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E-mail: jsae@mouau.edu.ng. Website: www.mouau.edu.ng.

Responses of Okra (*Abelmoschus esculentus* (L.) Moench) Varieties to Photoperiod

[1]A. E. Maduagwuna, [1]J. E Asiegbu, and [2]Onyeonagu, C. C.[*]

[1]Department of Crop Science, University of Nigeria, Nsukka.

[2]Department of Agronomy Michael Okpara University of Agriculture Umudike,Nigeria.

[*]Corresponding Author, e-mail: onyeonagu@yahoo.com

Abstract

In two light controlled experiments, the effects of 8, 10, 12, 14 and 16 hour photoperiods and natural daylength on flowering and pod set in four varieties of okra ('Awgu' early, NHAe47-4, 'Clemson' and 'Nsukka' local) were investigated. The first experiment was conducted between May and July, 1992 (Early season planting) and the second between October 1992 and February 1993 (Late season planting). Each was a factorial experiment set out in a randomized complete block design with three replications. From the results of the investigation, short photoperiods of 8 to 12 hours were generally more conducive to flower production and pod set. The results of experiment 1 conducted from May to July, 1992 when the temperatures were lower compared with the situation between October 1992 and February 1993, showed that 'Nsukka' local was more sensitive to its requirement of short photoperiod of 8 to 12 hours as it failed to attain anthesis or set pod at photoperiods of 12.28 hours and above. 'Awgu' Early and NHAe47-4 were less sensitive since they produced flower buds at 14 and 16 hours but however did not attain anthesis to produce harvestable pod at those long photoperiods. 'Clemson' showed more adaptation to a range of photoperiods as it produced harvestable pods even at 14 and 16 hours of photoperiods. In experiment 2, all the varieties produced flower buds and attained anthesis under both short and long photoperiods, more probably as a result of modifying effects of higher temperatures that occurred during the period of that experiment.

Key words: Okra varieties, pod set, flower buds, anthesis, photoperiod, pod yield

Introduction

Okra (*Abelmoschus esculentus* (L) Moench is a warm season, tropical, subtropical and temperate vegetable crop. Okra is a vegetable widely cultivated among farmers in Nigeria (Omeje *et al*., 2013). In Nigeria, it is grown for its immature edible pods and fresh leaves which are consumed as vegetables in making soup (Omeje *et al*., 2013). Changes in environmental conditions have been reported to influence growth and

development of okra (Katung, 2007).

There are large varietal differences in okra that may be of interest to the producer, the consumer and the breeder. These variabilities may be in growth, yield, maturity (Ikeh *et al*., 2013) and response to daylength (Udengwu, 1998). A better understanding of some of these attributes may help in the choice of varieties and in improving production.

It is now known that many tropical plants respond to even small variations in daylength (Udengwu, 1998). For example, in southern Nigeria, the late season okra, regardless of the date of sowing, does not initiate floral primordia until September when its critical daylength requirement of short-day is provided. It is only then that it flowers and produces pods for harvest.

With advancements made in plant breeding, new varieties of okra have been developed and there is need to understand their biology, including their photoperiodic requirements, in order to enhance good husbandry. Literature search showed that most photoperiodic studies on okra were based on photoperiodic cycles, involving exposure of the plants to a definite photoperiod only for a given short period (Udengwu, 1998). However, it would be of interest to know the effects of growing okra completely in certain chosen photoperiods, especially to study the general plant developmental and yield responses. The current study was therefore conducted to determine the effects of short and long photoperiods, applied throughout the life of the crop, on the flowering and pod set of four okra varieties.

Materials and Methods

Two experiments were performed in controlled Photoperiodic chambers to study the responses of okra to continuous exposure to short and long photoperiods. The experiments were conducted in the Department of Crop Science, University of Nigeria, experimental farm located at Nsukka, latitude 06° 52'N, longitude 07° 24'E, and on an altitude of 447.20 m above sea level.

Experiment I: Flower and pod set responses of okra to continuous short or long photoperiods. This was a poly-bag experiment.

Soil preparation:

The top soil for the experiment was obtained from a location characterized as sandy clay loam, and on which planting had not been made for many years. This was sterilized by heating the moistened top soil to a temperature of 100°C and steaming for 30 minutes, and then allowed to cool for two days. The soil mix made in the proportion of 3 parts of top soil, 2 parts of well rotted poultry manure and I part of river sand by volume. Seventy-two polytene bags each measuring 40 cm x 40 cm x 42 cm were filled with the growth medium and each poly bag contained 10 kg of the mixture.

Photoperodic chamber:

The photoperiodic chambers were constructed to a dimension of 1.5 m x 2 m x 4 m. There were five chambers each being well covered with a black cloth and made more opaque with

further sheeting.

Experimental treatments:

The experimental treatment comprised six light durations (photoperiods) and four varieties of okra. The six photoperiods consisted of 8, 10, 12, 14 and 16 hours of exposure to light per day and one natural daylight treatment. The okra varieties were 'Awgu' Early, 'Clemson', NHAe47-4 and 'Nsukka' local. 'Awgu' Early is an early cultivar with big seeds from Awgu. 'Clemson' is a selection from National Institute of Horticultural Research (NIHORT), Ibadan, characterized by big seed and early maturity. NHAe47-4 is also a selection from NIHORT and characterized by small spiny pods, while 'Nsukka' local is a late maturity variety widely cultivated in Nsukka area, and characterized by long big pods.

The 24 treatment combinations of six photoperiods and four okra varieties were laid out in a randomized complete block design with three replications. Allocation of the photoperiod treatments to the chambers and placement of the varieties within each block in the chamber was by use of table of random numbers.

The seeds of each of the four okra varieties were separately soaked in water overnight to enhance imbibition. Those that floated were discarded since they were regarded as unviable, while the viable ones were planted on 9th May, 1992. Sowing was at the rate of four seeds per bag. In all, there were 18 polytene bags of each okra variety. The plants were thinned down to two plants per bag.

Photoperiod treatment started at 17 days after planting (DAP). The seedling in the poly bags which had been under natural condition were put into the appropriate photoperiod chamber according to the treatment allocation schedule. For the 8 hours photoperiod, the chamber was covered to exclude light as from 2.00 p.m. to 6.00 a.m. the following day; for the 10 hours, it was similarly covered from 4.00 p.m. to 6.00 a.m.; for the 12 hours photoperiod, it was covered from 6.00 p.m. to 6.00 a.m.; and for the 14 hours photoperiod, natural light was extended in the chamber up to 8.00 p.m. by supplementary lighting with fluorescent lamps. The supplementary lighting was calculated at light intensity of 450 fluxes. For the 16 hours photoperiod, supplementary lighting was similarly supplied with electric fluorescent lamp till 10.00 p.m. The natural daylight served as the control. It was never covered with black cloth so that ambient conditions existed. The minimum and maximum temperatures in the chamber were kept, while the ambient air temperatures were obtained from the Crop Science Department agro-meteorological records.

Other cultural operations:

The plants were sprayed against insects especially lady beetles on the 22 days after planting (DAP) with Rogor 40EC at the rate of 20 1/10 ml. The polytene bags were mulched and the plants irrigated uniformly with 800 ml of water per bag whenever it was considered necessary.

Agronomic measurements:

Observations made at 2 days interval included: number of days to first flower bud initiation; number of buds/plant; number of bud abscission/plant; number of days to first anthesis; and number of fruits/plant.

Harvesting of pods:

Each flower was tagged on reaching anthesis. Pod harvest was usually done at 9 days after anthesis using sharp razor. Records were made on the pod: fresh weight (g), diameter (cm) at the widest portion (using vernier callipers), length (cm) of pod and volume of the pod obtained by Archimedes principle technique.

Experiment 2:

Flower and pod set responses of okra to continuous short or long photoperiods.

The experiment was essentially a repetition of experiment 1, except that 'Awgu' Early was not included. Also, while the experiment I was from May to June 1992, experiment 2 was from October 1992 to February 1993. The experiment consisted of six photoperiods and three okra cultivars, and the experimental design was the same as for experiment 1. Soil mix (growth medium) was prepared as in experiment 1.

Planting:

The seeds were sown on 14th October, 1992, at the sowing rate of 4 seeds per bag. Germination started at 3 days after planting (DAP), supplying was made where necessary while thinning to 2 plants per bag was made at the end of germination. Mulching was done and the plants were uniformly watered daily with 800 ml of water per day. Light treatments were imposed on November 5, 1992, at 22 DAP. The techniques employed were as described for experiment 1. Sinilar1y, data collections were as for experiment 1.

Statistical Analysis

All the data were analyzed according to the procedure for a factorial experiment in a randomized complete block design (RCBD) as outlined by Steel and Torrie (1980). Mean separation for significant effects was done using the method of least significant differences (LSD) as described by Obi (1986).

Results

Experiment I was performed between May and July, 1992 when the natural photoperiod for Nsukka was longest and ranged between 12.23 and I2.30 hours (Table 1). The maximum and minimum air temperatures for the growth chambers were on average higher than those for the natural conditions for the period.

Table 1: Total monthly day length and temperature for May, June and July 1992 in Nsukka.

	May	June	July
Mean day length (hours)	12.25	12.30	12.29
Mean maximum daily air temperature (^{0}C)	30.23	28.23	25.94
Mean minimum daily air temperature	21.13	20.83	20.94
Mean Maximum chamber temperature	40.43	37.77	34.72
Mean minimum chamber temperature	21.642	1.34	21.45

Plants grown in 12, 10, 8 hour photoperiods and natural conditions on the average took similar number of days to first flower bud initiation (Table 2). At the long photoperiods of 14 and 16 hours, 'Nsukka' local failed to produce buds while the other varieties produced. In the short photoperiods (8 to 12 hours) and under natural conditions (12.3 hours), 'Nsukka' local produced flower buds although it took much longer days (18-43 days longer) compared with the other varieties. 'Agwu' Early, NHAe47-4 and 'Clemson', produced flower buds under long photoperiods of 14 and 16 hours, however, those buds did not open or develop further to produce fruits. Similarly, the flower bud produced by 'Nsukka' local under the natural condition (12.3 hours) did not open or develop further to form fruit under that condition. 'Clemson' whose flower buds produced in the long photoperiods (14 and 16 hours) reached anthesis although it took much longer days than the other varieties to do so. Days to first anthesis followed this trend with days to first flower bud initiation. The effect of 'Nsukka' local x Natural on the number of days to first flower initiation was significantly ($P < 0.05$) higher than the others. 'Nsukka' local x 8, 10 and 12 hours were not statistically different. 'Clemson x 14 and 16 hours, 'Nsukka' local x 8, 10 and 12 hours were statistically similar for number of days to first anthesis but were significantly higher than the others.

Table 2: Effect of photoperiod on number of days to first flower bud initiation and to first anthesis

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
Days to first flower bud initiation							
'Awgu' Early	27.0	26.5	24.5	25.0	29.7	29.0	27.0
NHAe47-4	27.0	27.7	28.0	27.0	33.0	33.3	28.8
'Clemson'	27.0	27.3	25.0	26.0	33.0	30.6	28.1
'Nsukka' Local	70.0	44.5	44.0	46.0	NB	NB	51.1
Mean	37.8	31.5	30.4		31.9	30.8	33.8
Days to first anthesis							
'Awgu' Early	42.3	43.0	42.7	44.3	NF	NF	43.1
NHAe47-4	52.7	50.7	44.3	50.7	NF	NF	49.6
'Clemson'	42.7	47.7	43.0	41.3	70.0	72.0	44.5
'Nsukka' Local	-	67.3	66.7	72.5	NF	NF	68.5
Mean	45.8	52.2	49.2	52.2	70.0	72.2	51.6

	Flower bud	Anthesis
$LSD_{0.05}$ for 2 photoperiod means	5.2	8.4
$LSD_{0.05}$ for 2 variety means	3.7	5.9
$LSD_{0.05}$ for 2 photoperiod x variety means	10.4	16.8
$^{+}$chamber air temperature (^{0}C)	37.64/21.48	(day/night)
Natural condition temperature	28.03/20.98	(day/night)

* NB = no bud; NF = no flower

The 10 hours photoperiod gave significantly the highest number of flower buds compared with the other photoperiods, within each okra variety (Table 3). Flower bud was not produced by 'Nsukka' local under 14 and 16 hours of photoperiods while the number produced in such long photoperiod with NHAe47-4 was very low. The number produced by 'Nsukka' local under the natural condition was lowest. Percentage

flower bud abortion within the period of the observation (i.e. 70 DAP) was higher from the longer photoperiod. 'Nsukka' local x Natural, produced significantly ($P < 0.05$) the lowest number of buds compared with 'Nsukka' local x 8, 10 and 12 hours photoperiods, which, were statistically similar. 'Agwu' Early and 'Clemson' had similar number of buds across the photoperiods.

Table 3: Effect of photoperiod[+] on the total number of flower buds produced and on percentage flower bud abortion per plant at 70 DAP.

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
Total number of buds							
'Awgu' Early	10.7	11.0	12.5	9.0	8.7	8.3	10.0
NHAe47-4	8.3	11.6	14.7	15.0	2.7	2.7	9.2
'Clemson'	9.7	8.0	13.7	10.7	8.3	8.3	9.8
'Nsukka' Local	1.7	13.7	16.0	11.0	NB	NB	7.1
Percentage flower bud abortion							
'Awgu' Early	30.8	24.5	8.3	41.1	60.9	60.2	37.6
NHAe47-4	15.7	14.7	18.4	20.0	0.0	74.1	23.8
'Clemson'	17.5	21.3	19.7	18.7	48.2	72.3	33.0
'Nsukka' Local	58.8	0.0	0.0	0.0	0.0	0.0	9.8
Mean	30.7	15.1	11.6	20.0	27.3	51.7	23.7

	Total number of buds	Percentage bud
$LSD_{0.05}$ for 2 photoperiod means	3.30	8.70
$LSD_{0.05}$ for 2 variety means	2.60	5.10
$LSD_{0.05}$ for 2 photoperiod x variety means	7.70	17.50
[+]chamber air temperature (^{0}C)	37.64/21.88	(day/night)
Natural condition temperature	28.03/20.98	(day/night)

Dap = Days after planting

NB = no bud

More number of buds were produced between 39 and 45 DAP (Table 4). 'Nsukka' local produced flower buds later than other varieties but it failed to produce flower buds under the long photoperiods of 14 and 16 hours.

Table 4: Effect of photoperiod on number of flower buds produced in four okra varieties at various stages of plant growth

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
27 DAP							
'Awgu' Early	3.8	4.3	4.7	1.7	NB	NB	3.6
NHAe47-4	2.7	NB	2.2	2.2	NB	NB	2.4
'Clemson'	1.8	1.3	4.3	4.3	NB	NB	2.9
'Nsukka' Local	NB	NB	NB	NB	NB	NB	NB
Mean	2.8	2.8	3.7	2.7	NB	NB	3.0
39 DAP							
'Awgu' Early	1.6	0.7	1.5	2.7	2.8	2.6	1.5
NHAe47-4	3.2	4.0	3.3	3.2	0.2	0.3	2.4
'Clemson'	0.7	3.0	0.5	0.7	3.2	2.3	1.7
'Nsukka' Local	NB	NB	NB	NB	NB	NB	NB
Mean	1.8	2.6	1.8	2.2	2.1	1.7	1.9
45 DAP							
'Awgu' Early	2.0	1.0	0.7	1.3	1.2	2.7	1.5
NHAe47-4	1.7	2.1	2.8	2.6	0.3	0.1	2.9
'Clemson'	0.5	1.7	0.1	0.3	0.8	2.7	1.0
'Nsukka' Local	NB	5.7	5.3	4.3	NB	NB	5.1
Mean	1.4	2.6	2.2	2.1	0.8	1.8	2.6
70 DAP							
'Awgu' Early	3.0	5.1	5.1	2.3	4.7	3.0	3.9
NHAe47-4	2.7	5.3	5.7	7.0	2.2	2.3	4.2
'Clemson'	4.7	2.0	8.8	5.4	3.9	3.3	4.7
'Nsukka' Local	1.7	8.0	9.7	6.7	NB	NB	4.4
Mean	3.0	5.1	7.3	5.4	3.6	2.9	4.1

NB = no bud

The natural condition produced the highest number and weight of pods compared with the other photoperiods (Table 5). NHAe47-4 produced significantly greatest weight of pods than 'Agwu' Early and Clemson while there was strong variation in the number of pods/plant, which ranged from 0.7 produced by 'Clemson' to 5.0 (NHAe47-4). 'Nsukka' local significantly gave the lowest pod weight while NHAe47-4 gave the highest pod weight compared with the other varieties. 'Agwu' Early x Natural gave significantly ($P < 0.05$) the highest pod weight compared with 'Agwu' Early x 8, 10 and 12 hours of photoperiod.

Table 5: Effect of photoperiod on total pod yield of four okra varieties

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
Total number of pods/plant							
'Awgu' Early	4.0	2.0	4.3	1.0	NP	NP	2.8
NHAe47-4	5.0	3.7	3.0	4.3	NP	NP	4.0
'Clemson'	3.7	4.3	4.3	3.7	0.7	NP	3.3
'Nsukka' Local	NP	3.3	3.7	1.0	NP	NP	1.7
Mean	4.2	3.3	3.8	2.5	0.7	NP	3.0
Pod weight (g)							
'Awgu' Early	145.5	22.6	91.9	40.0	-	-	75.1
NHAe47-4	134.3	102.8	84.1	116.8	-	-	109.5
'Clemson'	100.3	91.4	66.6	102.4	8.3	-	78.8
'Nsukka' Local	-	38.9	48.3	0.7	-	-	29.3
Mean	126.7	63.9	72.8	65.1	8.3	-	73.2

	Pod number	Pod weight
$LSD_{0.05}$ for 2 photoperiod means	0.8	20.8
$LSD_{0.05}$ for 2 variety means	0.6	16.7
$LSD_{0.05}$ for 2 photoperiod x variety means	1.5	41.5
$^{+}$chamber air temperature (^{0}C)	37.64/21.88	
Natural air temperature	28.03/20.98	

NB = no bud

During the early stages of fruit production (45 DAP), 8 hours produced the highest number of pods (Table 6). The period of 68 DAP appeared to be the peak of pod production since a high number of pods was produced in each photoperiod compared with the other periods. 'Awgu' Early and 'Clemson' gave the highest number of pods between 45 and 52 DAP, but were overtaken by 'Clemson' at 68 DAP. As yield started to decrease in the other varieties, it started to increase in 'Nsukka' local.

Table 6: Effect of photoperiods on number of pods/plant produced by four varieties of okra at various growth stages

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
45 DAP							
'Awgu' Early	1.0	1.2	1.3	0.2	-	-	0.9
NHAe47-4	0.2	0.0	0.2	0.0	-	-	0.2
'Nsukka' Local	0.3	1.2	0.2	1.2	-	-	0.7
'Clemson'	-	-	-	-	-	-	-
Mean	0.5	1.2	0.6	0.7	-	-	0.6
52 DAP							
'Awgu' Early	1.0	0.8	2.4	1.5	-	-	1.4
NHAe47-4	1.1	1.3	0.1	1.0	-	-	0.9
'Clemson'	1.7	15	2.8	2.1	-	-	2.0
'Nsukka' Local	-	-	-	-	-	-	-
Mean	1.3	1.2	1.8	1.5	-	-	1.5
68 DAP							
'Awgu' Early	1.3	0.0	0.6	0.6	-	-	0.8
NHAe47-4	3.4	2.4	2.7	3.3	-	-	3.0
'Clemson'	1.3	1.3	0.3	0.4	0.3	-	0.5
'Nsukka' Local	-	1.0	2.0	-	-	-	1.5
Mean	2.0	1.6	1.4	1.4	0.3	-	1.5
78 DAP							
'Awgu' Early	0.7	0.0	0.0	0..0	-	-	0.7
NHAe47-4	0.3	0.0	0.0	0.0	-	-	0.3
'Clemson'	0.4	0.0	1.3	0.0	0.4	0.3	0.6
'Nsukka' Local	-	2.3	1.7	1.0	-	-	1.4
Mean	0.5	2.3	1.5	1.0	0.4	0.3	0.8

Plants grown under natural conditions (12.3 hours) on average gave thicker and longer pods than the others except 10 hours photoperiod with which it had a similar value (Table 7). Pod volume was greatest with the natural condition compared with others. Similarly, the NHAe47-4 gave the highest pod diameter, length and volume than the other varieties, while 'Nsukka' local gave the least value. Only 'Clemson' produced fruits at the long photoperiods of 16 hours but the fruits had particularly low pod diameter, length and volume. 'Awgu' Early had greater values of pod length, diameter and volume at the natural photoperiod (natural condition) or at 12 hours photoperiod compared with the lower hours of photoperiod. 'Nsukka' Local gave higher value at 8 to 10 hours of photoperiod, while NHAe47-4 and 'Clemson' showed a wide range of tolerance to photoperiod. However, 14 and 16 hours of photoperiod were not tolerated for pod production. 'Agwu' Early x Natural had pod volume that was significantly ($P < 0.05$) higher than where 'Agwu' Early was considered at any photoperiod.

Table 7: Effect of photoperiod on pod diameter, length and volume in four okra varieties

	Photoperiod (hours)						
Variety	Natural 12.28	8	10	12	14	16	Mean
Pod diameter (cm)							
'Awgu' Early	13.13	3.85	13.00	5.31	-	-	8.80
NHAe47-4	13.97	11.95	10.26	13.75	-	-	12.5
'Clemson'	11.69	10.07	10.63	10.38	0.80	-	8.70
'Nsukka' Local	-	7.25	9.98	1.59	-	-	0.30
Mean	12.0	8.30	11.00	7.70	0.80	-	9.10
Percentage flower bud abortion							
'Awgu' Early	39.43	10.49	35.64	19.83	-	-	26.30
NHAe47-4	33.73	33.10	24.47	35.94	-	-	31.80
'Clemson'	31.28	3.198	28.77	36.17	3.11	-	26.30
'Nsukka' Local	-	17.49	29.11	2.13	-	-	16.20
Mean	34.80	23.30	29.50	23.52	3.11	-	25.20
Pod volume (cm^3)							
'Awgu' Early	221.00	28.33	150.67	60.33	-	-	115.1
NHAe47-4	188.00	151.67	112.00	152.33	-	-	151.0
'Clemson'	146.67	118.00	95.00	149.33	10.00	-	103.8
'Nsukka' Local	-	63.67	83.67	3.00	-	-	50.10
Mean	185.20	90.42	110.33	91.25	10.00	-	105.0

	Diameter (cm)	Length (cm)	Volume (cm3)
$LSD_{0.05}$ for 2 photoperiod means	2.20	7.42	33.71
$LSD_{0.05}$ for 2 variety means	1.79	6.12	27.53

$LSD_{0.05}$ for 2 photoperiod x variety means	4.39	14.83	67.42
$^{+}$chamber air temperature (^{0}C)	37.64/21.48		
Natural air temperature	28.13/20.97		

Experiment 2 was performed between October 1992 and February 1993 when the natural day length at 'Nsukka' was lowest and ranged between 11.45 and 12 hours (Table 8). The maximum and minimum air temperatures for the growth chamber were usually higher than those for the natural condition. The maximum air temperature in the chamber was higher than that in the open condition by 9.68 to 11.04^{0}C units while the corresponding minimum temperature was higher by smaller margin of 0.44 to 0.5^{0} C. The diurnal temperature ranges, i.e., the temperature ranges between the maximum and minimum air temperature both for the growth chambers and the open air condition were higher in experiment 2 than in experiment 1.

Table 8: Total monthly day length and temperature for Nsukka in 1992/93.

	Oct.	Nov.	Dec.	Jan.'93	Feb.'93
Mean daylength (hrs)	12.00	11.49	11.45	11.46	11.54
Mean max. daily air temp. (^{0}C)	28.41	29.27	31.16	30.45	32.79
Mean min. daily air temp. (^{0}C)	20.52	19.17	17.42	19.10	20.26
Mean max. daily air temp. (^{0}C)	38.40	39.15	41.66	40.72	43.83
Mean min. daily air temp. (^{0}C)	21.02	20.19	17.86	19.57	20.76

The 10 hours photoperiod was on average fastest in initiating flower buds and inducing anthesis which were attained in about 41.7 and 55 DAP, respectively, compared to about 60.9 and 85 DAP with 16 and 48.9 and 68 days with 14 hours photoperiod (Table 9). 'Nsukka' local took significantly more number of times than others to initiate flower

buds and attain anthesis either on average or within any photoperiodic treatment. 'Clemson' was significantly earliest to initiate flower bud and to attain anthesis followed by NHAe47-4. 'Nsukka' local x 16 hours gave significantly ($P < 0.05$) the highest number of days to first anthesis compared with the other varieties at any photoperiod.

Table 9: Effect of photoperiod[+] on number of days to first flower bud initiation and anthesis

		Photoperiod (hours)					
Variety	Natural (11.49)	8	10	12	14	16	Mean
Days to first flower initiation							
NHAe47-4	42.3	47.6	37.0	41.0	40.0	44.0	42.0
'Clemson'	38.1	41.0	38.3	36.0	36.7	36.7	37.8
'Nsukka' Local	47.7	48.0	46.7	46.3	69.0	69.0	54.5
Mean	42.7	45.5	40.7	41.1	48.6	60.9	44.8
Days to first anthesis							
NHAe47-4	55.0	55.7	46.3	59.0	68.7	94.0	63.1
'Clemson'	52.0	53.7	51.7	45.7	47.7	55.3	51.0
'Nsukka' Local	67.3	67.7	67.7	67.0	86.3	104.7	77.1
Mean	58.1	59.6	55.2	57.2	67.6	84.7	63.7

	First initiation	First anthesis
$LSD_{0.05}$ for 2 photoperiod means	3.00	3.98
$LSD_{0.05}$ for 2 variety means	2.20	2.87
$LSD_{0.05}$ for 2 photoperiod x variety means	5.10	6.80
[+]chamber air temperature (^{0}C)	40.75/19.88	(day/night)
Natural air temperature	30.48/19.40	(day/night)

Greater number of flower buds were produced between 53 and 61 DAP (Table 10). The highest number of flower bud was produced by natural condition between 53 and 69 DAP, followed by 12 and 10 hours in that

order. 'Nsukka' local did not perform well in the long photoperiod while NHAe47-4 appeared to produce higher number of buds than other varieties with longer stages of growth. NHAe47-4 and 'Clemson' aborted higher percentage number of buds than 'Nsukka' local.

Table 10: Effect of photoperiod on the number of flower buds produced in three okra varieties at different stages of growth

	Photoperiod (hours)						
Variety	Natural 11.49	8	10	12	14	16	Mean
53 DAP							
NHAe47-4	7.67	2.67	5.33	4.33	3.00	0.67	3.95
'Clemson'	6.00	4.00	4.33	6.67	4.00	2.30	4.55
'Nsukka' Local	3.67	2.67	4.00	3.67	1.00	2.30	2.89
Mean	5.78	3.11	4.55	4.89	2.67	1.76	3.80
61 DAP							
NHAe47-4	3.33	3.00	2.00	2.67	2.00	0.33	2.22
'Clemson'	4.00	4.67	2.00	3.67	2.67	1.00	3.00
'Nsukka' Local	4.67	4.33	2.30	3.33	NB	NB	3.66
Mean	4.00	4.00	2.10	3.22	2.34	0.67	2.96
69 DAP							
NHAe47-4	4.67	2.30	2.00	2.00	0.67	2.70	2.39
'Clemson'	3.3	2.00	0.30	0.30	3.33	1.00	1.71
'Nsukka' Local	2.0	1.00	3.67	4.00	NB	NB	2.67
Mean	3.23	1.77	2.00	2.10	1.33	1.23	2.26
81 DAP							
NHAe47-4	1.67	1.00	5.30	0.00	4.33	NB	8.33
'Clemson'	0.3	1.00	0.30	3.67	3.00	2.00	1.71
'Nsukka' Local	3.67	3.00	1.30	2.33	0.67	NB	2.19
Mean	1.88	1.67	2.30	3.00	2.67	2.00	4.08

NB = no bud

Natural condition (11.49 hours) produced the highest significant total number of buds compared to others at 81 DAP (Table 11). 'Nsukka' local produced negligible number of buds in the long photoperiods of 14 and 16 hours compared to the others. 'Clemson' on the average produced the highest number of buds, although there was no significant difference among the varieties. The least percentage number of buds was aborted at short photoperiods of 8 hours, while on the average, the photoperiods longer than 10 hours aborted higher percentage number of buds. 'Nsukka' local x 8, 14 and 16 hours had significantly ($P < 0.05$) the lowest percentage flower bud abortion compared with the other varieties at any photoperiod.

Table 11: Effect of photoperiod^{+} on the total number of flower buds produced and on percentage flower bud abortion per plant of three okra varieties at 70 DAP

	Photoperiod (hours)						
Variety	Natural 11.49	8	10	12	14	16	Mean
Total number of flower buds							
NHAe47-4	17.5	9.0	14.6	9.0	10.0	3.7	10.6
'Clemson'	13.6	11.7	6.9	14.4	13.0	6.3	11.0
'Nsukka' Local	14.1	11.0	11.3	13.3	1.7	2.3	9.0
Mean	15.0	10.3	10.9	11.6	8.3	4.1	10.2
Percentage flower bud abortion (%)							
NHAe47-4	38.7	22.2	32.2	36.7	37.0	45.9	35.4
'Clemson'	31.6	15.2	29.0	34.7	25.4	58.7	32.5
'Nsukka' Local	26.2	0.0	20.4	20.3	0.0	0.0	11.2
Mean	32.2	12.5	27.2	30.6	20.8	34.9	26.4

	No buds	% abortion
$LSD_{0.05}$ for 2 photoperiod means	3.8	5.2
$LSD_{0.05}$ for 2 variety means	2.4	3.7
$LSD_{0.05}$ for 2 photoperiod x variety means	6.5	9.5
$^{+}$chamber air temperature (^{0}C)	40.75/19.88	(day/night)
Natural air temperature	30.48/19.40	(day/night)

The number of pods produced followed a similar trend as the number of flowers produced (Table 12). However, although flower was produced in every photoperiod for each variety, 'Nsukka' local produced more harvestable fruits under the 16 hours photoperiod. The photoperiods of 8 to 12 hours (including the natural condition photoperiod of 11.49 hours) gave the highest number of flowers and harvestable pods. Flower and pod production were most seriously depressed under the 16 hours photoperiod, less by 14 hours and still less by the shorter photoperiod. The adverse effects of long photoperiods (14 and 16 hours) on flower and pod production were more under 'Nsukka' local and less with 'Clemson'. Generally, 'Clemson' produced more flowers and pods under a wider range of photoperiods than others, followed by NHAe47—4 while 'Nsukka' local was more responsive to the short photoperiods of 8 to 12 hours. 'Clemson' x 10 hours produced significantly ($P < 0.05$) higher number of pods per plant compared with the other varieties at the 8, 14 or 16 hours of photoperiod.

Table 12: Effect of photoperiod[+] on number of flower that opened and number of pod produced per plant up to 126 DAP

	Photoperiod (hours)						
Variety	Natural 11.49	8	10	12	14	16	Mean
Total number of flowers/plant							
NHAe47-4	11.0	8.3	14.0	9.3	6.3	2.3	8.6
'Clemson'	9.3	8.7	10.0	11.0	7.3	7.5	9.1
'Nsukka' Local	18.0	7.7	11.7	11.7	3.0	1.0	9.2
Mean	12.8	8.2	11.9	10.7	5.9	3.1	8.9
Total number of pods/plant							
NHAe47-4	10.0	5.3	9.7	8.7	4.3	1.0	6.5
'Clemson'	6.3	6.0	6.7	10.3	6.0	3.7	6.5
'Nsukka' Local	7.7	6.3	7.0	8.7	3.0	-	6.6
Mean	8.0	5.9	7.8	9.2	4.4	2.4	6.5

	Number of flowers	Number of pods
$LSD_{0.05}$ for 2 photoperiod means	3.63	2.00
$LSD_{0.05}$ for 2 variety means	N.S	N.S
$LSD_{0.05}$ for 2 photoperiod x variety means	6.29	3.50
[+]chamber air temperature (^{0}C)	40.75/19.88	(day/night)
Natural air temperature	30.48/19.40	(day/night)
DAP = Days after planting		

Pod yield was on average highest with the natural condition of 11.49 hours photoperiod, 12 and 10 hours photoperiods and lowest with 16 hours photoperiod (Table 13). The photoperiods of 14 and 8 hour gave similar yield values. 'Nsukka' local gave the least yield on average apparently because of no yield was recorded with the 16 hours photoperiod. NHAe47—4 and 'Clemson' produced more fruits at 10

to 12 hours photoperiods and less at 14 but very poorly at 16 hours in contrast to 'Nsukka' local, that produced more fruits at 8 to 12 hours and very poorly or none at all at 16 hours, showing its greater sensitivity for short photoperiods in fruit production. 'Clemson' x Natural, 8, 10, 14 and 16 hours had similar pod yield. 'Nsukka' local also had similar pod yield across the various photoperiods. NHAe47-4 x 10 hours gave significantly ($P < 0.05$) higher pod yield than 'Clemson' x 16 hours and NHAe47-4 x 16 hours of photoperiod.

Table 13: Effect of photoperiod^{+} on pod yield (g/plant) in three okra varieties at 126 DAP

	Photoperiod (hours)						
Variety	Natural 11.49	8	10	12	14	16	Mean
NHAe47-4	224.61	84.44	248.52	217.76	124.79	20.01	153.97
'Clemson'	180.64	98.87	155.20	165.15	166.78	86.63	142.21
'Nsukka' Local	170.40	126.25	112.46	157.40	63.93	-	126.09
Mean	191.89	104.52	172.06	180.10	118.40	53.32	141.62

$LSD_{0.05}$ for 2 photoperiod means	64.79
$LSD_{0.05}$ for 2 variety means	N.S
$LSD_{0.05}$ for 2 photoperiod x variety means	112.22
$^{+}$chamber air temperature (^{0}C)	40.75/19.88 (day/night)
Natural air temperature	30.48/19.40 (day/night)

DAP = Days after planting

The natural condition and 14 hours photoperiod had similar pod lengths, pod volumes and average pod weight which consistently was significantly greater than the 8, 10 or 12 photoperiodic treatments (Table 14). Except for pod diameter, the size characters of pod length, volume and mean pod weight were significantly greater with Clemson and NHAe47-4 compared with 'Nsukka' local. The average pod weight per plant remained statistically the same for 'Nsukka' local across the different photoperiods. NHAe47-4 x 14 hours had similar pod weight with NHAe47-4 x natural, 10 and 12 hours but was significantly ($P < 0.05$) higher than NHAe47-4 x 8 and 16 hours of photoperiod.

Table 14: Effect of photoperiod[+] on length, diameter, volume and weight of pod per plant in three okra varieties

	Photoperiod (hours)						
Variety	Natural 11.49	8	10	12	14	16	Mean
Average pod length (cm)/plant							
NHAe47-4	8.34	5.47	7.82	7.10	6.55	8.27	7.26
'Clemson'	9.28	6.62	5.99	5.76	10.99	4.96	7.27
'Nsukka' Local	5.84	8.11	5.99	6.84	6.59	-	6.67
Mean	7.84	6.73	6.60	6.57	8.04	6.62	7.09
Average pod diameter (cm)/plant							
NHAe47-4	2.75	1.86	3.07	2.68	2.79	2.51	2.61
'Clemson'	2.57	2.44	2.31	2.07	2.86	2.25	2.42
'Nsukka' Local	2.36	3.01	2.29	2.63	3.62	-	2.78
Mean	2.56	2.44	2.56	2.46	3.09	2.38	2.59
Average pod volume (cm^3)/plant							
NHAe47-4	33.60	18.19	31.36	29.04	28.14	27.00	27.89
'Clemson'	35.62	23.22	25.54	21.02	38.15	25.79	28.22
'Nsukka' Local	24.41	27.37	18.07	20.79	23.78	-	22.88
Mean	31.21	22.93	24.99	23.62	30.02	26.39	26.53
Average pod weight (g)/plant							
NHAe47-4	22.46	15.32	25.32	24.51	28.47	20.01	22.68
'Clemson'	28.38	16.09	22.02	15.59	27.59	23.21	22.15
'Nsukka' Local	22.08	17.53	15.97	17.55	20.99	-	18.82
Mean	24.31	16.31	21.10	19.22	25.67	21.61	21.36

	Length	Diameter	Volume	Weight
$LSD_{0.05}$ for 2 photoperiod means	0.93	0.29	5.08	4.21
$LSD_{0.05}$ for 2 variety means	N.S	0.20	3.59	2.98

$LSD_{0.05}$ for 2 photoperiod x variety means	1.62	0.50	8.80	7.29
$^{+}$chamber air temperature (^{0}C)		40.75/	19.88	(day/night)
Natural air temperature		30.48/	19.40	(day/night)

Discussion

Flower bud production was earlier in experiment 1 than experiment 2 irrespective of the photoperiod. This might have been due to the higher temperatures and higher radiation that were obtained during the period of experiment 2.

In the short photoperiods (8-12.28 h), flower buds were initiated earlier than in the long photoperiods (14-16 h). Arulrajah and Ormrod (1973) made a similar observation that short photoperiod stimulated early flowering and reduced the period of vegetative growth in okra. Uchehara (1995) reported similar observation of early flowering at shorter day length (8 to 10 hours) in some bambara groundnut accessions grown in Nsukka, Nigeria. In the long photoperiods, Nsukka Local variety of okra did not produce flower bud all through in experiment 1, showing a response of an obligate short day plant. Similar report was obtained by Njoku (1958) that late okra variety did not initiate flower bud at photoperiod longer than 12 hours.

Other varieties 'Awgu' Early, NHAe47-4 and 'Clemson' produced flower buds in all the photoperiods, showing a response from a facultative short day plant. Njoku (1958) pointed that some Nigerian plants such as cowpea, okra and *Tridex procubens*, produced flowers in the long day, but more flowers in the short day and that the photoperiodic effect on flowering is more or less a quantitative one. Linnemann (1991) working with bambara groundnut, made observation of a group of accessions with a quantitative response to short days for flowering with an obligate response to short days for fruit set.

In experiment 1, only Clemson attained anthesis in the long photoperiod suggesting that 'Clemson' can tolerate wider range photoperiodic conditions. Njoku (1958) reported that in cowpea, although it did not show any critical daylength in formation of flower buds, there was a definite critical daylength for fruiting which was less than 12.5 h. The phenomenon of critical daylength requirement for fruiting might be the reason why 'Awgu' Early and NHAe47-4 which produced flower buds in the 14 and 16 hours photoperiods eventually failed to attain anthesis and fruiting under those photoperiods. Consequently, there was always a high rate of flower bud abortion recorded in the long photoperiod with eventually no pods produced.

In experiment 2 (conducted between October 1992 and February 1993), flower bud initiation and anthesis

occurred in all varieties under all the photoperiods studied, although flower bud initiation and anthesis were earlier in short photoperiods of 8 to 12 hours. This showed some sort of modification of the responses observed in experiment I (conducted between May and July, 1992) where flower bud initiation and anthesis failed to occur in all the varieties except 'Clemson' under long (14-16 h) photoperiods. This might be due to modulating effects of high temperature and radiation during the period of experiment 2. According to Confalone *et al*. (2009), there are variations in temperature and relative humidity regimes all through the year and this could modify the photoperiodic responses of photoperiodic-sensitive crops.

Flower production was highly favoured by short photoperiods (8 to 12 h). More number of flower buds and flowers were produced between 10 and 12 hours photoperiods, evidently showing that okra generally respond greatly to short photoperiod. However, 'Clemson' produced more number of flower buds and flowers than the other varieties both at short (8 to 12 h) and long (14 to 16 h) photoperiods. When the natural daylength was about 11.49 h (short day) 'Nsukka' local produced flowers and fruits than when it was 12.28 hours or more where no harvestable pod was produced. According to Njoku (1958), no harvestable pod was obtained from late okra at the photoperiod of 12.28 hours or more.

The present work demonstrates that considering the natural conditions existing at Nsukka, 'Awgu' Early, NHAe47—4 and 'Clemson' can be grown with success at any time of the year, although greater fruiting will be favoured under shorter photoperiods of 12 hours or less, that is obtained towards the end of the year in humid tropics.

'Nsukka' Local mandatorily required short photoperiods to flower and fruit. That might be the reason why when local farmers plant it early in the season with the early rains in March or April; it fails to flower until October/November when the photoperiod is 12 hours or less.

Early flower initiation is undesirable for okra as it will lead to poor vegetative development and low yields. The solution to the excessive growth experienced with 'Nsukka' Local planted in early season would be to evolve a proper timing that will strike a balance in the growth and reproductive phases of the plant life. This will ensure that the plants will not be planted when it will run into premature flowering and at the same time develop well vegetatively before the critical photoperiod for flowering and fruiting.

Conclusion

Pod yield was greatly favoured by the short photoperiod of 10 to 12.28 hours while long photoperiods of 14 to 16 hours were not conducive to pod production as they greatly depressed the yield. Generally, 'Clemson' produced higher pod yield and was more tolerant to wider range of photoperiod in pod production than others. 'Clemson', 'Awgu' Early and NHAe47-4 can be planted any time under the photoperiodic conditions that naturally exist at Nsukka without

drastic losses due to photoperiods. 'Nsukka' Local failed to produce any harvestable pod in the longest photoperiod of 16 hours, or when the natural photoperiod was greater than 12 hours. This means that timing the transition from the vegetative to the reproductive phase to occur between April and September will be unsuccessful as the plant will continue to grow vegetatively during those months. Since the shortest number of days to flower bud initiation in 'Nsukka' local was 44 days after sowing, planting in Mid-August would allow good time for vegetative growth before transition to the reproductive phase in October.

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