation for 20 WAP. The longest and shortest rhizome was recorded on the plots kept weed free throughout and those left weed infested throughout, respectively. Weed infestation for 8 WAP and more, produced shorter rhizome than corresponding weed free period. The highest number rhizome was recorded with weed free situation throughout crop life cycle, while the lowest rhizome count was recorded with weed infestation for 8 WAP and beyond. Weed infestation for only 4 weeks produced significantly higher number of rhizome than weed free 4 and 8 WAP. The highest and lowest rhizome yield was recorded on the plots kept weed free throughout and those left weed infested throughout, respectively. Keeping plots weed free for 20 WAP resulted in significantly higher yield than various weed infestation periods and those kept weed free for 12 WAP and below. Also, plots kept weed free for 12 and 16 WAP resulted in significantly higher rhizome yield

than various weed infestation periods and those weed free for 4 and 8 WAP (Table 5). Keeping plots weed free for only 4 WAP and those left weed infested for 12 WAP and more in both locations resulted in the lowest rhizome yield. Rhizome yield in both locations increase with increase in weed free periods with the highest yield recorded in Ibadan when plots were weeded throughout crop life cycle (Figure 3). Along the weed free curve, the highest yield accumulation of 51.9% was recorded between 4 and 8 WAP. While along the weed infestation curve, the highest yield loss of 46.3% was recorded between 4 and 8 WAP (Figure 4). Uncontrolled weed infestation throughout the season caused 88.6% yield reduction.

Stands of mango ginger reduce with increased in period of weed infestation, and increase with weed free period. Mango ginger is a slow growing crop initially, this give weed an advantage over the crop, overtaking the crop and forming canopy over the crop. The weed canopy obstruct light getting to the crop, thereby reducing crop vigour and leading to crop death when the situation is prolonged. This result corroborates earlier report of Eshetu and Addisu (2015) who reported less ginger stands as a result of weed infestation.

Higher yield and yield components recorded in Ibadan could be ascribed to the optimum environment the soil provided for the crop. The soil is Ibadan is more fertile than that of Ikenne as shown in the soil physic chemical table. Also, the soil in Ibadan is lighter than that of Ikenne in terms of the bulk density. Mango ginger rhizome penetrates well in loosed soil. Furthermore, higher weed infestation recorded in Ikenne could be also responsible for the lower yield at the location. Higher rhizome yield on the weed free plots compared to weed infested plots could be attributed to lesser or no weed-crop competition or interaction on the weed free plots. This enables the crops on the weed free plots to maximize the environmental resources available to them. This was evident in the growth parameters as well as the yield. Our results also showed that, the more the weed free period, the more the rhizome yield. Weed infestation for up to 8 WAP caused 66.4% reduction in rhizome yield, while there was additional 18.3% reduction in

257 Table 5: Effect of location and weed interference period on yield and yield component of
258 mango ginger

Treatments	Stand Count at Harvest (x 000/ha)	Rhizome Length (cm)	Number of Rhizome Per Plant	Rhizome Yield (t/ha)
Location (L)				
Ibadan	70.3a	8.328	7.9a	11.7a
Ikenne	66.1b	7.719	7.6b	11.2b
SE(±)	0.0196	0.1577ns	0.0708	0.055
Weed Interference Period (W)				
Weed Free 4WAP	28.5h	5.2f	3.8f	3.5g
Weed Free 8WAP	96.0d	8.1e	9.7d	15.4e
Weed Free 12WAP	99.0c	11.4c	11.5bc	19.2c
Weed Free 16WAP	99.0c	11.7bc	11.8b	19.4bc
Weed Free 20WAP	99.5b	11.9b	11.7bc	19.5b
Weed Free Throughout	101.0a	12.5a	13.7a	22.9a
Weed Infested 4WAP	99.0c	10.8d	11.2c	18.3d
Weed Infested 8WAP	77.0e	5.5f	5.0e	7.7f
Weed Infested 12WAP	34.0f	5.1f	3.8f	3.5g
Weed Infested 16WAP	33.5g	5.1f	3.8f	3.2gh
Weed Infested 20WAP	33.5g	5.1f	3.3f	3.0h
Weed Infested Throughout	18.8i	4.0g	3.3f	2.6i
SE(±)	0.0481	0.1471	0.1765	0.0952
Interaction				
L x W	0.0680	0.2541	0.2492	0.1402

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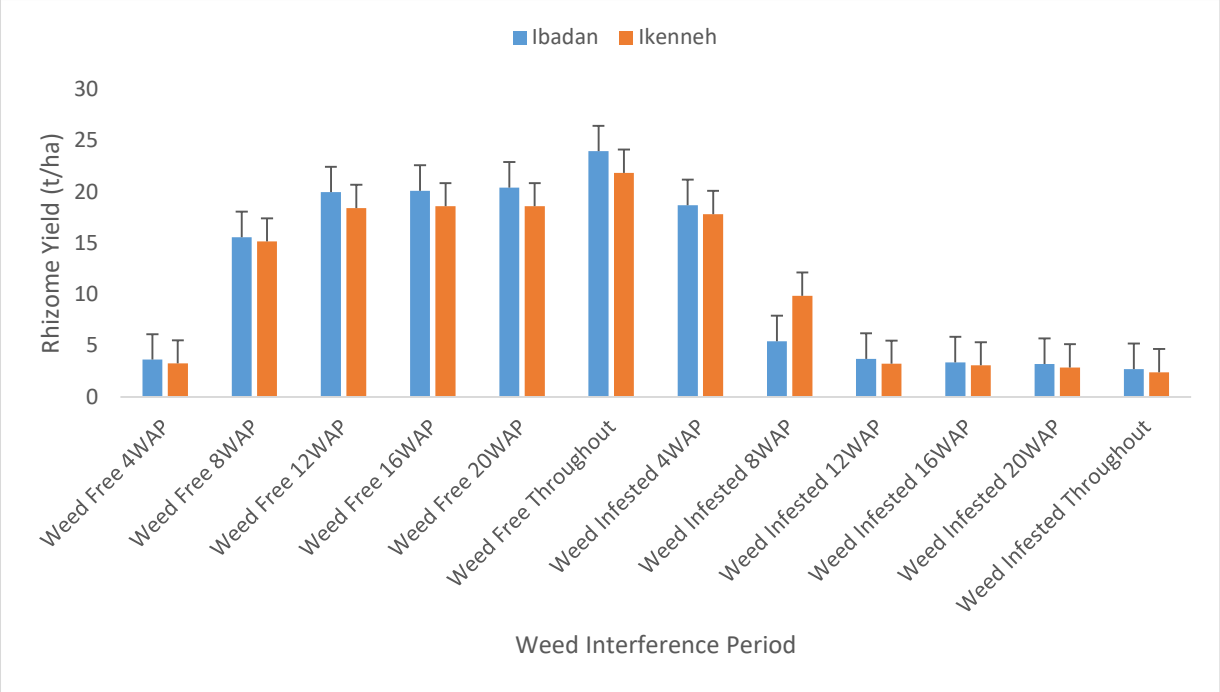

Figure 3: Interaction of location and weed interference period on rhizome yield

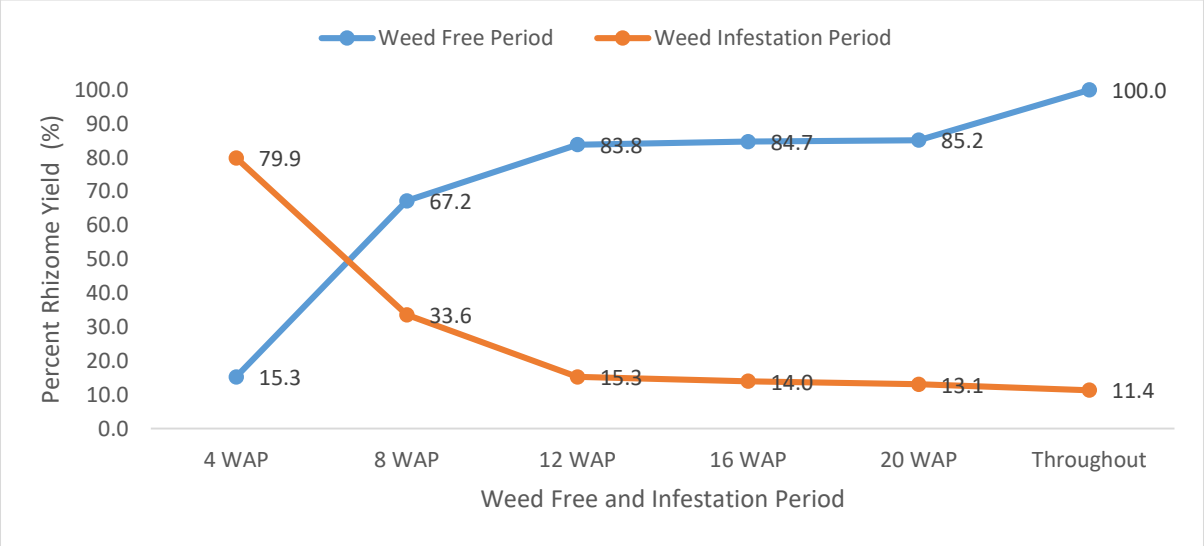

Figure 4: Effect of period of weed infestation and removal on percent yield in both locations

yield when mango ginger was left weed infested till 12 WAP. This further confirm how vulnerable mango ginger is to weed infestation. This results is similar to earlier report of Salawudeen (2017), who reported notable reduction in yield of mango ginger as a result of prolong weed infestation. Osunleti et al., 2023 also reported 53% reduction in the yield of mango ginger when weeding stops at 12 weeks after planting.

Weed Parameters

Weed interference period had significant effect on weed cover score throughout the period of observation. At 8 WAP, leaving plots weed infested for 8 WAP and more resulted in significantly higher weed cover score than various weed free periods and those weed infested for 4 WAP (Table 6). At 12 WAP, keeping plots weed free for 4 WAP only and weed infestation for 12 WAP and more resulted in significantly higher weed cover score than weed free for 8 WAP and more and those weed infested for 4 and 8 WAP. At 16 and 20 WAP, plots left weed infested for 20 weeks and beyond resulted in significantly higher weed cover than keeping plots weed free for at least 8 WAP and weed infestation for 16 WAP and below (Table 6).

Location had significant effect on weed dry matter production throughout the period of observation with higher values recorded in Ikenne (Table 7). At 4 WAP, significantly higher weed dry matter was recorded on plots left weed infested for various periods than those on plots kept weed free for various periods. At 8 WAP, weed infestation for 8 WAP and more resulted in significantly higher weedy matter than those kept weed free for 8 WAP and more. At 12 WAP, plots left weed infested for 12 WAP and more produced significantly higher weed dry matter than plots kept weed free for 12 WAP and those kept weed infested initially for 4 and 8 WAP. At harvest and total weed weight, the lowest and highest weed dry matter production was recorded on plots kept weed free throughout and those left weed infested

293 Table 6: Effect of location and weed interference period on weed cover score in mango
294 ginger

	Weed Cover Score			
Treatments	8 WAP	12 WAP	16 WAP	20 WAP
Location (L)				
Ibadan	30.4	31.7	40.3	43.8
Ikenneh	31.0	34.2	40.7	44.2
SE(±)	0.547ns	0.295ns	0.295ns	0.170ns
Weed Interference Period (W)				
Weed Free 4WAS	25.8c	45.0a	73.3b	84.2c
Weed Free 8WAS	16.7e	28.3b	42.5d	60.0d
Weed Free 12WAS	19.2de	17.5c	33.3e	45.0e
Weed Free 16WAS	19.2de	17.5c	15.0g	29.2f
Weed Free 20WAS	17.5de	16.7c	15.0g	10.0i
Weed Free Throughout	20.0d	17.5c	15.0g	10.0i
Weed Infested 4WAS	27.5c	26.7b	25.0f	20.0h
Weed Infested 8WAS	41.7b	30.0b	25.0f	25.0g
Weed Infested 12WAS	45.8a	48.3a	25.0f	25.0g
Weed Infested 16WAS	45.0a	50.0a	66.7c	25.0g
Weed Infested 20WAS	45.0a	50.0a	73.3b	94.2b
Weed Infested Throughout	45.0a	47.5a	76.7a	100.0a
SE(±)	0.885	1.966	1.023	0.589
Interaction				
L x W	ns	ns	ns	ns

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Table 7: Effect of location and weed interference period on weed dry matter production in mango ginger

Treatments	Weed dry matter production (kg/ha) 4 WAP	8 WAP	12 WAP	Harvest	Total
Location (L)					
Ibadan	78.4b	91.7b	101.0b	63.3b	334.5b
Ikenneh	91.2a	183.9a	156.9a	87.9a	520.1a
SE(±)	0.0786	0.0393	0.0393	0.0196	0.1375
Weed Interference Period (W)					
Weed Free 4WAP	75.8f	160.7f	176.2d	228.2b	640.8b
Weed Free 8WAP	76.5de	79.0h	69.5e	54.0c	279.0g
Weed Free 12WAP	77.0d	78.5i	61.5h	38.0h	255.0i
Weed Free 16WAP	77.0d	78.5i	61.5h	39.5f	256.5h
Weed Free 20WAP	76.5de	78.5i	61.5h	37.5i	254.0j
Weed Free Throughout	76.0ef	72.5j	56.0i	25.5j	230.0l
Weed Infested 4WAP	93.0bc	79.5g	62.0g	16.5k	251.0k
Weed Infested 8WAP	93.5ab	200.5e	63.0f	16.0l	373.0f
Weed Infested 12WAP	92.5c	202.0d	228.5c	39.0g	562.0e
Weed Infested 16WAP	94.0a	203.0b	228.5c	40.5e	566.0c
Weed Infested 20WAP	92.5c	202.5c	229.0b	41.0d	565.0d
Weed Infested Throughout	93.5ab	219.0a	250.5a	332.0a	895.0a
SE(±)	0.1925	0.0962	0.0962	0.0481	0.3368
Interaction					
L x W	0.2722	0.1361	0.1361	0.0680	0.4763

throughout, respectively. On the total weed dry matter, there was significant increase in weed dry matter with increase in period of weed infestation and significant decrease in weed dry matter with increase in period of weed removal (Table 7). The highest removal of 40.4% and was recorded between 4 and 8 WAP (Figure 5). The highest weed dry matter production was recorded in Ikenne on plots kept weed infested throughout crop life cycle (Figure 6).

The higher weed dry matter production in Ikenne compared to Ibadan could be attributed to higher rain fall at Ikenne. Rapid weed growth caused by favourable meteorological circumstances, such as temperature, rainfall, and relative humidity, was also documented by Adigun et al. (1992). There is reduction in weed accumulation with increase in duration of weed free situation. Conversely, there in increase in weed accumulation with increase in weed infestation period. The findings support those of Korav et al., 2018 and Osunleti et al., 2022 who found that as the length of the weed interference period increased, the biomass accumulation of weeds increased.

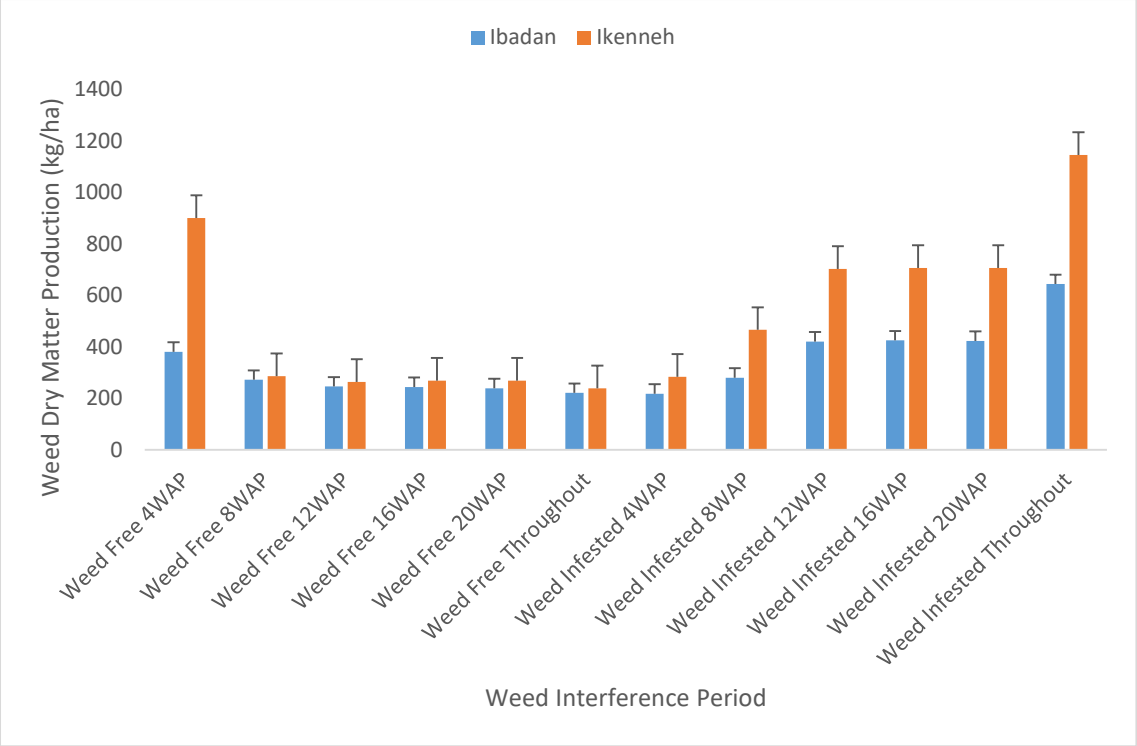

Figure 5: Interaction of location and weed interference period on weed dry matter production at 20 WAP.

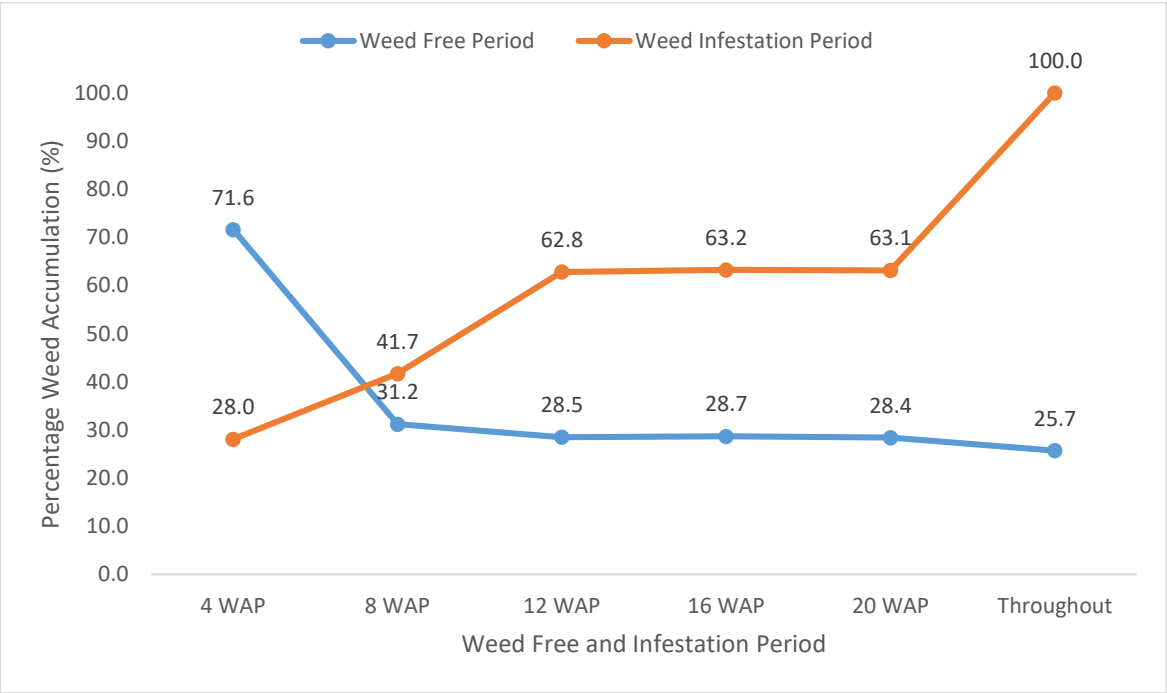

Figure 6: Effect of period of weed infestation and removal on weed accumulation in both locations

Conclusion

The highest weed accumulation and removal in this trial occurred between 4 and 8 weeks after planting. Similarly, the highest mango ginger yield gain and loss occurred between 4 and 8 weeks after planting, which makes the period critical during the life cycle of the crop. Further weed free period in mango ginger till 12 weeks after planting ensure at least 80% yield gain. Therefore for acceptable yield in mango ginger, the crop should be kept weed free for the first twelve weeks.

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