Global Journal of Science Frontier Research
Agriculture & Biology
Volume 12 Issue 3 Version 1.0 March 2012
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

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GJSFR-D Classification : FOR Code: 070199

IMPACTS OF VARIATION IN AGROCLIMATOLOGICAL INDICES AND CROP COMBINATION ON GROWTH AND YIELD RESPONSE OF OKRA IN MIXTURES WITHTWO SORGHUM CULTIVARS AND MAIZE IN A FOREST -SAVANNA TRANSITION ZONE OF NIGERIA

Impacts of Variation in Agroclimatological Indices and Crop Combination on Growth and Yield Response of Okra in Mixtures with Two Sorghum Cultivars and Maize in a Forest-Savanna Transition Zone of Nigeria.

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Abstract - Impacts of variation in agroclimatological indices and crop combination on growth and yield response of okra in mixtures with two sorghum cultivars and maize in a forest-savanna transition zone of Nigeria was investigated at the Experimental Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan during the 2009 and 2010 cropping seasons. Plants phenological stages formed the basic unit of time for the investigation. During these phenological stages, agroclimatological thermal and moisture indices were measured daily and processed into ten-day (decadal) averages likewise selected agronomic growth and yield parameters of the components crops were taken fortnightly. The results showed that the 2010 season crops had relatively longer growth duration, received more rainfall than 2009 season (692mm *vs* 487.2mm) while 2009 experienced warmer temperature during establishment and early vegetative stage than 2010 season (33.2°C *vs* 32°C), and (28.5°C *vs* 27 °C) during the reproductive phase for 2009 and 2010 season respectively. The mean pod yields of okra in both seasons were dependent on crop combination since pod yield in sorghum cultivars mixtures (Farin Dawa and Janare) (97.33 *and* 93.67 pods) was significantly higher than in maize mixtures (58.33 *and* 49.65 pods) in 2009 season likewise in 2010 season when okra pods in sorghum mixtures (Farin Dawa and Janare) had (309.67 *and* 232.33 pods) against (162.67 *and* 67 pods) in maize mixtures for the two sorghum cultivars. The lower pod yield in 2009 season can be attributed to a higher frequency of a 5-day dry spell during flowering stage which led to a condition of moisture deficient, reduced pollination or cause spikes to dry out and heavy flower abortion. Also, it took okra pods longer to reach marketable size in the 2009 season than 2010 season (i.e. 5-9 v. 2-6 days).

Keywords : Phenological stages, agroclimatological indices, okra, sorghum, maize

I. Introduction

In crop production, climate has direct effect on the rate and duration of growth of individual plant, which ultimately determines the final yield (Egli 2004). The extent of weather influence on crop yield depends not only on the magnitude of weather variables but also on the distribution pattern of weather over the crop season which as such calls for the necessity of dividing the whole crop season into fine intervals. Controlled environment studies have shown that lower night temperature and higher day temperature can substantially decrease yields (Allen and Boote 2000).

Intercropping ensures efficient utilization of light by component plants and other environmental resources and helps to maintain greater stability in crop yields. It also guarantees greater land occupancy and higher net returns. Although some researchers, Ikeorgu et al. (1983) and Olasantan (2005) have evaluated the effects of intercropping on common vegetable crops, there is still paucity of information on this. In particular, information on okra-sorghum-maize mixtures is not available from forest-savanna transition zone of Nigeria despite wide cultivation of okra in this zone. Kurt (1984) explained that specific intercropping systems have developed over the centuries in the different regions and they are closely adapted to the prevailing ecological and weather conditions. An investigation was therefore, carried out to determine if variation in agroclimatological indices and crop combination might be associated with differences in growth and yield of okra(*Abelmoschus esculentus* (L. Moench) in mixtures with two sorghum cultivars and maize in a forest-savanna transition zone of Nigeria.

II. Materials and Methods

a) *Experimental site*

The experiment was carried out at Experimental, Teaching and Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan (7° 22'N, 3° 50'E) during the 2009 and 2010 cropping seasons (Figure 1). The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated relatively with the prevalence of the moist maritime southerly monsoon from Atlantic Ocean and the dry season by the continental North Easterly harmattan winds from the Sahara desert. The

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area is also characterized by bimodal rainfall pattern (April to July being the wettest months, followed by August to October). The annual rainfall ranges between 1400 and 1500mm in Ibadan and its environs. Isolated and scanty rains usually start in mid-March and steadily increase to reach the peak values in July followed by a short break in August and another peak in September. The dry season is normally from October to March and often characterized by hot days. The region is characterised by relatively high temperature with mean annual air temperature of about 30°C. The greatest variation in temperature is experienced between July (25.7°C) and February (30.2°C). The humidity is lowest (37-54%) at the peak of dry season in February and highest (78-85%) at the peak of the rainy season in June to September.

b) Planting and crop management

Two Sorghum cultivars; (*Farin Dawa* and *Janare*) , one maize(*suwan 1*) and okra(*NHAe 47-4*) cultivars were used in two field trails during 2009 and 2010 planting seasons. About three and four seeds of sorghum, maize and okra were planted at a depth of 2.5cm. Sorghum was planted three weeks after planting okra and maize to enable the okra and maize gain establishment. Sorghum spacing was 90 x 60cm (2 seedlings/stand), maize spacing was 90 x 30 cm (1 seedling/stand) and okra spacing was 90 x 30 cm (1seedling/stand). Each plot size was 6m by 3m; making a total plot size of 100 m x 20 m. The plots were hoe weeded at 3 and 6 weeks after planting. The experimental plots were arranged in a randomize complete block design (RCBD) fitted into split-plot design with three replicates. Three sets of data were collected based on critical phenological stages. These data sets were: agroclimatological indices, growth Parameters and yield parameters .

i. *Agroclimatological data*

This includes moisture base, thermal base and aerodynamic indices of the plant micro-environment easured daily from meteorological enclosure 200m from the experimental site and were later processed into decadal values. Moisture base indices include rainfall (P, mm) relative humidity (%) and open water evaporation (mm). Thermal base indices include maximum and minimum temperature (T, °C), and sun shine hour while aerodynamic indices measured is wind speed (Ws at a height of 2m (ms^{-1})).

ii. *Growth parameters*

The data were collected on the desired growth parameters of the components crops as per treatment by using standard procedures. Major growth parameters considered include: Plant height (cm), Leaf area (cm^2), Number of leaves and Stem diameter (mm) for each of the component plants.

The leaf area was determined by non destructive method. Ten leaves were measured for each treatment plot and the mean leaf area determined.
Okra leaf area was estimated, using a non-destructive method, from the equation;

$$Y = 115X - 1050$$

Where Y = leaf area (cm^2) and X = the length of mid rid (cm) (Asif, 1977).

The area of each individual sorghum and maize leaf blade (Y, in square centimetres) was computed as; length x maximum width x 0.75. The value of 0.75 was considered an acceptable average of reported values: 0.75 (Montgomery, 1911), 0.73 (Mckee, 1964; Dwyer and Stewart, 1986), 0.72 (Keating and Wafula, 1992), 0.79 (Birch *et al.,* 1998) and 0.74 (Stewart and Dwyer, 1999).

$$Y = (L \times W)\ 0.75 \text{ (leaf area factor)}$$
(Stewart and Dwyer, 1999)
Where L=length (cm) and W= maximum width (cm)

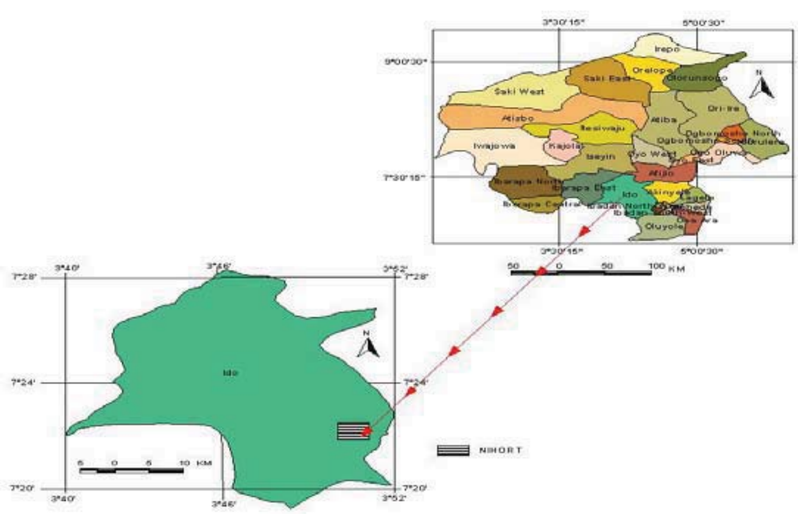


Figure 1 : Location of NIHORT within Ido local government area in Oyo state

iii. *Yield parameters*

Yield parameters considered include grain yield (sorghum and maize), panicle length (sorghum), cob weight (maize), weight of 100 grains (maize), pods number/plant and pods weight, length and diameter of okra yield.

c) *Statistical analysis*

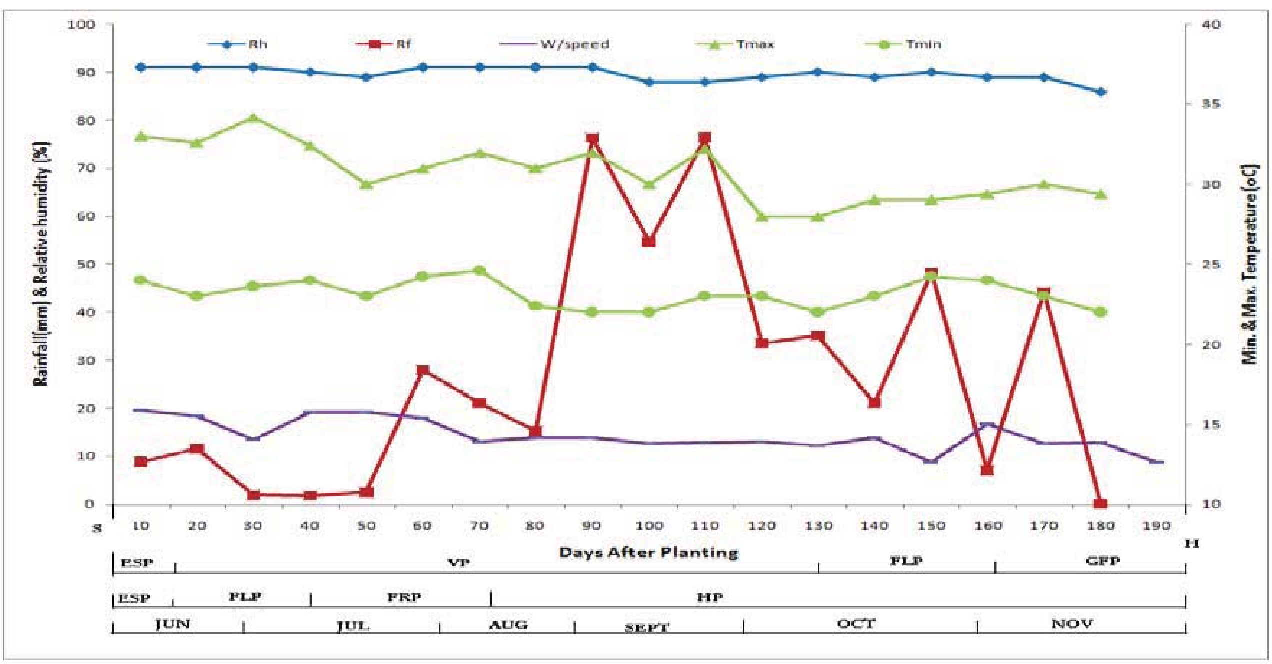
Analyses of variance were carried out by established methods (Steel *et al.* 1997) using the PROC GLM procedure of the SAS Statistics package (SAS Institute Inc. 2000). The cropping pattern and cultivars were considered as random effects, while the planting seasons were fixed effects. Cultivars and cropping patterns mean differences within each planting season were separated using Fishers' protected least significant difference (l.s.d.) test at $P \leq 0.05$.

III. Results and Discussion

a) *Distribution of Agroclimatological indices*

Agroclimatological indices for the growing seasons differed considerably at various stages of the crop growth. The 10-days values for rainfall, maximum and minimum temperature, relative humidity and wind speed for 2009 and 2010 seasons at National Horticultural Research Institute (NIHORT), Ibadan were related to the main phases of vegetative growth and reproductive development of sorghum in Fig. 2 & Fig. 3. Rainfall during stages of growth was much higher in 2010 cropping season than 2009 cropping season (i.e 692 *vs.* 487.2 mm). Consequently, rainfall during the vegetative growth stages was lower in the 2009 season than 2010 season crops (i.e 331.5 *vs* 537.5mm). The same scenario was observed during the reproductive phase in 2009 season with 366.6mm against 560.2mm in 2010 season.

Temperature also varied during the the two seasons (Fig. 2 & Fig.3) and was similar in its distribution to that found elsewhere in the savanna region (7° 49'N, 6° 03'E) of Nigeria (Olaniran and Babatolu, 1987). Minimum temperature varied between 22 and 24 °C in 2009 season while it ranged between 21.2 and 23.4 °C in 2010 season. Maximum temperature ranged between 28 and 33°C in 2009 season while it range between 27 and 32 °C in 2010 season. Temperatures were warmer during planting, establishment and early vegetative stages than during reproductive stage in 2009 season (24 v 22 and 33 v 28 °C) and similar trend was observed in 2010 season (23 v 22 and 31v 27 °C).



ESP: Establishment; VP: Vegetative period; FLP: Flowering period; GFP: Grain filling period; H: Harvesting
FRP: Fruiting period; HP: Harvesting period; S: Sown.

Figure 2 : Distribution of Agroclimatological indices during different phenological stages of experimental crops in 2009 season (June-November) at NIHORT, Ibadan

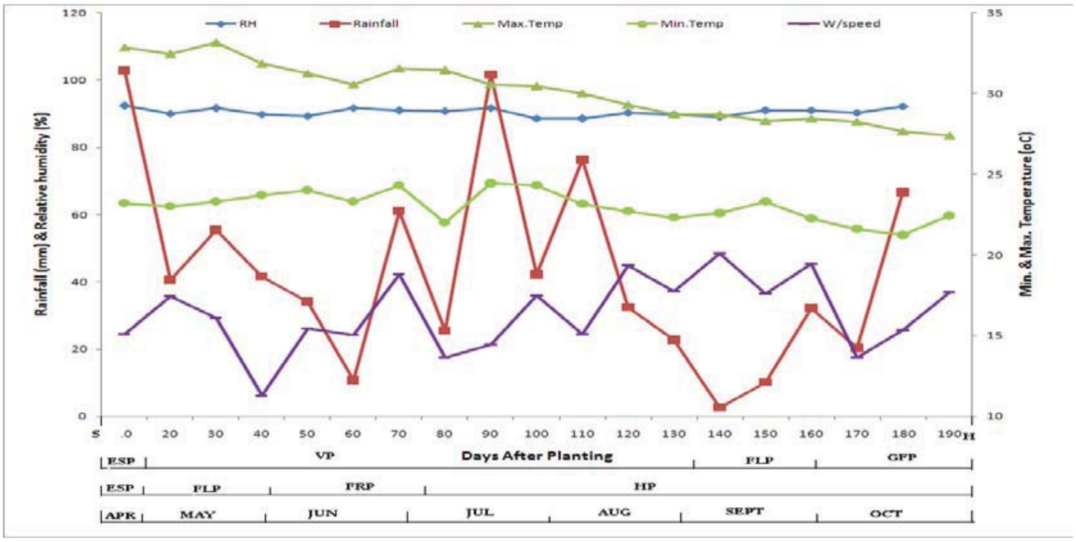


Figure 3 : Distribution of Agroclimatological indices during different phenological stages of experimental crops in 2010 season (April-October) at NIHORT, Ibadan

The pattern of thermal trends (maximum and minimum air temperature) for both the 2009 and 2010 seasons at NIHORT, Ibadan is as shown in figure 4. The mean minimum temperature during the early growing season was 24°C during 2009 season at establishment stage (ESP) but dropped to 23°C at flowering period (FLP) while the least minimum temperature of 22°C was observed at grain filling period (GFP). The growing season of 2010 experienced a much lower minimum temperature with ESP, FLP and GFP having 23.2, 22.57 and 21.6°C, respectively. Displayed in figure 5 is the trend of maximum temperature for both the 2009 and 2010 seasons at NIHORT, Ibadan. The results revealed that 2009 season maximum temperature trend dropped from 33°C at ESP to 29.3°C at FLP while 30°C was recorded at GFP. In 2010 season maximum temperature values were 32.7, 28.71 and 28.24°C at ESP, FLP and GFP, respectively.

Presented in figure 5 is the aerodynamic trend (wind speed (m/sec)) for both the 2009 and 2010 seasons at NIHORT, Ibadan. The prevailing wind situation from 10 – 60 days after planting (DAP) was higher during 2009 season (19.56 – 13.4 m/sec) than 2010 season (15.07- 11.3 m/sec). However, the prevailing wind situation during 2010 season (20.08 – 133.62 m/sec) from 70- 180 DAP was higher than during 2009 season that ranged from 16.74 to 8.73 m/sec. Days with higher wind speed experienced a relatively windy situation though not enough to cause physical damage as plant had fully established and nearing maturity or at maturity while those days with lower wind speed experienced a calm weather condition when plant can stand in proper position to receive sun light for maximum photosynthesis.

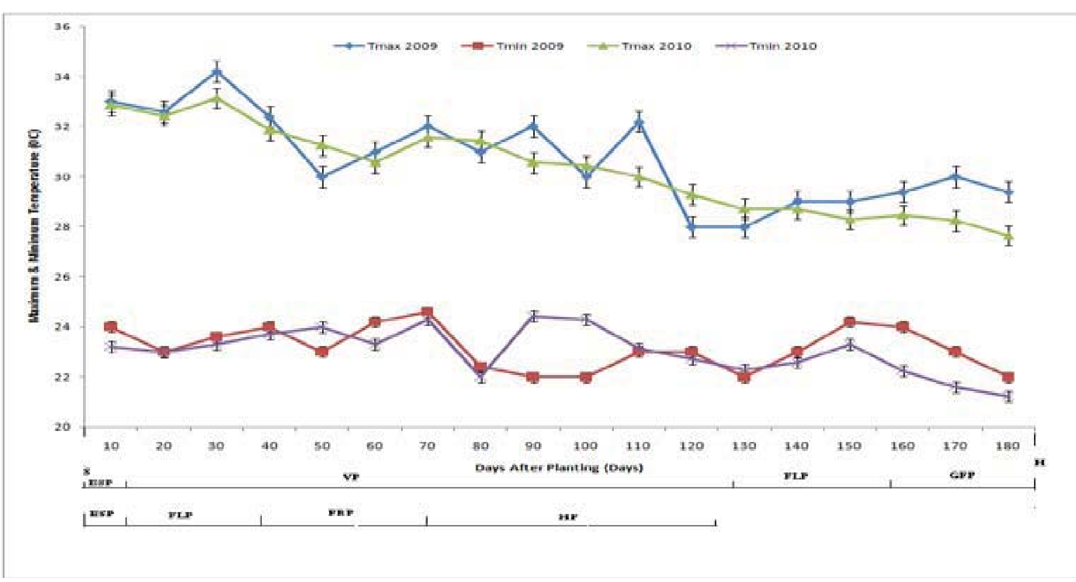


Figure 4 : Comparison of thermal trends for 2009 and 2010 seasons at NIHORT, Ibadan.

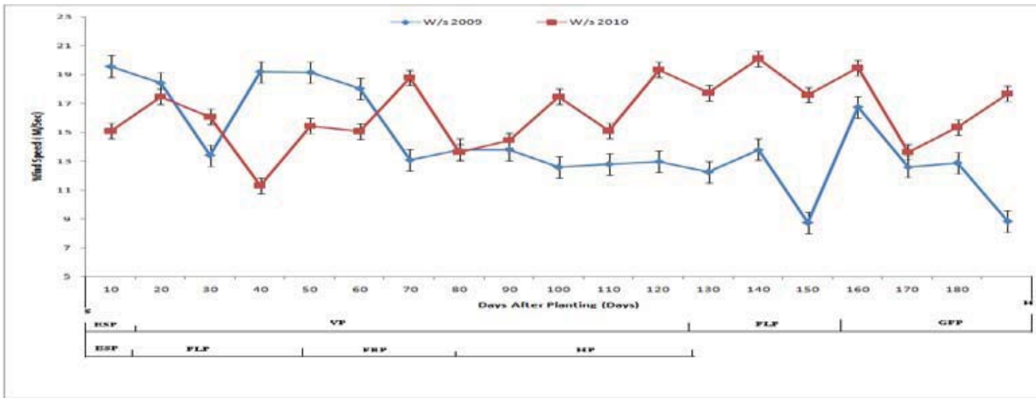


Figure 5 : Aerodynamic trends during 2009 and 2010 seasons at NIHORT, Ibadan

b) *Okra growth characteristics*

i. *Plant height*

a. 2009 season

Figure 6 showed the difference in plant height of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/ red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP). The result showed that there was generally no statistical difference in okra plant height in both monoculture and mixtures. Okra plant height in okra/red sorghum mixtures (S2O) increased from 15.48cm at 4WAP to 70.51cm at 12WAP while okra height in okra/white sorghum mixtures (S1O) increased from 16.44cm to 69.15cm at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, okra height in maize/okra/white sorghum (MOS1) increased from 15.45cm to 55.86cm against okra height in maize/okra/red sorghum (MOS2) combination that increased from 14.73cm to 67.87cm at 4 and 12 WAP respectively.

Plant height in maize/okra mixture (MO) ranged from 16.06 to 68.03cm while okra plant height in okra/white sorghum (S1O) mixtures ranged from 16.44 to 69.15cm and okra/red sorghum mixtures ranged from 15.48 to 70.51cm. Though no significant difference was observed in the treatments means, the okra plants perform better in red sorghum (S2) than white sorghum (S1).

b. 2010 season

Okra height in okra/red sorghum mixtures (S2O) increased from 17.77cm at 4WAP to 73.00cm at 12WAP while okra height in okra/white sorghum mixtures (S1O) increased from 17.78cm to 82.78cm at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, okra height in maize/okra/white sorghum (MOS1) increased from 17.25cm to 60.00cm against okra height in maize/okra/red sorghum (MOS2) combination that increased from 15.02cm to 69.22cm at 4 and 12 WAP respectively. Okra plant height in maize/okra mixture (MO) ranged from 17.46 to 68.89cm while okra plant height in okra/white sorghum (S1O) mixtures ranged from 17.78 to 82.78cm and okra/red sorghum mixtures ranged from 17.77 to 73.00cm.

ii. *Number of leaves*

a. 2009 season

Mean difference in number of leaves per plant of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP) is presented in figure 7 in 2009 and 2010 seasons. The figure revealed that the difference in number of leaves per plant of okra in both monoculture and mixtures was significant at all sampling occasions for treatments containing white sorghum (S1) cultivar while difference in treatment containing red sorghum (S2) was significant at 6,8,10 and 12 WAP. Leaves per plant in okra/red sorghum mixtures (S2O) increased from 6.93 at 4WAP to 22.74 at 12WAP while leaves per plant of okra in okra/white sorghum mixtures (S1O) increased from 7.33 to 20.00 at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, leaves per plant of okra in maize/okra/white sorghum (MOS1) increased from 6.48 to 12.78 as against the values in maize/okra/red sorghum (MOS2) combination that increased from 7.62 to 17.23 per maize plant at 4 and 10 WAP respectively.

b. 2010 season

In 2010 season, significant difference existed in number of leaves per plant of okra in both monoculture and mixtures at 8, 10 and 12WAP for treatments containing white sorghum (S1) cultivar while the difference was significant in treatment containing red sorghum (S2) at 10 and 12 WAP (Figure 7). Leaves per plant of okra in okra/red sorghum mixtures (S2O) increased from 7.44 at 4WAP to 19.11 at 10WAP while in okra/white sorghum mixtures (S1O) it increased from 7.78 to 23.67 at 4 and 10WAP respectively. In maize/okra/sorghum intercrop, leaf per plant of in maize/okra/white sorghum (MOS1) increased from 6.89 to 10.45 against the corresponding values of 7.22 to 13.33 in maize/okra/red sorghum (MOS2) combination at 4 and 10 WAP respectively.

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iii. *Leaf area (cm²)*

a. *2009 season*

Presented in figure 8 is the leaf area of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/ red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP). The figure showed that leaf area of okra in both monoculture and mixtures was not statistically difference except at 12WAP for treatments containing white sorghum (S1) cultivar while the difference was significant ($p<0.05$) in treatment containing red sorghum (S2) at 6,10 and 12WAP. Leaf area of okra in okra/white sorghum mixtures (S1O) increased from 1288.9 cm^2 at 4WAP to 3839.3cm^2 at 12WAP while in okra/red sorghum mixtures (S2O) it increased from 829.1 to 4237.3 cm^2 at 4 and 8WAP respectively. In maize/okra/sorghum intercrop, okra leaf area in maize/okra/white sorghum (MOS1) increased from 904.5 to 3046.7cm^2 at 4 to 12WAP while the values in maize/okra/red sorghum (MOS2) combination increased from 766.2 to 3650.4 cm^2 at 4 and 8 WAP respectively.

b. *2010 season*

During the 2010 season leaf area of okra was not different significantly except at 12WAP for treatments containing white sorghum (S1) cultivar and similar trend was observed for treatments containing red sorghum (S2) except at 10WAP. Leaf area of okra in okra/white sorghum mixtures (S1O) increased from1301.4 cm^2 at 4WAP to 3811.8cm^2 at 10WAP while in okra/red sorghum mixtures (S2O) it increased from 941.8 to 3630.9 cm^2 at 4 and 8WAP respectively. In maize/okra/sorghum intercrop, okra leaf area in maize/okra/white sorghum (MOS1) increased from 986.7 to 2962.4cm^2 at 4 to 10WAP while the values in maize/okra/red sorghum (MOS2) combination increased from 815.7 to 2988.4 cm^2 at 4 and 8 WAP respectively.

iv. *Days to 50% flowering and first harvest of Okra plant*

a. *2009 season*

The data on average number of days to 50% flowering and days to first harvest as influenced by two sorghum cultivars and maize intercrop on okra phenology are presented in Table 1. It is evident from the table that the two sorghum genotypes and maize intercrop had significant effects on the days taken to reach 50% flowering and days to first harvest. During 2009 season the two sorghum genotypes hastened the 50% flowering and days to first harvest of okra than maize intercrop. Days to 50% flowering of okra treatment containing white sorghum (S1), sole okra (O) and okra/white sorghum mixtures (S1O) took 49 days while both maize/okra (MO) and maize/okra/white sorghum (MOS1) mixtures took longer days of 52 days. The values in red sorghum combination ranged from 50 days for both sole okra (O) and red sorghum/okra mixture (S2O) followed by okra/maize/red sorghum mixtures (MOS2) of 53 days while it took maize/okra (MO) mixture 54 days.

Days to first harvest of okra for treatment containing white sorghum (S1), sole okra (O) and okra/white sorghum mixtures (S1O) took 53 days while both maize/okra (MO) and maize/okra/white sorghum (MOS1) mixtures took longer days of 57 days. Days to first harvest in red sorghum combination ranged from 54 days for red sorghum/okra mixture (S2O) followed by both sole okra (O) that took 55 days then maize/okra (MO) and okra/maize/red sorghum mixtures (MOS2) that took longer days of 59.

b. *2010 season*

During 2010 season, the two sorghum genotypes hastened the time to 50% flowering and days to first harvest of okra than maize intercrop. Days to 50% flowering of okra treatment containing white sorghum (S1), sole okra (O) took 49 days followed by okra/white sorghum mixtures (S1O) of 50.67 days while both maize/okra (MO) took 51.00 days and maize/okra/white sorghum (MOS1) mixtures took longer days of 53 days. Days to 50% flowering in red sorghum combination ranged from 51 days for both sole okra (O) followed by red sorghum/okra mixture (S2O) that took 52 days then okra/maize/red sorghum mixtures (MOS2) of 53 days while maize/okra (MO) mixture took 55 days.

Days to first harvest of okra for treatment containing white sorghum (S1), sole okra (O) took 55 days followed by okra/white sorghum mixtures (S1O) and maize/okra (MO) that took 56 days while maize/okra/white sorghum (MOS1) mixtures took longer days of 57 days. Days to first harvest in red sorghum (S2) combination ranged where not significantly different as all treatments have pods ready for harvest at 58 days after planting.

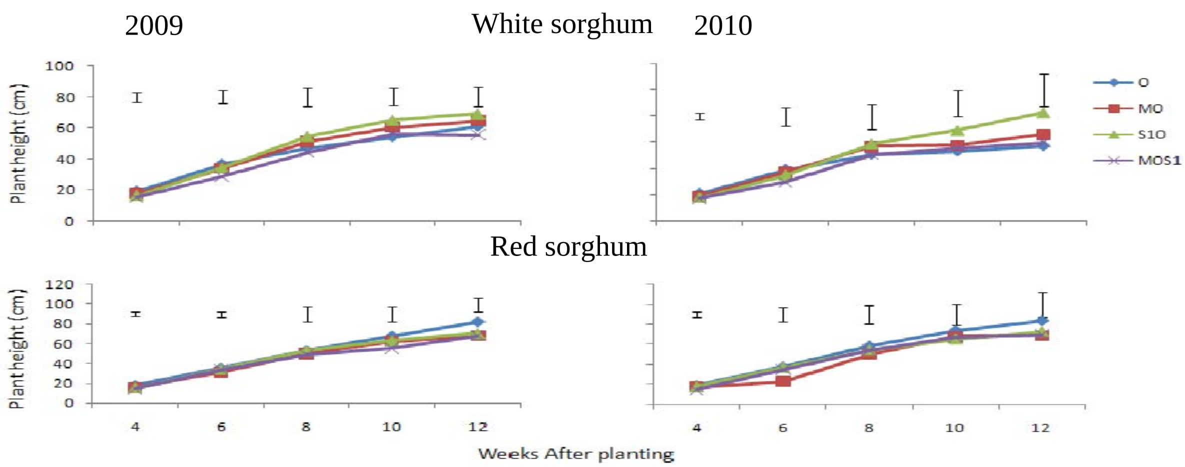

Figure 6 : Effects of intercropping two sorghum cultivars and maize on plant height (cm) of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

MOS1: Maize/okra/White Sorghum Intercrop; MO: Maize/Okra Intercrop; MOS2: Maize/Okra/Red Sorghum Intercrop; O: Okra (NHAe 47-4); S1O: White sorghum/okra intercrop; S2O: Red sorghum/okra intercrop.

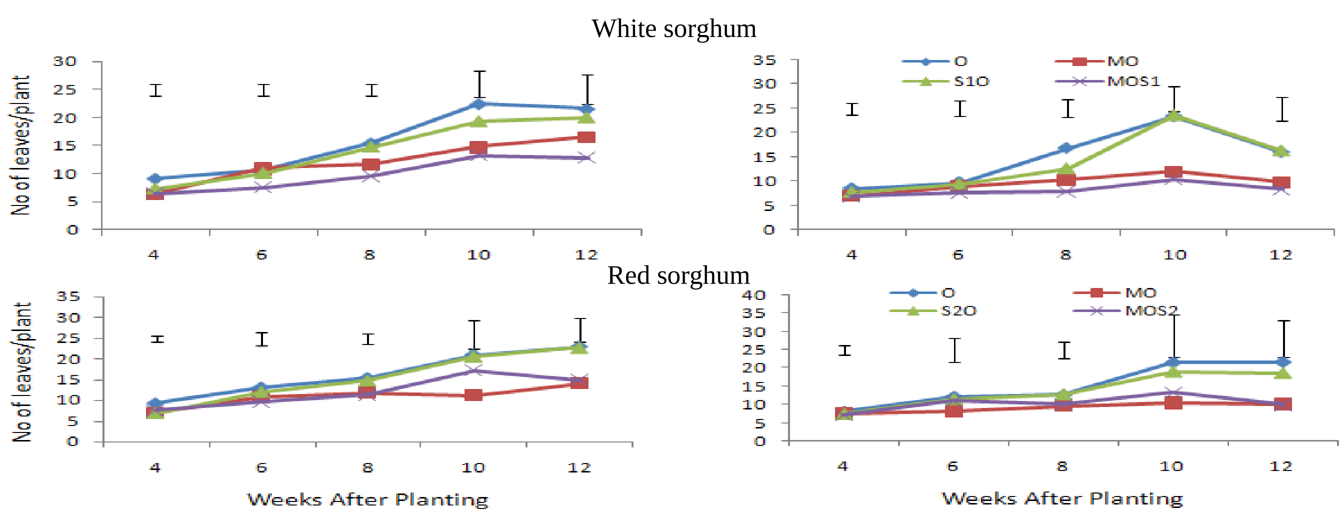

Figure 7 : Effects of intercropping two sorghum cultivars and maize on the number of leaves per plant of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

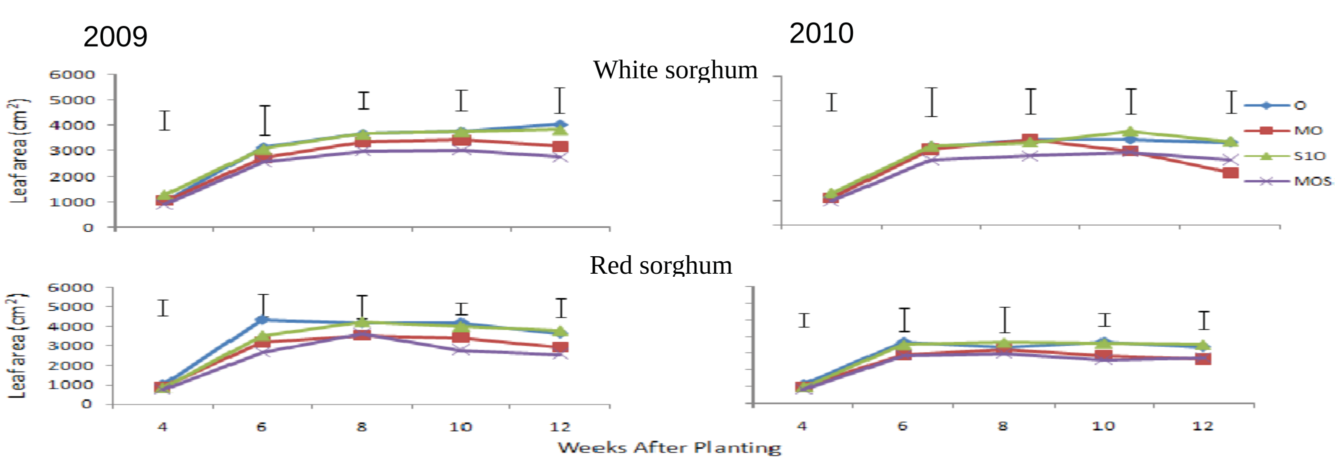

Figure 8 : Effects of intercropping two sorghum cultivars and maize on the leaf area (cm^2) of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

MOS1: Maize/okra/White Sorghum Intercrop; MO: Maize/Okra Intercrop; MOS2: Maize/Okra/Red Sorghum Intercrop; O: Okra (NHAe 47 - 4); S1O: White sorghum/okra intercrop; S2O: Red sorghum/okra intercrop.

Table 1 : Effects of intercropping two sorghum cultivars and maize with okra on the phenology of Okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

	2009		2010	
Treatments	Days to 50% flowering	Days to first harvest	Days to 50% flowering	Days to first harvest
White sorghum				
O	49	53	49	55
MO	52	57	51	56
S1O	49	53	51	56
MOS1	52	57	53	57
Red sorghum				
O	50	55	51	59
MO	54	59	55	59
S2O	50	54	52	59
MOS2	53	59	53	59
LSD(0.05)	1.62	1.08	1.32	1.83
White sorghum (mean)	50	55	51	56
Red sorghum (mean)	52	57	53	59
LSD(0.05)	1.84	1.50	1.35	1.74
Sole okra (mean)	49	54	50	57
Okra/sorghum (mean)	50	54	51	57
Okra/maize (mean)	53	58	53	57
Okra/Sorghum/ maize (mean)	53	58	53	58
LSD(0.05)	2.06	1.91	1.38	1.65

MOS1 : Maize/okra/White Sorghum Intercrop ; MO : Maize/Okra Intercrop ; MOS2 : Maize/Okra/Red Sorghum Intercrop ; O : Okra (NHAe47-4) ; S1O : White sorghum/okra intercrop ; S2O: Red sorghum/okra intercrops.

c) Okra yield and Pod components

i. *Yield frequency*

a. 2009 season

Shown in Figure 9 is the frequency of okra pod harvest during 2009 and 2010 seasons in both monoculture and mixtures of okra/maize (MO), okra/white sorghum (S1O) and maize/okra/white sorghum (MOS1). In 2009, fresh pod yield of okra intercropped with white sorghum (S1O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 12pods at 8WAP through 26 pods at 10WAP and reach peak value of 26.33pods at 12WAP while the least harvest of 8.67pods was observed at 16WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 5.67 pods at 8WAP through 12.67pods at 10WAP and reach peak harvest of 21pods at 12WAP while the lowest yield of 5.33pods was also observed at 16WAP. The pod yield in white sorghum/okra (S1O) mixtures was 8.33, 20.33, 39 and 8pods at 8, 10, 12 and 16WAP respectively. Also, the pod yield in maize/okra/white sorghum (MOS1) mixtures was 7, 14.67,27 and 5pods at 8, 10, 12 and 16WAP respectively.

In treatments containing red sorghum, fresh pod yield of okra intercropped with red sorghum (S2O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 9pods at 8WAP through 35 pods at 10WAP and reach peak value of 43pods at 12WAP while the least harvest of 8pods was observed at 16WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 3.33 pods at 8WAP through 13.33pods at 10WAP and reach peak harvest of 16.66pods at 12WAP while the lowest yield of 4pods was also observed at 16WAP. The pods yield in red sorghum/okra (S2O) mixtures was 4.67, 27.67, 30 and 6pods at 8, 10, 12 and 16WAP respectively. Also, the pod yield in maize/okra/red sorghum (MOS2) mixtures was 2.33, 15.67,18 and 4pods at 8, 10, 12 and 16WAP respectively.

b. 2010 season

In 2010 season, pod yield of okra intercropped with white sorghum (OS1) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 7pods at 8WAP through 13 pods at 10WAP and reach peak value of 42pods at 14WAP while 11pods was harvested at 20WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 7.67pods at 8WAP through 19.33pods at 10WAP and reach peak harvest of 39.67pods at 18WAP while 6pods was harvested at 20WAP. The yield in white sorghum/okra (S1O) mixtures was 17.33, 25.67, 89 and 10pods at 8, 10, 14 and 20WAP respectively. Also, the yield in maize/okra/white sorghum (MOS1) mixtures was 6.33, 22, 40 and 5.67pods at 8, 10, 18 and 20WAP respectively.

In red sorghum treatment combinations, fresh pod yield of okra intercropped with red sorghum (S2O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 6.67pods at 8WAP through 28.67 pods at 10WAP and reach peak value of 95pods at 18WAP while 13pods was harvested at 20WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 2pods at 8WAP through 3.33pods at 10WAP and reach peak harvest of 21.67pods at 18WAP while 6pods was harvested at 20WAP. The yield in red sorghum/okra (S2O) mixtures was 4.33, 25.67, 61 and 11.33pods at 8, 10, 14 and 20WAP respectively. Also, the yield in maize/okra/ red sorghum (MOS2) mixtures was 2.33, 10.66, 38.67 and 5pods at 8, 10, 18 and 20WAP respectively.

2009 2010

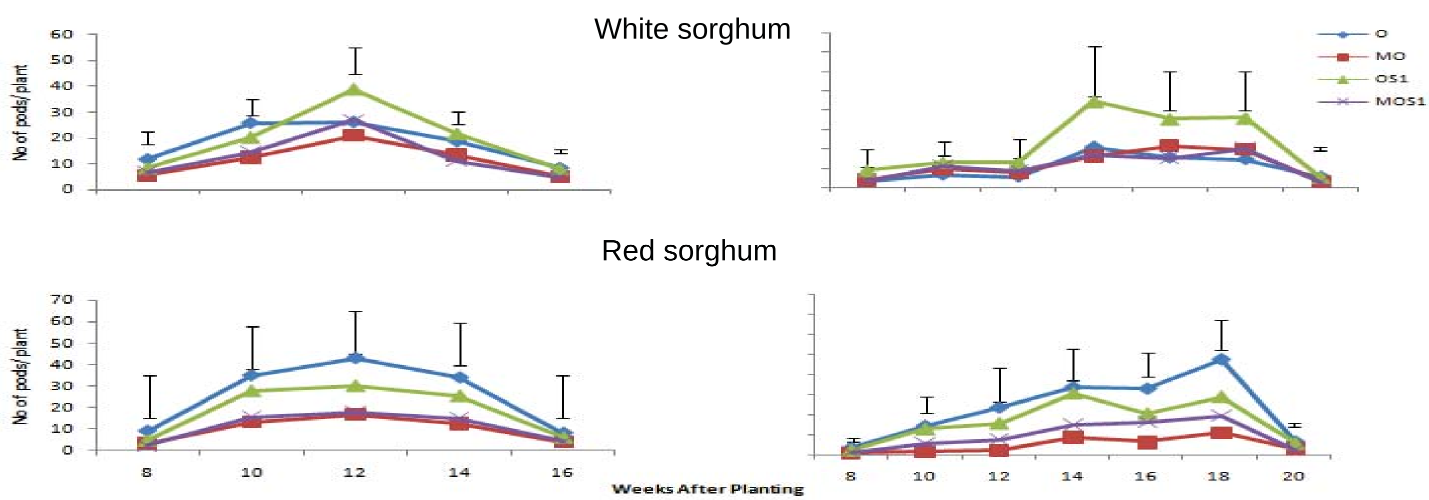

Figure 9 : Effects of intercropping okra with sorghum cultivars and maize on the yield frequency of fresh okra pods during 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

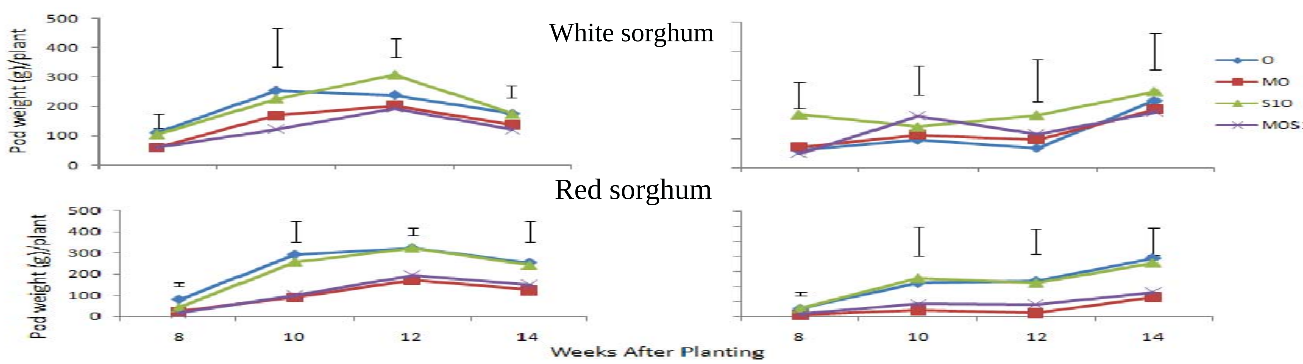

Figure 10 : Effects of Intercropping two sorghum cultivars and maize on the weight (g) of fresh okra pods per plant in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

ii. *Okra Pod weight*

a. 2009 season

The weight of fresh okra pods in monoculture and mixtures of okra/white sorghum (S1O), okra/ red sorghum (S2O), okra/maize (MO) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 8,10,12 and 14 weeks after planting (WAP) is presented in figure 10. The figure showed that the pods weight in both monoculture and mixtures was statistically difference at all sampled occasions except at 8WAP. Similarly pod weight of okra in red sorghum (S2) treatment showed significant

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difference ($p<0.05$) at all sampled occasions. Pod weight of sole okra (O) in white sorghum (S1) treatments ranged from 111.18 to 253.18g whereas pod weight of sole okra (O) in red sorghum (S2) treatment ranged from 80.67 to 324.00g. Pod weight of Okra (O) in okra/white sorghum mixtures (S1O) increased from 106.07 to 307.27g while the value in red sorghum (S2) treatment for okra/red sorghum mixtures (S2O) increased from 42.82 to 325.50g. In the mixtures of maize/okra (MO) in white sorghum treatment, the values ranged from 59.64 to 201.77g compared with that in red sorghum treatment that ranged from 25.20 to 170.50g. In maize/okra/sorghum mixtures, pod weight in white sorghum treatment for maize/okra/white sorghum (MOS1) increased from 60.65 to 192.94g while the values in red sorghum treatments for maize/okra/red sorghum (MOS2) combination increased from 15.53 to 194.81g.

b. 2010 season

Pod weight was significantly different at all sampled occasions except at 8 weeks after planting for treatments containing white sorghum (S1) cultivar. Similarly, the difference in pod weight was significant for treatments containing red sorghum (S2) at all sampled occasions. Pod weight of okra in white sorghum treatment for sole okra (O) ranged from 59.40 to 230.50g whereas the values in sole red sorghum treatments ranged from 52.08 to 387.20g. Pod weight in okra/white sorghum mixtures (S1O) ranged from 140.00 to 561.60g while the corresponding values in red sorghum treatment for okra/red sorghum mixtures (S2O) ranged from 52.47 to 356.02g. In the mixtures of maize/okra (MO), pod weight ranged from 71.45 to 200.00g compared to the values in maize/okra (MO) that ranged from 10.00 to 129.08g. In maize/okra/sorghum mixtures, pod weight in maize/okra/white sorghum (MOS1) ranged from 48.62 to 191.30g while the corresponding values in maize/okra/red sorghum (MOS2) combination from 15.28 to 162.00g. Generally, pod weight of okra in both sorghum cultivars was higher than the pod weight in sorghum/maize intercrop during 2009 and 2010 season.

iii. *Pods components*

Number of pods, pod weight, pod length, pod diameter and pod yield of okra in 2009 and 2010 seasons in both monoculture and mixed stands are presented in Table 2. These characters varied significantly among the treatments in both 2009 and 2010 seasons. Yield characters in 2010 season were generally higher than their corresponding values in 2009 season. Pods attributes in okra/sorghum mixtures regardless of the sorghum cultivars were significantly higher than pods attributes obtained in okra/maize mixtures in both 2009 and 2010 seasons.

a. Number of pods/plant

Number of pods per plant in white sorghum mixtures was generally higher than in red sorghum mixtures in both 2009 and 2010 season. In 2009 season, for white sorghum mixtures, the highest number of pods/plant was from S1O mixtures (10 pods/plant) followed by Sole okra (O) with 9 pods/plant then MOS1 mixtures with 7 pods/plant while the least values came from MO mixtures with 6 pods/plant. In case of red sorghum mixtures, numbers of pods were in the following order sole okra (12 pods/plant), followed by S2O mixtures with 9 pods/plant then MOS2 mixtures with 6 pods per plant while MO mixtures had lowest number of pods per plant (5 pods/plant).

The trend of number of pods/plant in 2010 season revealed that in white sorghum mixtures, the highest pods/plant was from S1O mixtures with 22 pods/plant followed by MO mixtures with 12 pods/plant then MOS1 with 11 pods/plant while sole okra (O) produced the least with 10 pods/plant. On the other hand, in red sorghum mixtures, sole okra (O) had highest pods/plant with 23 pods followed by S2O mixtures with 16 pods/plant then MOS2 mixtures which had 10 pods/plant while the lowest was from MO mixtures with 5 pods/plant.

b. Pod length/plant (cm)

Table 2 also shows the length of fresh okra pods/plant in monoculture and mixtures of okra/white sorghum (S1O), okra/ red sorghum (S2O), okra/maize (MO) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) in 2009 and 2010 seasons at NIHORT, Ibadan. Pods length in both monoculture and mixtures was statistically difference among the treatment means with pods length in sorghum cultivars mixtures having higher values than in maize mixtures in both 2009 and 2010 seasons. Generally, pod length/plant in white sorghum was slightly higher than corresponding values from red sorghum. In 2009 season, for white sorghum mixtures, S1O mixtures had longest pods of 4.3 cm followed by sole okra (O) with 4.2 cm then MO mixtures with 3.5cm while the shortest pod was obtained in MOS1 mixtures with 3.4 cm. Whereas, in the mixtures containing red sorghum cultivar the values were in the following order, sole okra (O) (4.6 cm) followed by S2O mixtures with 4.5 cm then MOS2 which had 3.2 cm while MO mixtures produced shortest pod of 2.9 cm.

In white sorghum mixtures during 2010 season, pods length of okra in S1O mixtures had longest pod of 5.0 cm followed by MOS1 mixtures with 4.8cm then MO mixtures with 4.4cm while the shortest pod (3.2cm) was found in sole okra (O). In contrast, for red sorghum mixtures, longest pod of 4.9 cm was obtained in sole okra (O) followed by 4.6 cm from S2O mixtures then 3.5 cm from MOS2 mixtures while shortest pod of 2.9 cm was from MO mixtures.

c. Pod diameter/ plant (mm)

Trend of pod diameter in 2009 season, for white sorghum mixtures, as shown in Table 2 revealed that the highest pod diameter was from S1O mixtures (21.5mm) followed by Sole okra (O) with18.6mm then MOS1 mixtures with 17.4mm while the least values came from MO mixtures with 17.2 mm. In case of red sorghum mixtures, pods diameter were in the following order sole okra (23.4mm), followed by S2O mixtures with 20.6mm then MOS2 mixtures with 16.4 mm while MO mixtures had lowest pod diameter of 13.9 mm.

In 2010 season for white sorghum mixtures, the highest pods diameter was from S1O mixtures with 24.8 mm followed by MOS1 mixtures with 23.9 mm then MO with 21.8 mm while sole okra (O) had the least with 19.9 mm. On the other hand, in red sorghum mixtures, sole okra (O) had highest pods diameter with 24.2 mm followed by S2O mixtures with 21.5 mm then MOS2 mixtures which had 21.0 mm while the lowest was from MO mixtures which had 15.1 mm.

d) Okra yield (tha^{-1})

In 2009 season, in white sorghum mixtures, the highest pod yield was obtained in okra/white sorghum mixtures (S10) (3.1tha^{-1}), followed by sole okra (O) (2.8 tha^{-1}), then okra/maize mixtures (MO) (2.0 tha^{-1}) while the least pod yield is from maize/okra/white sorghum mixtures (MOSI) (1.9 tha^{-1}). The result showed that for red sorghum treatment combinations, the highest pod yield is obtained in sole okra (O) (4.2 tha^{-1}), followed by okra/red sorghum mixtures (S2O) (3.4 tha^{-1}), then maize/okra/red sorghum mixtures (MOS2) (2.1 tha^{-1}) while the least pod yield was obtained in maize/okra mixtures (MO) (1.8 tha^{-1}) the mean yields were statistically different.

Similarly during 2010 season, in white sorghum combinations, the highest pod yield was recorded in okra/ white sorghum mixtures (S1O) (9.9 tha^{-1}), followed by sole okra (O) (5.5 tha^{-1}) then maize/okra/white sorghum mixtures (MOS1) (4.4 tha^{-1}) while the least yield was obtained in maize/okra (MO) (4.3 tha^{-1}). Whereas in red sorghum combinations, the yield were in the following order, sole okra (O) (9.5 tha 1) followed by red sorghum/okra mixtures (S2O) (7.1tha^{-1}), then maize/okra/red sorghum mixtures (MOS2) (3.6 tha^{-1}) while the least yield in maize/okra (MO)(2.1tha^{-1}).

IV. Conclusion

The study proved that growing okra between sorghum rows rather than okra/maize mixtures is more valuable cropping option to diversify food production and improve economic returns for farmers and starch-based diets of the people in forest-savanna transition zone of Nigeria. This study also indicates that intercropping okra with sorghum varieties resulted in vegetative and yield comparable to the sole okra. Okra in monoculture or mixed stand showed great potential for environmental modification. Study confirmed that minimal rainfall availability prolong harvesting period of okra as witnessed in the experiment and the optimum planting date for okra production must be the one which will make the period of harvest coincide with the period when minimal rainfall is steady and not the peak rainfall. Again, in order to reduce the risk of total crop loss to peasant farmers due to unpredictable weather conditions, okra/sorghum intercropped is highly recommended as their combinations maximize the use of available environmental resources at all season and therefore reduce the potential negative impact of climate change on component crops.

Table 2 : Effects of intercropping sorghum cultivars and maize on the yield characters of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

Treatment	2009 No of pods/plant	2009 Pod weight (g)	2009 Pod length (cm)	2009 Pod diameter (mm)	2009 Pod yield (t/ha)	2010 No of pods/plant	2010 Pod weight (g)	2010 Pod length (mm)	2010 Pod diameter (mm)	2010 Pod yield (t/ha)
White Sorghum										
O	9	38.9	4.2	18.6	2.8	10	22.7	3.2	19.9	5.5
MO	6	28.3	3.5	17.2	2.0	12	24.0	4.4	21.8	4.3
S1O	10	40.7	4.3	21.5	3.1	22	38.2	5.0	24.8	9.9
MOS1	7	24.9	3.4	17.4	1.9	11	26.8	4.8	23.9	4.4
Red Sorghum										
O	12	47.6	4.6	23.4	4.2	23	44.9	4.9	24.2	9.5
MO	5	20.6	2.9	13.9	1.8	5	10.2	2.9	15.1	2.1
S2O	9	43.5	4.5	20.6	3.4	16	44.3	4.6	21.5	7.1
MOS2	6	23.1	3.2	16.4	2.1	10	17.1	3.5	21.0	3.6
LSD (0.05)	5.63	15.35	1.19	3.85	0.82	9.26	18.21	2.27	7.02	4.67
White sorghum (mean)	9	33.2	3.9	18.7	2.5	14	27.9	4.4	22.6	6.0
Red sorghum (mean)	8	33.7	3.8	18.6	2.9	14	29.1	4.0	20.4	5.6
LSD (0.05)	2.05	7.65	1.2	4.40	0.75	3.80	9.82	2.1	7.40	0.51
Sole okra (mean)	11	43.2	4.4	21.0	3.5	17	33.8	4.0	22.0	7.5
Okra/sorghum (mean)	10	42.1	4.4	21.1	3.3	19	41.3	4.8	23.1	8.5
Okra/maize (mean)	5	24.4	3.2	15.5	1.9	8	17.1	3.6	18.4	3.2
Okra/maize/sorghum (mean)	6	24.0	3.3	16.9	2.0	10	22.0	4.1	22.4	4.0
LSD (0.05)	3.24	10.34	1.12	4.96	1.32	10.35	12.65	1.93	7.77	3.6

MOS1 : Maize / okra / White Sorghum Intercrop ; MO : Maize / Okra Intercrop ; MOS2 : Maize / Okra / Red Sorghum Intercrop ; O : Okra (NHAe47-4) ; S1O : White sorghum / okra intercrop ; S2O : Red sorghum/okra intercrops.

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