



Agronomic Evaluation of Performance of Sesame Varieties in Maize-based Intercropping System in the Southern Guinean Savanna of Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author ATA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author GOK performed the statistical analysis and corrected the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Field experiments were conducted to determine compatibility of sesame varieties for intercropping with maize.

Study Design: The experiment was a randomized complete block design with three replications.

Place and Duration of Study: Teaching and Research Farm, LAUTECH, Ogbomoso, southern guinea savanna area of Nigeria during the 2010 and 2011 cropping seasons.

Methodology: The treatments included Sole maize (Oba Super 1 variety), five sole sesame varieties (E-8, O3I, O1m, O2 m, Exotic-Sudan) and their intercrops, making a total of eleven treatments. Sole maize was planted at a spacing of 75 cm x 25 cm. For intercrops, maize was planted at a spacing of 100 cm x 25 cm and sesame seeds were planted at a spacing of 100 cm x 10 cm such that sesame row alternated maize row. Maize was planted first and sesame was introduced two weeks after.

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Results: Intercropping maize with sesame varieties significantly ($P = 0.05$) reduced number of pods and grain yield of sesame varieties in both years. However, variety O2m produced grain yield in the intercrop similar to the mono crop. Generally, Intercropping sesame with maize significantly reduced the grain yield of maize by 36% compared to the sole crop. Exotic-Sudan varieties caused the highest percentage yield reduction (52%). Sesame varieties O2m and O3l were the only varieties whose yield advantage in intercropping with maize had land equivalent ratio (LER) of 1.28 and 1.18 while other varieties had values less than 1 indicating yield advantage of O2m and O3l with maize. The relative crowding coefficient (K) value of maize (4.98) was higher than sesame (0.44) thus indicating its dominance in the mixture.

Conclusion: It is concluded that the prospective sesame farmers could grow varieties O2m and O3l in place of the popular E-8 because intercropping with maize did not affect their performances in both years.

Keywords: Sesame varieties; maize; intercropping; crop compatibility; Southern Guinean savanna zone.

1. INTRODUCTION

Traditional agriculture, as practised through the centuries, has always included different forms of intercropping. Farmers intermingled a variety of crops, in the same field, to sustain themselves and their families. In many developing countries, traditional agricultural systems are based on the growing of crops in mixtures [1]. According to [2], multiple cropping is the most dominant cropping system in Nigeria and it is the best cropping system for the soil of the humid tropics. Intercropping has been associated with such advantages as better utilization of environmental factors, greater yield stability, soil protection, variability of food supply, increasing the return per unit area and insurance against crop failure [3]. Intercropping using improved cultivars of crop and improved agronomic practices remains the most feasible approach to optimise crop production and maximise the use of available land [4].

In most traditional cropping systems in Nigeria, maize is one of the most prominent crops severally intercropped with assorted crops thereby forming an integral component of various cropping systems [5]. It is the most popular cereal due to its high yielding, ease of processing and easy digestibility than other cereals [6]. Also, it is a versatile crop that grows across a range of agro-ecological zones [7].

Sesame (*Sesame indicum* L.) also known as beni-seed belong to the Pedaliaceae family and genus *Sesamum* [8]. Sesame is a fairly high valued food crop harvested for its whole seeds [9]. It is one of the most ancient crops grown for its oil rich seeds. It is increasingly gaining

popularity in Nigerian agriculture because of the economic importance of its seeds in the world market and the nutritional content of its leaves when used as a vegetable [10]. Sesame seeds are also used in various food preparations, raw or roasted. The seeds are unusually high in oil around 50% and protein content of 21% [11] which is highly comparable to those of other prominently grown legumes including groundnut and soybean. Sesame oil is colourless and odourless. The presence of important antioxidants such as sesaminol, sesamol and tocopherol makes sesame oil highly preserveable as it does not get rancid [12]. The high demand for sesame has also been attributed to the fact that products from sesame meet the health requirements for food in the developed countries and has become an important part of their diet [13]. After the oil is extracted from the seed, the remaining meal is a high protein material suitable for feeding livestock [9]. The oil is also used as a carrier for medicines and perfumes and as synergist for pyrethrin-based insecticides. Poor grades are used in the production of soaps, paints, lubricants and lamp oil [14]. Nonetheless, in spite of its multi-dimensional uses, the commercial and mechanised cultivation of sesame in Nigeria is not very encouraging, and its yield is very low. On average 500 kg of sesame seeds is harvested per hectare in Nigeria [15] which is much lower than the average yield of other countries including Egypt (1120 kg/ha), Mexico (960 kg/ha) and China (900 kg/ha) [16].

The crop is grown under a range of environments, which probably affects its performance. The environmental factors that influence sesame productivity include climatic factors such as temperature, rainfall and day

length, soil types and management practices such as plant densities, time of sowing, irrigation, fertilisers, herbicides and fungicides, some of which may partially mitigate others [17,18]. Among the measures adopted to increase the production of sesame is the introduction of new varieties with high yield potentials as well as the application of suitable cultural practices such as fertilisation, and weed control etc.

Sesame had been successfully introduced into cropping systems in the different major growing and potential growing areas in Nigeria often grown as a sole crop, as well as in mixtures with cereals. Its integration into the farming systems reduces the risk of crop failure associated with growing sesame in pure stand and put less demand on labour and fertile land, both of which are limited in supply. The integration also restores soil fertility and suppresses weed [19].

Broadly speaking, the traditional cropping system is prone to the use of low yield crop cultivars, which results in low yield, due partly to species compatibility problem due to problems of severe competition [20,21,22,23].

Maximization of yields in crop mixtures will always be on the basis of high species compatibility [24] and the minimization of above and below ground competition for growth [25]. Crop compatibility is the most essential factor for the intercropping system. The success of any intercropping system depends on the proper selection of crop species where competition between them for light, space, moisture and nutrients is minimum [22,23]. A careful selection of crops could reduce competition to a considerable extent [26], increase overall production per unit of land and time [27]. As it is not all crops that grow well in mixtures, a careful study is necessary to assess the compatibility of different varieties to be intercropped.

Therefore, there is the need to develop sustainable system which will maximize gains from high compatibility with other crops. Thus, the objective of this study was to evaluate the compatibility of sesame varieties for intercropping with maize.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria between 3rd

June and 20th November in 2010 and 7th May and 28th October in 2011. The climatic condition of the area is mostly influenced by the north-east trade wind and the south-west trade wind. The area has a minimum temperature of 28°C and a maximum of 33°C. The humidity of the area is high (74%) all year round except in January when the dry wind from the north flows in. The annual rainfall of the area is between 1150 mm-1250 mm.

2.2 Treatments and Experimental Design

Maize (Oba Super 1 variety) and five sesame varieties (E-8, O3I, O1m, O2m, Exotic-Sudan) were used for the experiment. Oba Super 1 is white coloured maize developed by Premier Seed, Nigeria Limited of Chikayi Industrial Estate, Zaria. The hybrid maize was selected on the basis of its high yield, adaptability to the climatic zone and its resistance to diseases, especially striga. Sole maize, five sole sesame varieties (E-8, O3I, O1m, O2m, Exotic-Sudan) and their intercrops, making a total of eleven treatments, were laid out in a randomized complete block design with three replications. The total experimental area was 16 m x 27 m (432 m²) and plot size was 4 m x 3 m. Each replicate measured 4 m x 27 m (108 m²) separated by a 2 m path.

2.2.1 Planting and cultural practices

For sole sesame plantings, two pinch of seeds were planted per hole at a spacing of 60 cm x 10 cm and later thinned to one plant per stand to give a plant population of 16666.67 plants/ha [16]. Also for sole maize, two seeds were planted per hole at a spacing of 75 cm x 25 cm and the seedlings later thinned to one stand to give a plant population of 533.33 plants/ha. For intercrops, maize was planted at a spacing of 100 cm x 25 cm and sesame seeds were planted at a spacing of 100 cm x 10 cm. Sesame row alternated maize row, that is, sesame was planted in between 2 maize rows. Maize was planted first on the 3rd June in 2010 and 7th May in 2011. Sesame was introduced two weeks after in both years [19]. Weeding was done with the native hoe at 3 and 6 weeks after planting (WAP). The recommended rate of compound fertilizer NPK (15:15:15) for sole maize: 100 kg N/ha, 40 kg P/ha and 60 kg K/ha; for sole sesame: 30 kg N/ha, 30 kg P/ha and 30 kg K/ha and for maize-sesame intercrop: 100 kg N/ha, 100 kg P/ha and 100 kg K/ha were applied [28]. The band method of

fertiliser application was employed. The fertiliser was applied twice to each plot at 3 and 6 WAP.

2.3 Harvesting and Data Collection

Ten maize and sesame plants were randomly selected from the net plot (3 m x 2 m) and tagged for data collection. Data were collected on number of pods of sesame per plant, sesame seed weight (g/plot) and maize grain weight (g/plot). Numbers of pods per plant were determined by direct counting followed by total seed weight obtained from the net plot (3 m x 2 m) and converted to the seed yield (kg/ha). Sesame harvesting commenced on 4th October in 2010 and 4th September in 2011, when lower leaves, pod and stem turned to lemon yellow colour. Harvesting was done by cutting the plants from ground level and these were bundled. Bundles of harvested plants were sun dried. Fully matured maize cobs were harvested on 12th November in 2010 and 7th September in 2011, when the leaves turned yellowish and fallen off, which were signs of senescence and cob maturity [29]. The maize cobs were fully dried and dehusked after which the grains were separated from the cob. The seeds were winnowed, cleaned and weights of seeds obtained from each net plot were recorded.

2.3.1 Intercropping indices

The various intercropping indices were worked out.

2.3.2 Land equivalent ratio (LER)

Land equivalent ratio (LER) was used as criterion for measuring efficiency of intercropping advantage. When the value of LER is greater than one, the intercropping favors the growth and yield of the species. When LER is lower than one the intercropping negatively affects the growth and yield of crops grown in mixtures and if LER is equal to one, then it indicates no profit, no loss from the intercropping. Land equivalent ratio (LER) was calculated using the formula of [30]:

$$\begin{aligned} \text{LER} &= (\text{Ls} + \text{Lm}) \\ \text{Ls} &= (\text{Ysm}/\text{Yss}) \\ \text{Lm} &= (\text{Yms}/\text{Ymm}) \end{aligned}$$

Where Ysm = sesame seed yield in mixture,

Yss = sesame seed yield in pure stand
Yms = maize grain yield in mixture
Ymm = maize seed yield in pure stand

2.3.3 Land equivalent coefficient (LEC)

Land equivalent coefficient (LEC) was calculated to measure the intercrop interaction using the formula of [31]:

$$\text{LEC} = (\text{Ls} \times \text{Lm})$$

2.3.4 Relative crowding coefficient (K)

Relative crowding coefficient (K) was calculated to measure the dominance of one species over the other in the mixture using the formula of [32]:

$$\text{K} = \text{Ks} \times \text{Km}$$

Where $\text{Ks} = \text{Ysm} \times \text{Zms} / (\text{Yss} - \text{Ysm}) \times \text{Zsm}$ and $\text{Km} = \text{Yms} \times \text{Zsm} / (\text{Ymm} - \text{Yms}) \times \text{Zms}$
Zsm = proportions of sesame in the intercrop and
Zms = proportions of maize in the intercrops

When the value of K is greater than 1, there is a yield advantage, when it is equal to 1, there is no yield advantage and if less than 1 there is no yield advantage and the system has disadvantage.

2.3.5 Competitive ratio (CR)

Competitive ratio (CR) was calculated to measure the degree with which one crop competes with the other using the formula of [33]:

$$\begin{aligned} \text{CR (sesame)} &= \text{Ls} \times \text{Zsm}/\text{Lm} \times \text{Zms} \\ \text{CR (maize)} &= \text{Lm} \times \text{Zms}/\text{Ls} \times \text{Zsm} \end{aligned}$$

2.3.6 System productivity index

System productivity index was calculated using the formula of [34]:

$$\text{SPI} = (\text{Yss} / \text{Ymm} \times \text{Yms}) + \text{Ys}$$

2.4 Data Analysis

Data was analyzed using analysis of variance (ANOVA) and means were compared using least significant difference (LSD) at 5% level of probability [35].

Table 1. Details of sesame varieties used in this study

Variety	Days to maturity	Seed color	Seed size (mm)	Oil content (%)	Potential yield (kg/ha)
O1m	102-115	White	3	45%	1000
O2m	102-115	Light brown	3	45%	750
O3l	125-140	Brown	2	40%	600
E-8	90	White	3.6	50%	1000
Exotic-Sudan	90	White	2.0	50%	1200

Source: [36,37]

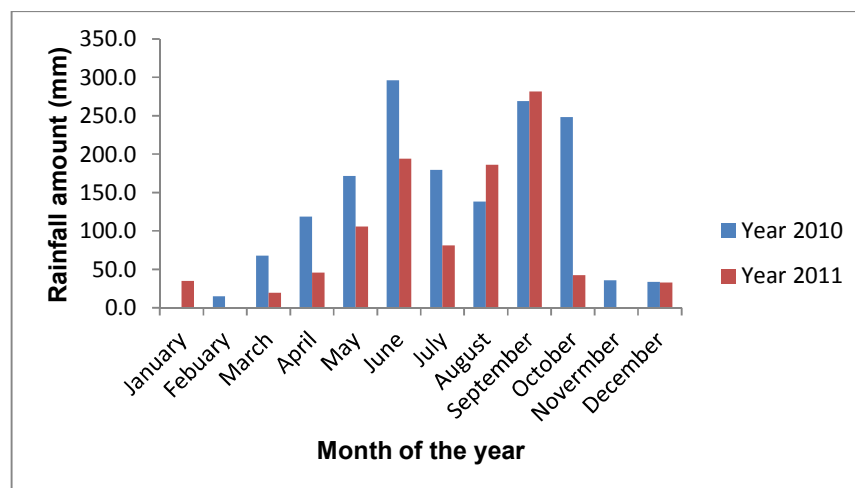


Fig. 1. Rainfall record of the study area in year 2010 and 2011

3. RESULTS AND DISCUSSION

3.1 Rainfall Record of the Study Area

The total annual rainfall of study area was 1539.3 mm and 990.3mm in 2010 and 2011, respectively (Fig. 1). The highest total annual rainfall was recorded in the year 2010 which was above the average of the study area (1150 mm-1250 mm).

3.2 Number of Pods and Seed Yield of Sesame Varieties

The effect of cropping system on number of pods and seed yield of sesame is as presented in Tables 2 and 3. Cropping system had significant effect ($P = 0.05$) on the number of pods and seed yield of sesame in both planting seasons. Significantly higher number of pods and seed yield was recorded in the sole cropping system.

There was no significant difference in the seed yield of the intercropped sesame except in 2010. Among the intercropping treatments in 2010, O3l

and O2m recorded significantly higher seed yield, while O1m produced the least.

Variety had no significant effect ($P = 0.05$) on number of pods per plant except on sesame seed yield. However, in 2010 planting season, significantly higher seed yield was recorded in the O3l variety which was comparable to O1m and E-8 varieties, while the least seed yield was recorded in the Exotic-Sudan variety. In 2011 planting season, significantly higher seed yield were recorded in the E-8 variety which was comparable to O1m and O3l varieties, while the least seed yield was recorded in the Exotic – Sudan and O2m varieties.

3.3 Seed Yield of Maize

The effect of intercropping on maize grain yield is as presented in Table 4. Grain yield of maize measured in all the intercrop plot was significantly ($P = 0.05$) reduced compared to the sole crop in 2010. However in 2011, sole maize yield (2188 kg/ha) was comparable to values recorded in maize plots intercropped with O1m (2090 kg/ha) and O2m (1911 kg/ha) varieties.

Table 2. Effect of cropping system on number of pods/plant

Variety	Cropping system (2010)			Cropping systems (2011)		
	Sole	Intercrop	Mean	Sole	Intercrop	Mean
O1M	72	14	43	53	12	32
O2M	43	22	32	41	20	31
O3L	73	32	53	53	24	38
E-8	87	16	51	81	14	47
Exotic-Sudan	59	14	37	45	12	29
Cropping system	67	20		55	16	
Mean						
LSD _{0.05} cropping system (2010)	15					
LSD _{0.05} variety (2010)	ns					
LSD _{0.05} cropping system (2011)	19					
LSD _{0.05} variety (2011)	ns					

Table 3. Effect of cropping system on sesame seed yield (kg/ha)

Variety	Cropping system (2010)			Cropping systems (2011)		
	Sole	Intercrop	Mean	Sole	Intercrop	Mean
O1m	466	72.97	190.84	331.70	49.78	269.60
O2m	266	145.67	132.45	177.33	81.57	205.95
O3l	469.33	227.31	236.33	376.00	96.67	348.32
E-8	489.00	103.31	276.38	471.00	81.77	296.16
Exotic-Sudan	241.67	82.10	111.95	184.33	39.57	161.88
Cropping system	386.49	126.27		308.11	71.07	
mean						
LSD _{0.05} cropping system (2010)	70.88					
LSD _{0.05} variety (2010)	112.08					
LSD _{0.05} cropping system (2011)	84.27					
LSD _{0.05} variety (2011)	ns					

Table 4. Effect of cropping system on maize yield (kg/ha)

	2010	2011
	Maize yield (kg/ha)	Maize yield (kg/ha)
Sole maize	2048	2188
O1m + maize	1492	2090
O2m + maize	1392	1911
O3l + maize	1468	1408
E-8 + maize	1224	1443
Ex-Sudan + maize	984	1209
LSD _{0.05}	672	909

Table 5. Effect of intercropping on of LER and K in maize-sesame intercrop

	2010			2011		
	LER	K of sesame	K of Maize	LER	K of sesame	K of maize
O1m + maize	0.91	0.19	2.68	1.11	0.18	2.1
O2m + maize	1.23	0.46	2.21	1.36	0.98	6.9
O3l + maize	1.20	0.94	2.53	1.16	0.35	1.81
E-8 + maize	0.80	0.29	1.49	0.83	0.21	1.94
Ex-Sudan + maize	0.83	0.51	0.92	0.76	0.27	1.24

Table 6. Effect of intercropping on of SPI, CR and LEC in maize-sesame intercrops

	2010				2011			
	SPI	CR of sesame	CR of maize	LEC	SPI	CR of sesame	CR of maize	LEC
O1m + maize	1816	0.13	0.80	0.13	2418	0.14	0.87	0.14
O2m + maize	2038	0.38	0.56	0.38	2991	0.36	0.64	0.43
O3l + maize	2462	0.35	0.60	0.35	2553	0.45	0.55	0.33
E-8 + maize	1657	0.13	0.75	0.13	1823	0.20	0.80	0.11
Ex-Sudan + maize	1679	0.15	0.58	0.15	1679	0.28	0.72	0.12

3.3 Determination of LER, LEC, K, CR and SPI in Maize-sesame Intercrops

3.3.1 Land equivalent ratio (LER) and relative crowding coefficient (K)

The land equivalent ratio (LER) and relative crowding coefficient (K) of maize-sesame intercrops in 2010 and 2011 is presented in Table 5. A land use advantage (i.e. LER > 1) was recorded in O2m and O3l varieties over their sole crops. Intercropping maize into sesame with O2m and O3l resulted in LER 1.23, 1.20 and 1.36, 1.16 in 2010 and 2011, respectively. In both planting seasons land use advantage of intercropping O2m and O3l (1.28 and 1.18) was superior to that of sole crop, while other varieties had LER less than one. The total LER was highest with the O2m and O3l.

The total LER in sesame intercrop varieties in both years were less than 1.0, indicating that there was an intercropping disadvantage.

The relative crowding coefficient (K) values of maize was higher than sesame, thus indicating its dominance in the mixture. However, the sesame intercrop K values were less than 1, thereby indicating that sesame crop produced less yields than expected.

3.3.2 System productivity index (SPI), competitive ratio (CR) land equivalent coefficient (LEC)

The system productivity index (SPI), competitive ratio (CR) land equivalent coefficient (LEC) of maize-sesame intercrops in 2010 and 2011 is presented in Table 6. The system productivity index (SPI) which standardized the yield of the secondary crop (sesame) in terms of the primary crop (maize) and also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance showed that the O3l and O2m varieties (2462

and 2991) gave the highest values than the other arrangements and monoculture in the year 2010 and 2011 respectively. The values of SPI were higher and largely determined by maize intercrop yields which were not reduced much by intercropping with sesame.

The CR values of maize were generally greater than those of sesame irrespective of crop combinations. Among the five sesame varieties, O1m had the highest CR maize values (0.82 and 0.87), while O2m had the highest sesame CR values (0.44 and 0.36) in year 2010 and 2011, respectively. Regardless of the intercrop variety, there was a positive sign for intercropped maize and a negative sign for the intercropped sesame, indicating that sesame was dominated. The positive sign indicated the dominant crop while the negative sign indicated the dominated crop.

Land equivalent coefficient (LEC), in terms of intercrop compatibility for the maize/sesame, O2m and O3l intercrop recorded LEC values (0.35, 0.37 and 0.43, 0.33) greater than 0.25 derived from the expected 50:50 yield ratio from a mixture of two crops.

4. DISCUSSION

In the cropping season, intercropped number of pods per plant and sesame yields were generally low due to the shading effect by the taller and faster growing maize. This might probably have resulted due to reduction in solar radiation from shading by taller maize crops, which subsequently resulted in decreased yield. Generally, biomass production of shorter component crops is reduced by depression of photosynthesis due to reduction in solar radiation by shading of taller component crops. [38] had earlier reported reductions in both dry pod weight and dry grain yield of intercropped pigeon pea genotypes ascribing it to long competitive interactions with the traditional red sorghum, which, is endowed with unique proliferation of

robust fine root network equipped for better competition for below-ground growth resources. It must also be noted that [39] also reported that intercropping with wheat decreased the number of pods per plant of mustard and chickpea. The higher yield variable recorded in the sole sesame compared to the intercrop in both years agrees with the findings of [40]. [41] in maize cowpea mixtures as well as [38] in corn soybean and sorghum soybean intercrops that the sole crop components produced yield higher than the corresponding crops in intercropping situation. The result is also in line with the findings of [39] who reported that shading of sesame plants result in lower yield.

The LER recorded in sesame varieties O2m and O3I which was greater than 1 indicated there was a yield advantage from the intercropping. This in line with the findings of [30].

The relative crowding coefficient (K) values of maize indicated its dominance in the mixture. The sesame intercrop K values were less than 1, thereby indicating that sesame crop produced less yields than expected, presumably due to inadequate utilisation of resources. [30] that where the relative crowding coefficient of a particular crop species is less than, equal to or greater than 1, then that species produced less yield, the same yield or more than 'expected' yield, respectively. However, this is in disagreement with the findings of [41] who reported that sesame grown in association with mungbean, mashbean and cowpeas utilized the resources more aggressively than the respective sole crops.

However, in terms of intercrop compatibility for the maize/sesame, O2m and O3I intercrop recorded LEC values greater than 0.25 derived from the expected 50:50 yield ratio from a mixture of two crops [31]. The other intercropping systems that recorded $LEC < 0.25$ could be described as not giving complementary yield. The effect of the dominant crop (Maize) on the intercrop (O2m and O3I) with $LEC > 0.25$ showed competitive complementarily.

The relative crowding coefficient (K) values of maize were higher than those of sesame, thus indicating its dominance in the mixture. [30] reported that where the relative crowding coefficient of a particular crop species is less than, equal to or greater than 1, then that species produced less yield, the same yield or more than 'expected' yield, respectively. The sesame

intercrop K values were less than 1, thereby indicating that sesame crop produced less yields than expected, presumably due to inadequate utilization of resources. This is in disagreement with the findings of [41] who reported that sesame grown in association with mungbean, mashbean and cowpeas utilized the resources more aggressively than the respective sole crops.

The system productivity index (SPI) which standardized the yield of the secondary crop (sesame) in terms of the primary crop (maize) and also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance showed that the O3I and O2m varieties (2462 and 2991) gave the highest values than the other arrangements and monoculture in the year 2010 and 2011 respectively. The values of SPI were higher and largely determined by maize intercrop yields which were not much reduced by intercropping with sesame.

5. CONCLUSION

The two varieties (O2m and O3I) have intercropping potentials in the derived savanna transition zone. It is therefore suggested that the prospective sesame farmers could grow O2m and O3I in place of the popular E-8 because intercropping did not affect their performances in both years.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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