International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 3 (8), pp. 610-614, October, 2013. Available online at www.internationalscholarsjournals.org

Full Length Research Paper

Critical period of weed interference in okra (*Abelmoschus esculentus* (L.) Moench) in a humid forest and Rainforest-Savanna transition zones of Eastern and Western Nigeria: A Review

Imoloame EO

Kwara State University, Malete, P.M.B. 1530, Ilorin, Nigeria.
E-mail: oyaimoloame@yahoo.com or emmanuel.imoloame@kwasu.edu.ng

Accepted 19 August, 2013

Data for this review were obtained from the research conducted in Owerri, in the humid forest zone of Nigeria (latitudes 5^{0}20'N and 5^{0}27'N and between longitudes 7^{0}E and 7^{0}07'E) in 2007 and 2008, in Ibadan (latitude 7^{0}23'N, longitude 3^{0}53'E) and Ogbomosho (latitude8^O 8'N; longitude 4^O 16'E) in the rainforest – savanna transition ecological zones. The objective was to determine the critical period of weed control in okra. In both humid forest and rainforest – savanna transition ecological zones, the critical period of weed control was observed to be between 2 weeks after sowing (WAS) and harvest. However in areas dominated by *Tithonia diversifolia* weeds in the forest-savanna transitional zone, the critical period of weed control in okra was observed to be between 2 and 4 WAS during the rainy season and only one hoe weeding at 2 (WAS) in the dry season was enough.

Key Words: Critical period, weed interference, okra, weed control, Nigeria.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L) Moench) is one of the most important vegetables grown in Nigeria. It is a member of the plant family *Malvaceae* cultivated in all agro-ecological zones in Nigeria for its immature fruits and leaves consumed as vegetable. It is produced predominantly by peasant farmers usually in home gardens or in mixture with other cereal crops (Lombin et al., 1988). Okra seeds contain about 20% protein and 20% oil (Siemonsma and Hamon, 2002). The fruits are exported by some African and Caribbean countries to Europe and America where there is ready demand from the resident ethnic groups from tropical and sub-tropical countries including Indians, West Africans, Pakistanis etc. (A3detola and Denton, 2003). The world production of Okra as fresh fruit vegetable is estimated at 6 million tonnes per hectare (Iyagba et al., 2012).

One of the main problems that affect yield and quality of crops is weed interference and their competition with the crop (Hager et al., 2002). Weeds in okra must be controlled up to 9 weeks after planting (Adejonwo et al., 1989). The cumulative effects of weeds on crop production eventually lead to crop losses due to weed activities including competition, allelopathy, acting as alternative host to pests and pathogens, adulteration of farm produce etc. Comparing fruit yield on uncontrolled weed plot to plastic mulch plot, Olabode et al., (2006) reported 85% loss in the Southern Guinea savanna. Uncontrolled weed growth had resulted in yield losses ranging from 40% (Akobundu, 1987) to 97% (Olabode et al., 1999) in Maize, 91% in sweet potato (Akobundu, 1987) and 80% respectively in a yam/maize/okra/sweet potato intercropping system (Orkwor,1990).

The critical period of weed control (CPWC) is a key component of an integrated weed management (IWM) programme. It is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses (Knezevic et al., 2002). Field research studies suggest that critical period for weed control within a crop is influenced by season, soil condition, weed species, weed density, location and management practices (Holloway and Shaw, 1996; Kropff et al., 1992; Miller and Hopen, 1991; Mulugeta and Boerboom, 2000; Stoller et al., 1987; Van Acker et al., 1993b). It has been reported that the critical period of weed competition in okra occurred between 3 and 7 WAS (William and Warren, 1975). Adejonwo et al. (1989), reported that keeping the crop weed free until 3 WAS depressed growth and yield of okra due to the adverse effect of subsequent weed infestation while weed infestation until 3 weeks after sowing (WAS) and there after keeping the plots weed-free had no adverse effect on okra plants. The study of critical period of weed interference (CPWI), involves two components. The weed free to weedy component determines the duration that weed control efforts must be maintained to prevent crop yield loss from weeds emerging later. The weedy to weed free component determines the length of time that weeds emerging with a crop can remain before reducing his yield. Most farmers are unaware of the right time to weed their crops in Nigeria. This could result in untimely weeding which will likely lead to poor weed control and low yields. A review of research carried out on CPWI will help to provide comprehensive information to farmers in the humid forest and the rain forest-transitional zones of eastern and western Nigeria, on the right time to weed okra and also enable the development of cost-effective weed management strategies for effective weeding and higher crop yields.

The objective of this paper is to review works on the CPWI in a humid forest and rainforest-savanna transition ecological zones in okra in order to facilitate the development of an appropriate and efficient weed control measure and its timely application.

MATERIALS AND METHOD

Table 1, represents the research carried out by Iyagba et al. (2012). It had 45 treatments consisting of three varieties of okra, namely, NHAe47-4, Lady's finger and V35, a weedy check, regular weeding up to 5WAS, weed infested for 3WAS, weed infested for 4WAS and weed free treatment. Treatments were laid out in a split plot design with variety allocated to the main plot, while weeding regime was allocated to the sub plot. The treatments were replicated three times. Data collected were subjected to analysis of variance (ANOVA) and means were compared using the Duncan's Multiple Range Test (DMRT) at a probability level of 5%.

In Table 2 and 3 representing the research conducted by Awodoyin and Olubode (2009), there were two sets of treatments carried out in a randomized complete block design and replicated three times. In first set of treatments, the plot was kept free of weeds for the first 2, 4, 6 and 8 weeks after planting (WAP) and subsequently weed-infested (weed-free-weedy WF-WD) till harvest to determine when emerging weeds would no longer reduce the crop performance. In the second set of treatments, weeds where permitted to grow with the crops for an increasing length of time as listed above and subsequently weed free (weedy-weed free, WD-WF) to determine when weeds emerging with crops began to suppress the growth of crops and reduce the yield. Season-long weed free (WD-0-WF) and weedy (WF-0-WD) treatments served as checks to compare other treatments and asses the crop yield loss due to uncontrolled associated weeds. The treatments were laid out in randomized complete block design (RCBD) and replicated three times. Data were subjected to analyses of variance (ANOVA) and means were separated using the least significant difference (LSD) at 5% level of probability.

In the study carried out by Olabode et al. (2012), as represented in Table 4, there were 10 treatments divided into 2 schemes. In the first scheme were: weed free conditions for only 2, 4, 6 and 8 WAP each followed by weed infestation till harvesting. The control treatment for this scheme is clean weeding (no weed infestation). In the second scheme, the treatment were: *tithonia* weed infestation for only the first 2, 4, 6 and 8 WAP each followed by clean weeding till harvesting. The control of the scheme is no weeding. The treatments were laid out in a randomized complete block with three replications. Data collected were subjected to analysis of variance and means were compared using the least significant difference (LSD)

RESULTS AND DISCUSSION

Effect of weed interference on growth and yield of okra in Owerri, in the humid forest

Table 1, presents the effect of weed interference on growth and yield of okra in Owerri, Nigeria (Iyagba et al., 2012). It was observed that in 2007, okra plant height was significantly highest under weed-free until harvest compared with the rest of the treatments which produced significantly lower plant height. The same trend was observed in 2008, however, weed infested for 3 WAS produced significantly higher and comparable plant height with weed-free till harvest. The other treatments produced significantly shorter plants with weedy check producing significantly the shortest plants. The leaf area of okra under weed-free until harvest was significantly larger than that of other treatments but comparable with the leaf area under weed infested for only 3 WAS in both years. The other treatment produced significantly smaller leaf area in both years.

In both years, weed-free until harvest resulted in significantly higher fresh fruit weight/plant compared with the other treatments which produced significantly lesser fresh fruit weight per plant. Similarly, in both years, weed free until harvest produced significantly highest okra fruit yield per hectare which was comparable only with weed infested for only 3 WAS. The other treatments produced significantly lower yields.

The significantly shorter plants and smaller leaf area re-

Table 1. Effect of weed interference on growth parameters and yield of okra in Owerri, Nigeria.

TREATMENT	PLANT HEIGHT AT HARVEST		LEAF AREA/PLANT (cm^2)		FRESH FRUIT WEIGHT/PLANT (g)		FRUIT YIELD (t ha^1)	
	2007	2008	2007	2008	2007	2008	2007	2008
Weedy check	33.8c	33.6bc	18.2b	17.9b	1.08d	1.05d	6.72d	6.24c
Weed infested for 3WAS	61.0b	60.4a	34.6a	33.8a	18.06b	17.26b	22.16a	20.43a
Weed infested for 4WAS	37.16c	36.7b	29.9b	28.4ab	14.79b	13.98b	13.98b	13.73b
Weed free until 5WAS	46.9b	46.2b	22.1b	20.7b	3.80c	10.24c	10.24c	9.54c
Weed free until harvest	69.2a	48.8a	38.2a	36.2a	21.21a	24.20a	24.20a	22.12a
Mean	49.6	49.14	28.6	27.4	11.79	15.46	15.46	14.41
SE (±)	15.20	13.55	8.4	9.79	8.98	7.53	7.53	6.11

Source: Iyagba et al. (2012).
1 = means that have the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiples Range Test (DMRT).

Table 2. Effect of period of weed interference on the plant height of okra at Ibadan, Nigeria.

Period of Interference	Plant Height (cm)/plant 2006	2007	Treatment Mean
Wf-2-wd	56.7cd± 2.6	60.5ce± 0.6	58.6cd
Wf-4-wd	60.3cd± 3.5	64.8ce± 1.9	62.5bc
Wf-6-wd	66.8bc± 3.7	69.5bc± 4.1	68.2b
Wf-8-wd	68.4bc± 4.5	66.5bcd± 5.9	67.4b
Weed-free till harvest (wd-O-wf)	84.3a± 2.7	79.2ab± 10.5	81.8a
Wd-2-wf	78.3ab± 3.4	85.8a± 5.8	82.1a
Wd-4-wf	66.9bc± 2.8	72.8bc± 4.4	69.8b
Wd-6-wf	50.3±2. 4cd	65.2cde± 2.3	57.8cd
Wd-8-wf	49.4d± 3.1	54.2±5. 1de	51.8d
Weedy till harvest (wf-O-wd)	48.6d± 3.2	52.8±2. 4e	50..9d
Year mean	63.0	67.1	

Source: Awodoyin and Olubode (2009).
The LSD (0.05) to compare year means = 2.3, over all treatment means = 9.0, treatment means (in year) = 12.77. CV (year) = 3.2%; CV (treatment) = 11.8%.
Wf-n-wd = weed-free for n weeks after planting and subsequently weedy till harvest.
Wd-n-wf = Weedy for n weeks after planting and subsequently weed-free till harvest.

corded under weed infested for 4 WAS, weed-free at 5 WAS and the weedy check could be as a result of weed competition with okra plant for light, nutrients and sunlight which probably led to reduction in plant height and leaf area. Both weed-free until harvest and weed infested for only 3WAS resulted in significantly higher fresh fruit weight/plant and fruit yield per hectare compared to other treatments. This could have resulted from the significantly taller plants and larger leaf area of these treatments which produced the required amount of dry matter for higher yield. The above results show that the critical period of weed interference is between 3 WAS and weed free until harvest. The result is in line with the findings of Adejonwo *et al*. (1989) that keeping the crop weed free until 3WAS depressed growth and yield of okra due to the adverse effect of subsequent weed infestation, while weed infestation until 3 WAS and thereafter keeping the plots weed-free had no adverse effect on okra plants.

Table 3. Effects of period of weed interference on the total number of marketable fruits pr plant of okra at Ibadan, Nigeria.

Period of Interference	Total Number of Marketable Fruits /Plant		
	2006	2007	Treatment Mean
Wf-2-wd	8.3e±1.2	9.1±0.7e	8.7g
Wf-4-wd	11.6e±1.9	12.4±0.9d	12.0fg
Wf-6-wd	20.7c±2.4	22.1±1.0bc	21.4cd
Wf-8-wd	23.0abc±2.8	23.2±1.9bc	23.1bc
Weed-free till harvest (wd-O-wf)	30.3a±2.8	30.5±2.4a	30.4a
Wd-2-wf	29.0ab±2.5	25.3±2.8ab	27.2ab
Wd-4-wf	18.3cd±3.7	18.5±2.3cd	18.4de
Wd-6-wf	13.7de±2.4	16.1±2.1cd	14.9ef
Wd-8-wf	11.7e±0.6	11.3±1.9e	11.5fg
Weedy till harvest (wf-O-wd)	9.3e±2.1	9.3±1.2	9.3g
Year mean	17.6	17.8	

Source: Awodoyin and Olubode (2009)

The LSD (0.05) to compare year means = 1.4; over all treatment means = 4.3; treatment means (in year) = 6.1. CV (year) = 6.2% CV (treatment) = 20.7%. wf-n-wd = weed free for n weeks after planting and subsequently weedy till harvest wd-n-wf = weedy for n weeks after planting and subsequently weed free till harvest.

Table 4: Effect of season and period of *Tithonia* infestation in the growth of okra in Ogbomoso, Nigeria.

Period of infestation	Plant height(cm)		Leaf area (cm^2)		Fruit yield (kg /ha)	
	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season
Weed free for 2WAP followed by weed infestation	35.2b	24.4b	31.3d	21.9d	0.2b	1.3ab
Weed free for 4WAP	66.2a	35.7a	940.7b	658.5a	3.1a	1.9ab
Weed free for 6WAP	66.2a	35.5a	1047.2ab	732.9a	4.9a	2.5ab
Weed free for 8WAP	71.0a	38.0a	1167.2ab	805.4a	5.4a	2.5a
Weed free for life	72.5a	39.2a	1257.8a	860.5a	5.4a	2.8a
Weed infestation for 2WAP	72.2a	39.0a	1094.6ab	766.2a	5.3a	2.8a
Weed infestation for 4WAP	67.2a	25.5b	529.3c	370.5b	1.2b	1.5a
Weed infestation for 6WAP	34.5b	18.7b	109.5d	75.0c	0.3b	0.0b
Weed infestation for 8WAP	35.2b	19.0b	23.0d	14.8d	0.0b	0.0b
Weed infestation for life	37.7b	18.0b	27.0d	14.5d	0.0b	0.0b
LSD (5%)	8.29		257.40		2.72	

Source: Olabode *et al.* (2010).

Also, it has been reported that the critical period of weed competition in okra occurred between 3 and 7 WAS (William and Warren, 1975).

Effect of weed interference on growth and yield of okra in Ibadan, in the rainforest-savanna transitional ecological zone

The effect of period of weed interference on plant height of okra in Ibadan is presented in Table 2, (Awodoyin and Olubode, 2009). In 2006, weed-free till harvest produced significantly the tallest plant which was comparable to weed infestation for 2 weeks after planting (WAP). The rest of the treatments produced significantly shorter plants with weedy till harvest and 8 WAS producing significantly shorter plants. In 2007 and the combined treatments, similar trend was obtained. Table 3 presents the effects of weed interference on the total number of marketable fruits per plant of okra (Awodoyin and Olubode, 2009). In 2006 and combine mean, weed free till harvest produced significantly highest number of marketable fruits per plant which was only comparable to weed infested until 2 WAS. The rest of the treatments produced significantly lesser number of fruits/plant with weedy check, weed infested till 4WAS producing significantly lowest number of fruits/plant. The same trend was obtained in 2007 and the combined mean.

The above result shows the sensitivity of okra to weed infestation in almost all the stages of growth and development with a prolonged critical period of weed interference. This is similar to the findings of Adejonwo et al. (1989), that weed in okra must be controlled up to 9 WAS.

Effect of season and period of *Tithonia diversifolia* infestation on growth and yield of okra in Ogbomoso, in the rainforest-savanna transition ecological zone

Table 4, presents the effect of season and period of *Tithonia* infestation on growth and yield of okra in Ogbomoso (Olabode et al., 2010). It was observed that weed free for life resulted in significantly tallest plants in both the rainy and dry seasons which was comparable to weed free for 4, 6 and 8 WAS and weed infested for 2 WAS in both seasons and only for rainy season at 4WAP. The rest of the treatments including weed-free at 2 WAP and weed infested for 6 and 8 WAP and weedy infestation for life produced significantly shorter plants in both seasons. Generally plant height of okra was shorter in the dry season than in rainy season. Weed-free for life produced significantly larger leaf area which was comparable to weed free for 6 and 8 WAS and weed infested for 2 WAP during the rainy season. Similar results were observed in the dry season. The fruit yield was significantly higher under weed-free for life, but comparable to weed free for 4, 6 and 8 WAP and weed infestation for 2 WAP in the rainy season. However in the dry season, similar results were obtained except that weed-free at 2 WAP and weed infestation for 4 WAP produced comparable significant higher yields with weed-free for life. The rest of the treatments produced significantly lower yields.

Weed-free for 2 WAP and weed-infested for 6 and 8 WAP produced significantly shorter plants in the rainy season probably as a result of the weed competition with the okra plant for growth factors which lead to shorter plants. Weed-infested for 4 WAP gave significantly taller plants in the rainy season while the opposite was the case in the dry season. This could be as a result of limited supply of moisture during the dry season compared to the rainy season. Weed-free for 2 WAP and weed infestation for 4WAP produced comparable significant higher okra yield comparable to weed-free for life, probably due to low weed dry matter and density occasioned by limited amount of water in the soil in the dry season which reduced weed competition for water and nutrients leading to significantly higher okra yields. The critical period of weed interference in okra in the rainy season under *Tithonia* weed infestation is between 2 and 4 WAP, while the critical period of weed interference during the dry season is 2 WAP.

CONCLUSION

It can therefore be concluded that okra is a crop that is very sensitive to weeds irrespective of whether it was grown in the humid forest or the forest-savanna transition zone. The critical period of weed control in the humid forest and forest-savanna transition zone is between 2WAP and harvest. However the critical period of weed control was affected by weed infestation and season. In the forest-savanna transition zone, the critical weed control in okra under *Tithonia diversifolia* infestation during the rainy season is between 2 and 4 WAP, while it is 2 WAS in the dry season. However in the rainforest-savanna transitional zone of Nigeria under *Tithonia diversifolia* infestation, weed control in okra at 2 and 4 WAS during the rainy season is ideal while only one weed control at 2 WAS during the dry season will suffice.

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