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Growth and Yield Performance of Sesame (*Sesamum indicum* L.) Varieties at Varying Levels of Inter-row Spacing in Northern Part of Sokoto, Nigeria

B. Mohammed[1*] and G. A. Hamidu[2]

[1]Desert Research Monitoring and Control Center, Yobe State University Damaturu, Nigeria.
[2]Department of Crop Science, Usmanu Danfodiyo University, Sokoto, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author BM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GAH managed the analyses of the study. Author BM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field trials were conducted at Dry Land Teaching and Research Farm Usmanu Danfodiyo University Sokoto during the 2015 and 2016 rainy seasons to study the Growth performance of sesame (*Sesamum indicum* L.) varieties at varying levels of inter-row spacing in the Northern part of Sokoto. The treatments consisted of four levels of inter-row spacing (40, 50, 60 and 70 cm) and three sesame varieties (Ex-Sudan, Gulbarga Local White and Tumkur Local Black). The treatments were arranged in a randomised complete block design (RCBD) replicated three times with factorial combinations of inter-row spacing and varieties. Results of the study indicated that inter-row spacing level of 70 cm consistently recorded the highest values for all the parameters studied. Similarly, the use of Tumkur Local Black variety of sesame showed superiority among the treatments in all the growth characters investigated except for leaf length per plant, leaf diameter per plant and leaf area

**Corresponding author: E-mail: muhbukar565@gmail.com;*

per plant where Ex-Sudan and Gulbarga Local White varieties respectively recorded the highest values. Besides, Gulbarga local white sesame variety had the highest seed yield when compared with the two other varieties. From the finding of this research, it could be concluded that Tumkur Local Black sesame variety planted at 70 cm inter-row spacing gave the highest growth performance compared to Ex-Sudan and Gulbarga Local white while Gulbarga Local white gave the highest yield performance of the crop under the same conditions.

Keywords: Inter-row spacing; sesame; varieties; growth.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) otherwise known as beniseed in Nigeria belongs to the division Spermatophyte and family Pedaliaceae. It is known by many names such as gingelly, simsim, sesame and till [1]. The crop is one of the most ancient oilseed crop known and used by humankind mainly due to its ease of extraction, high stability, and resistance to drought [2]. It is believed to have originated from tropical Africa [3]. However, India is held as the subcontinent where sesame was first domesticated and then spread to other places in the world such as Africa, the Far East, China and America along trade routes [4]. Sesame occupies the sixth position in the world production of edible oil and 12th position among world vegetable oils in 2001 [5]. All the wild species are found in Africa, and also the importance of Sesame in the economy of several African countries justify African continent to be the ultimate centre of origin [6].

Sesame crop is cultivated in almost all tropical and subtropical Asian and African countries for its highly nutritious and edible seeds [2]. Fifty-six percent of the world's production of the crop is in Asia, with Africa having a production analysis of about 44% [7]. The total world production of sesame in 2013 was 4,756,752 tonnes, of which Africa contributed 2,117,585 and Nigeria contributed 165,000 tonnes. The total area cultivated in 2013 for World and Africa were 9,398,770 ha and 4,741,100 ha with Nigeria cultivating about 340,000 ha. The average yields obtained from these hectares were 506.1 kg, 446.6 kg and 485.3 kg respectively [7]. In Nigeria, Sesame is widely grown in the Middle Belt, Northern and Central Nigeria as a minor crop. It became a major cash crop in many Northern States like Benue, Kogi, Gombe, Jigawa, Kano, Nasarawa, Katsina, Plateau, Yobe and Federal Capital Territory [8].

Sesame seed is rich in fat, protein, carbohydrates, fibre and some minerals. The oil seed is renowned for its stability because, it actively resists oxidative rancidity even after prolonged exposure to air [9]. The oil fraction shows remarkable stability to oxidation, and this could be attributed to endogenous antioxidants namely lignins and tocopherols [10,11]. The seed is rich in protein and has an excellent nutritional value similar to soybean [8]. The composition of sesame shows that the seed is a significant source of oil (44-58%), protein (18-25%), carbohydrate (~13.5%) and ash (~5%) [12]. Sesame seed is approximately 50 percent oil (out of which 35% is monounsaturated fatty acids and 44% polyunsaturated fatty acids) and 45 percent meal (out of which 20% is protein) [13]. According to [14], Sesame oil is used as a fixative in the perfumery industry, in various cosmetics as a carrier for fat-soluble substances, in pharmaceuticals as penicillin, in insecticides, paints and the manufacture of soaps. Sesame meal left after the oil is pressed from the seed is an excellent high protein (34 to 54%) feed for poultry and livestock. The young leaves of Sesame crop are used as soup vegetable in some areas of Africa, such as West Africa. Fried seeds are consumed in soups and eaten after sweetening with sugar [15].

Despite the high commercial potentials of sesame in the Nation's economy and its high nutritional values, research on the crop remains significantly scanty in the study area. However, lack of using appropriate inter-row spacing and high yielding varieties by farmers more often than not lead to low seed yield and productivity of the crop. Seed yield of 69.93kg/ha and 318.6kg/ha was obtained in the year 2006 and 2007 respectively with an inter-row spacing of 25cm [16]. Owing to these reasons, it is, therefore, important to devote time and resources to study the best ways to improve the growth performance of sesame regarding variety and inter-row spacing in the Northwestern region of Sokoto, Nigeria.

2. MATERIALS AND METHODS

The experiments were conducted during the 2015 and 2016 cropping seasons at the Usmanu

Danfodiyo University Teaching and Research Dryland Farm, (Latitude 13º01^{l}N and Longitude 5º15^{l}E) at Sokoto. The annual rainfall of the area ranges between 380 mm and 889 mm, the temperature ranges between 17ºC and 40ºC [17]. The climate of the area is dry sub-humid, characterised by a long dry season with cold, dry air during harmattan from November to February and hot dry air from March to May followed by short rainy season [18] cited in [19].

The treatments consist of four different inter-row spacing (40 cm, 50 cm, 60 cm and 70 cm) and three sesame (*Sesamum indicum* L.) varieties (Gulbarga Local White, Tumkur Local Black and Ex-Sudan) making up to 12 treatment combinations. The treatments were factorially combined and laid out in a Randomised Complete Block Design with three (3) replications. The treatments were randomly allocated to the plots using randomisation technique. All the plots received the same Agronomic practices. The main agronomic characteristics of the three varieties of sesame used include;

1. ex-Sudan is an exotic variety native to Sudan. It is a short duration variety maturing in 90 days [20]. The seed colour is white and contains about 50% oil. This type is capable of yielding up to 1,200 kg/ha, and 1,000 seeds of this variety weigh about 2.0 g.
2. *Gulbarga local white* is a medium duration variety that matures between 80 to 105 days. The seed colour is white and contains a high percentage of oil similar to ex-Sudan. This type of sesame variety is capable of yielding up to 1.0 to 1.5t ha^{-1} and 1000 seed of this variety weight about 2.0 g.
3. *Tumkur local black* is a long duration variety that grows and matures between 105 and 123 days. The seed colour is black and shiny in appearance with a low percentage of oil.

The experimental site was ploughed, harrowed, leveled and worked to fine tilt. The prepared land was then marked and subdivided into the required plots and replications in accordance with the layout of the experiment. The gross plot size was 3.0 m x 2.0 m (6m^2), consisting of rows each measuring 2.0 m in length with 20 cm intra-row spacing within each row. The inter-row spacing of 40, 50, 60 and 70 cm was used. Net plot size of 4.4, 4.0, 3.6 and 3.2m^2 for treatments with 40, 50, 60 and 70cm inter-row spacing was used with 6, 4, 3 and 2 inner rows for each. However, 2 border rows for each were used for destructive sampling.

The seeds were sown on the 4th July 2015 and 27th June 2016 for first and second trial respectively when soil moisture was adequate. A mixture of one part of sesame seed and two parts of river sand was planted manually at a shallow depth of about 1 cm, by the dibbling method. The plots were kept free of weed throughout the period of the Experiment. Removal of the unwanted plant was carried out with the use of hoe at 3 and 9WAS and by manually as weed appears.

Growth parameters such as a number of leaves, leaf length, leaf diameter, leaf area, and the number of branches were measured at 4, 6, 8 and 10WAS when the plants are at their growing stages. The data generated were subjected to analysis of variance (ANOVA) using STATISTIX 8.0 computer package. Means found to be statistically significant were compared using Dunkan's New Multiple Range Test (DNMRT).

3. RESULTS AND DISCUSSION

3.1 Number of Leaves per Plant

Results on the number of leaves per plant of sesame at 4, 6, 8 and 10 WAS as influenced by Inter-row spacing and Variety during 2015 and 2016 rainy seasons are presented in Table 1. Number of leaves of sesame was significantly ($P<0.05$) influenced by Inter-row spacing at 4 and 8WAS only in 2015 season, but in the subsequent growth stages, it was not significant ($P>0.05$). In 2015 season, at 4WAS, Inter-row spacing of 20x70 cm significantly ($P<0.05$) recorded the highest number of leaves per plant though was statistically the same with 20x50 cm spacing. The rest of the spacings were statistically the same in their number of leaves at 4 WAS. At 8 WAS, the same trend was observed. The number of leaves of sesame was not significantly influenced by inter-row spacing at 6 and 10 WAS during the 2015 season (Table 1). In 2016 season, number of leaves per plant of sesame was not significantly ($P>0.05$) influenced by inter-row spacing in all the growth stages studied (4, 6, 8 and 10 WAS). This agreed with the findings of [20], who reported that increased number of leaves leads to increase in capsule formation.

Table 1. Effect of inter-row spacing and variety on the number of leaf per plant of sesame at 4, 6, 8 and 10WAS during the 2015 and 2016 rainy seasons at Dry Land Teaching and Research Farm U.D.U.S

Treatment	2015				2016			
	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS
Spacing (S) in cm								
20 x 40	12.00[b]	28.00	52.00[b]	171.00	14.00	24.00	81.00	138.00
20 x 50	13.00[ab]	27.00	64.00[ab]	154.00	14.00	26.00	67.00	135.00
20 x 60	12.00[b]	22.00	48.00[b]	112.00	14.00	27.00	78.00	148.00
20 x 70	14.00[a]	30.00	78.00[a]	182.00	14.00	28.00	80.00	158.00
S.E±	0.54	2.21	6.14	24.35	0.33	2.02	7.25	9.94
Significant	*	Ns	*	Ns	Ns	Ns	Ns	Ns
Variety (V)								
Ex-sudan	12.00	22.00[b]	43.00[b]	78.00[b]	14.00[b]	19.00[b]	45.00[b]	80.00[b]
Tumkur Local Black	14.00	36.00[a]	87.00[a]	299.00[a]	15.00[a]	40.00[a]	132.00[a]	261.00[a]
Gulbarga Local White	13.00	23.00[b]	52.00[b]	87.00[b]	14.00[b]	19.00[b]	53.00[b]	94.00[b]
S.E±	0.47	1.92	5.32	21.09	0.29	1.75	6.28	8.61
Significant	Ns	*	*	*	*	*	*	*
Interaction								
S x V	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT)

** = Significant only at 5%, Ns = Not significant at 5%, WAS = Weeks after sowing*

S = Spacing and V = Variety

Number of leaves of sesame was not significantly (P>0.05) influenced by variety during the 2015 season at 4WAS only, but in the subsequent growth stages, it was significant (P<0.05) (Table 1). In 2015 season, at 4WAS, the number of leaves per plant was not significantly (P>0.05) influenced by variety. At 6, 8 and 10 WAS, Tumkur local black significantly (P<0.05) recorded the highest number of leaves per plant while the rest of the varieties were statistically the same in their number of leaves per plant. Similarly, in 2016 season, the number of leaves per plant of sesame was significantly (P<0.05) influenced by variety in all the growth stages studied (4, 6, 8 and 10 WAS). AT 4, 6, 8 and 10WAS, Tumkur local black significantly (P<0.05) recorded the highest number of leaves per plant while the rest of the varieties statistically had the same number of leaves. The significant difference between the three varieties in almost all the growth stages in terms of number of leaves may be attributed to the fast growth of sesame plants between emergence to 10WAS. This is in line with the findings of [21]. The interaction of spacing and variety on the number of leaves per plant was not significant (P>0.05) in both seasons.

3.2 Leaf Length per Plant

Results on the leaf length per plant of sesame at 4, 6, 8 and 10 WAS as affected by inter-row spacing and variety during the 2015 and 2016 rainy seasons are presented in Table 2. Leaf length of sesame was significantly (P<0.05) affected by Inter-row spacing in all the growth stages (4, 6, 8 and 10WAS) during 2015 season (Table 2). In 2015 season, at 4 and 10 WAS, inter-row spacing of 20x70 cm significantly (P<0.05) had the longest leaf length per plant though 20x40 and 20x60 cm spacing were statistically the same while 20x50 cm had the shortest leaf length per plant. At 6 WAS, inter-row spacing of 20x70 cm significantly (P<0.05) had the longest leaf length per plant while 20x60 cm inter-row spacing had the shortest leaf length. At 8WAS, 20x70 cm inter-row spacing significantly (P<0.05) had the longest leaf length whereas the rest of the spacing statistically had the same length (Table 2). In 2016 season, Leaf length of sesame was significantly (P<0.05) influenced by inter-row spacing only at 8 WAS, but in the subsequent growth stages (4, 6 and 10 WAS) it was not significant (P>0.05). The significant response of leaf length to inter-row spacing may be attributed to the fast growth of

Table 2. Effect of inter-row spacing and variety on the leaf length per plant (cm) of sesame at 4, 6, 8 and 10 WAS during the 2015 and 2016 rainy seasons at Dry Land Teaching and Research Farm U.D.U.S

Treatment	2015				2016			
	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS
Spacing (S) in cm								
20 x 40	3.28^{b}	7.31^{bc}	9.54^{b}	10.39^{b}	4.32	6.67	10.54^{b}	13.38
20 x 50	3.49^{ab}	8.27^{ab}	9.99^{b}	10.89^{ab}	4.43	7.19	11.23^{ab}	12.72
20 x 60	3.19^{b}	6.97^{c}	9.04^{b}	9.97^{b}	4.39	7.61	11.74^{ab}	13.60
20 x 70	3.96^{a}	9.12^{a}	11.19^{a}	11.87^{a}	4.52	7.76	12.51^{a}	13.70
S.E±	0.18	0.33	0.35	0.40	0.19	0.30	0.62	0.31
Significant	*	*	*	*	Ns	Ns	*	Ns
Variety (V)								
Ex-sudan	3.78^{a}	7.95^{ab}	10.18^{a}	10.85^{a}	4.66^{a}	7.61^{a}	13.21^{a}	15.60^{a}
Tumkur Local Black	3.15^{b}	7.31^{b}	8.86^{b}	9.79^{b}	3.96^{b}	7.63^{a}	8.80^{b}	9.12^{b}
Gulbarga Local White	3.52^{ab}	8.50^{a}	10.79^{a}	11.69^{a}	4.63^{a}	6.68^{b}	12.52^{a}	15.33^{a}
S.E±	0.15	0.29	0.29	0.34	0.16	0.26	0.53	0.27
Significant	*	*	*	*	*	*	*	*
Interaction								
S x V	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT)

* = Significant only at 5%, Ns = Not significant at 5%, WAS = Weeks after sowing

S = Spacing and V = Variety

sesame plants at the early growth stages. Leaf length of sesame was not significantly (P>0.05) influenced by inter-row spacing at 4, 6 and 10 WAS (Table 2). At 8WAS, inter-row spacing of 20x70 cm significantly (P<0.05) had the longest leaf length whereas 20x40 cm inter-row spacing had the shortest with 20x50 and 20x60 cm spacing statistically having the same leaf length.

Leaf length of sesame was significantly (P<0.05) influenced by variety in all the growth stages during 2015 and 2016 rainy seasons (Table 2). In 2015 season, at 4WAS, Ex-sudan significantly (P<0.05) had the longest leaf length though was statistically the same with Gulbarga local white sesame variety while Tumkur local black had the shortest leaf length. At 6WAS, Gulbarga local white significantly had the longest leaf length though statistically the same with Ex-sudan while Tumkur local black had the shortest. At 8 WAS, Gulbarga local white and Ex-sudan significantly (P<0.05) recorded the longest leaf length though statistically similar whereas Tumkur local black had the shortest leaf length. The same trend was observed in the rest of the growth stages studied. The interaction effects of spacing and variety on leaf length per plant of sesame at 4WAS during the first season is shown in Table 3. In 2015 season, at 4WAS, longest leaf length was recorded with 20x70 cm spacing in combination with Ex-sudan variety and shortest leaf length was recorded with 20x70cm spacing in combination with Tumkur Local Black.

3.3 Leaf Diameter per Plant

Results on the leaf diameter of sesame at 4, 6, 8 and 10 WAS as influenced by Inter-row spacing and Variety during 2015 and 2016 rainy seasons are presented in Table 4. Leaf diameter of sesame was not significant (P>0.05) only at 4WAS during 2015 season but in the subsequent growth stages it was significant (P<0.05). At 6WAS, inter-row spacing of 20x70 cm significantly (P<0.05) had the longest leaf diameter followed by 20x50 cm spacing whereas 20x40 and 20x60 cm inter-row spacing significantly (P<0.05) recorded the shortest leaf diameter though statistically similar. At 8 and 10WAS, 20x70 cm inter-row spacing significantly (P<0.05) had the longest leaf diameter whereas 20x40 and 20x60cm inter-row spacing significantly (P<0.05) had the shortest leaf diameters which are similar. In 2016 season, leaf diameter of sesame was significantly (P<0.05) affected by inter-row spacing only at 6WAS, but in the subsequent growth stages (4, 8 and 10 WAS) it was not significant (P>0.05). At 6 WAS, 20x70 cm inter-row spacing significantly (P<0.05) had the longest leaf diameter though

Table 3. Interaction of spacing and variety on the leaf length per plant (cm) of sesame at 4WAS during 2015 rainy season at Dry Land Teaching and Research Farm U.D.U.S

		2015 Rainy season	
		4WAS	
		Varieties (V)	
Spacing (S) (cm)	**Ex-sudan**	***Tumkur local blacK***	***Gulbarga local white***
20 x 40	3.30^{bc}	3.30^{bc}	3.23^{bc}
20 x 50	3.73^{ab}	3.57^{bc}	3.17^{bc}
20 x 60	3.53^{bc}	2.87^{c}	3.17^{bc}
20 x 70	4.53^{a}	2.83^{c}	4.50^{a}
S.E±		0.30	

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT),WAS = Weeks after sowing, S = Spacing and V = Varieties of Sesame

Table 4. The effect of inter-row spacing and variety on the leaf diameter per plant (cm) of sesame at 4, 6, 8 and 10WAS during the 2015 and 2016 rainy seasons at Dry Land Teaching and Research Farm U.D.U.S

Treatment	**2015**				**2016**			
	4 WAS	**6 WAS**	**8 WAS**	**10 WAS**	**4 WAS**	**6 WAS**	**8 WAS**	**10 WAS**
Spacing (S) in cm								
20 x 40	1.83	4.08^{c}	5.43^{b}	5.96^{b}	2.66	3.99^{c}	6.02	6.96
20 x 50	1.93	4.78^{b}	6.09^{ab}	6.64^{ab}	2.77	4.30^{bc}	6.69	6.54
20 x 60	2.43	3.87^{c}	5.42^{b}	5.94^{b}	2.50	4.87^{ab}	7.37	6.86
20 x 70	2.19	5.26^{a}	6.56^{a}	7.07^{a}	2.73	5.02^{a}	7.29	6.76
SE±	0.34	0.16	0.33	0.29	0.13	0.24	0.51	0.23
Significant	Ns	*	*	*	Ns	*	Ns	Ns
Variety (V)								
Ex-sudan	2.15	4.58^{a}	6.17	6.60	2.91^{a}	4.93^{a}	8.20^{a}	8.10^{a}
Tumkur Local Black	2.25	4.13^{b}	5.41	5.98	2.25^{b}	3.81^{b}	5.62^{b}	4.85^{c}
Gulbarga Local White	1.90	4.78^{a}	6.05	6.63	2.85^{a}	4.90^{a}	6.71^{b}	7.38^{b}
SE±	0.29	0.14	0.28	0.25	0.12	0.21	0.45	0.20
Significant	Ns	*	Ns	Ns	*	*	*	*
Interaction								
S x V	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT)

** = Significant only at 5%, Ns = Not significant at 5%, WAS = Weeks after sowing*

S = Spacing and V = Variety

statistically similar with 20x60 cm spacing while 20x40cm spacing had the shortest leaf diameter.

Leaf diameter of sesame was significantly (P<0.05) affected by variety only at 6WAS during 2015 season, but in the subsequent growth stages (4, 8 and 10 WAS) it was not significant (P>0.05). At 6WAS, Gulbarga local white and Ex-sudan significantly (P<0.05) recorded tallest leaf diameter though similar while Tumkur local black recorded the shortest. The same trend was observed at 4, 6 and 8 WAS in 2016 season (Table 4). At 10 WAS during 2016 season, Ex-sudan had the longest leaf diameter while shortest result was observed with Tumkur local black. The interaction of spacing and variety on the leaf diameter of sesame was only significant (P<0.05) at 6 WAS in the 2015 season. In 2015 season, at 6 WAS, longest leaf diameter was produced with 20x70cm spacing in combination with Gulbarga local white variety and shortest leaf diameter was produced with 20x60 cm spacing in combination with Tumkur local black.

3.4 Leaf Area per Plant

Table 9 below presents the results on leaf area of sesame at 4, 6, 8 and 10WAS as influenced by Inter-row spacing and Variety in the 2015 and 2016 rainy seasons. Leaf area of sesame was not significant (P>0.05) only at 4 WAS in the first trial but in the subsequent growth stages it was

significant (Table 5). In 2015 trial, at 6 WAS, 20x70 cm inter-row spacing significantly (P<0.05) recorded the highest leaf area of sesame whereas 20x60 cm spacing recorded the lowest though statistically similar with 20x40 cm spacing. At 8 and 10WAS, 20x70 cm inter-row spacing significantly (P<0.05) recorded the highest leaf area which was statistically the same with 20x50 cm inter-row spacing while 20x60 cm spacing recorded the lowest leaf area of sesame though statistically the same with 20x40 cm spacing. Leaf area of sesame was significantly (P<0.05) influenced by inter-row spacing at 6WAS only in 2016 season, but in the rest of the growth stages, it was not significant (P>0.05). At 6WAS, inter-row spacing of 20x70 cm significantly (P<0.05) recorded the highest leaf area though statistically similar with 20x60 and 20x50 cm spacing while 20x40 cm spacing recorded the lowest leaf area.

Leaf area per plant of sesame was not significantly (P>0.05) influenced by variety only at 4 WAS in the 2015 trial but in the subsequent growth stages it was significant (P<0.05). In 2015 trial, at 6, 8 and 10 WAS, Gulbarga local white significantly had the highest leaf area while Tumkur local black had the lowest. In 2016 trial, at 4 WAS, Ex-sudan significantly (P<0.05) had the highest leaf area though statistically the same with Gulbarga local white whereas Tumkur local black had the lowest leaf area. The same trend was observed at 6 and 8 WAS. At 10WAS, Ex-sudan variety had the highest leaf area while Tumkur local black had the lowest. This result implies that increase in leaf length and leaf diameter lead to increase in leaf area per plant of sesame. However, Large leaf area enhanced the capacity of the sesame plants to intercept adequate sunlight, which might have resulted in the production of more assimilate thereby enhancing growth and development of the crop as earlier observed by [22]. The interaction effect of spacing and variety at 4, 8, 10 and 4, 6, 8, 10 WAS in 2015 and 2016 seasons respectively were all not significant (P>0.05).

The interaction effects of spacing and variety on leaf area per plant at 6 WAS during the 2015 season is presented in Table 6. In 2015 season, at 6 WAS, highest leaf area per plant was recorded with 20x70 cm spacing in combination with Gulbarga Local White and lowest leaf area was recorded with 20x60 cm spacing in combination with Tumkur Local Black variety of sesame.

3.5 Number of Branches per Plant

Number of branches of sesame at 4, 6, 8, and 10 WAS as affected by Inter-row spacing and Variety during 2015 and 2016 rainy seasons are presented in Table 7. The number of branches of sesame was significantly (P<0.05) affected by Inter-row spacing in all the growth stages in 2015 season whereas, in 2016 season, number of branches of sesame was only significant (P<0.05) at 4WAS. In 2015 season, at 4 and 6WAS, 20x70 cm spacing significantly (P<0.05) had the highest number of branches though statistically similar with 20x40 and 20x50 cm spacing while 20x60 cm spacing had the lowest number of branches (Table 7). At 8 WAS, 20x70 cm spacing significantly (P<0.05) had the highest number of branches whereas 20x60 cm spacing had the lowest number though statistically the same with 20x40 cm spacing. Similarly, at 10 WAS, 20x70 cm spacing significantly (P<0.05) had the highest number of branches though statistically similar with 20x40 and 20x50 cm spacing while 20x60 cm spacing had the lowest number. In 2016 season, at 4WAS, 20x70 cm spacing significantly (P<0.05) had the highest number of branches of sesame whereas the rest of the spacings significantly (P<0.05) had the lowest numbers which were statistically similar. The increased values for number of branches of sesame with wider inter-row spacing could be probably due to the fact that, sesame plants grown at wider inter-row spacing are less exposed to intra specific competition for light, nutrient, moisture and space, therefore tend to grow more vigorously. The reverse is the case in which high plant population as a result of narrow inter-row spacing always tend to caused intra specific competition for both above and ground required resources thereby leading to poor vegetative and reproductive growth of the target crop. This finding is in line with what was reported by [23] that densely populated plants tend to exert pressure on needed growth and reproductive resources thereby causing poor growth of plant.

The number of branches per plant of sesame was not significantly (P>0.05) affected by variety only at 4WAS in 2015 season, but in the subsequent growth stages, it was significant (P<0.05). In 2015 season, at 6WAS, Tumkur local black significantly (P<0.05) had the highest number of branches while Ex-sudan had the lowest number though statistically the same with Gulbarga local white. Similar trend was observed

Table 5. Interaction of spacing and variety on the leaf diameter per plant (cm) of sesame at 6WAS during 2015 rainy season at Dry Land Teaching and Research Farm U.D.U.S

	2015 Rainy season		
	6WAS		
	Varieties (V)		
Spacing (S) (cm)	**Ex-sudan**	***Tumkur local black***	***Gulbarga local white***
20 x 40	4.30^{bde}	3.87^{ef}	4.07^{def}
20 x 50	4.80^{bcd}	4.90^{bc}	4.63^{bcde}
20 x 60	3.83^{ef}	3.40^{f}	4.37^{cde}
20 x 70	5.37^{ab}	4.33^{cde}	6.07^{a}
S.E±		0.28	

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT), WAS = Weeks after sowing, S = Spacing and V = Varieties of Sesame

Table 6. Effect of inter-row spacing and variety on leaf area per plant (cm^2) of sesame at 4, 6, 8 and 10WAS during the 2015 and 2016 rainy seasons at Dry Land Teaching and Research Farm U.D.U.S

Treatment	**2015**				**2016**			
	4 WAS	**6 WAS**	**8 WAS**	**10 WAS**	**4 WAS**	**6 WAS**	**8 WAS**	**10 WAS**
Spacing (S) in cm								
20 x 40	6.12	29.98^{c}	52.08^{b}	62.14^{b}	11.81	27.16^{b}	65.47	97.08
20 x 50	6.82	39.70^{b}	60.93^{ab}	72.50^{ab}	12.51	31.64^{ab}	76.31	86.61
20 x 60	7.70	27.43^{c}	50.36^{b}	60.31^{b}	11.10	37.96^{a}	92.84	97.96
20 x 70	9.23	49.07^{a}	74.47^{a}	84.90^{a}	12.72	39.44^{a}	94.90	97.14
SE±	1.17	2.75	4.67	4.92	1.01	3.14	11.35	4.27
Significant	Ns	*	*	*	Ns	*	Ns	Ns
Variety (V)								
Ex-sudan	8.47	37.14^{ab}	63.57^{b}	72.34^{a}	13.81^{a}	38.48^{a}	112.21^{a}	126.38^{a}
Tumkur Local Black	7.03	30.66^{b}	48.54^{b}	59.06^{b}	8.96^{b}	25.70^{b}	49.61^{b}	44.15^{c}
Gulbarga Local White	6.92	41.83^{a}	66.27^{a}	78.50^{a}	13.34^{a}	37.97^{a}	85.33^{a}	113.56^{b}
SE±	1.02	2.39	4.04	4.27	0.87	2.72	9.82	3.70
Significant	Ns	*	*	*	*	*	*	*
Interaction								
S x V	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns

*Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT), * = Significant only at 5%, Ns = Not significant at 5%, WAS = Weeks after sowing, S = Spacing and V = Variety*

Table 7. Interaction of spacing and variety on the leaf area per plant (cm^2) of sesame at 6WAS during 2015 rainy season at Dry Land Teaching and Research Farm U.D.U.S

	2015 Rainy season		
	6WAS		
	Varieties (V)		
Spacing (S) (cm)	**Ex-sudan**	***Tumkur local black***	***Gulbarga local white***
20 x 40	31.00^{cde}	27.17^{de}	31.00^{cde}
20 x 50	40.03^{bcd}	41.37^{bc}	37.70^{bcd}
20 x 60	26.67^{de}	21.53^{e}	34.10^{cde}
20 x 70	50.10^{b}	32.57^{cde}	64.53^{a}
S.E±		4.77	

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT), WAS = Weeks after sowing
S = Spacing and V = Varieties of Sesame

Table 8. The effect of inter-row spacing and variety on the number of branches per plant of sesame at 4, 6, 8 and 10WAS during the 2015 and 2016 rainy seasons at Dry Land Teaching and Research Farm U.D.U.S

Treatment	2015				2016			
	4 WAS	6 WAS	8 WAS	10 WAS	4 WAS	6 WAS	8 WAS	10 WAS
Spacing (S) in cm								
20 x 40	10.00^{ab}	18.00^{ab}	36.00^{b}	132.00^{ab}	11.00^{ab}	18.00	51.00	113.00
20 x 50	10.00^{ab}	17.00^{ab}	39.00^{ab}	99.00^{ab}	11.00^{ab}	19.00	60.00	112.00
20 x 60	9.00^{b}	17.00^{b}	31.00^{b}	84.00^{b}	1.00^{ab}	20.00	60.00	119.00
20 x 70	11.00^{a}	19.00^{a}	47.00^{a}	140.00^{a}	12.00^{a}	21.00	59.00	132.00
SE±	0.49	0.878	3.30	18.26	0.41	1.00	3.97	7.80
Significant	*	*	*	*	*	Ns	Ns	Ns
Variety (V)								
Ex-sudan	10.00	16.00^{b}	29.00^{b}	58.00^{b}	11.00^{b}	15.00^{b}	31.00^{b}	66.00^{b}
Tumkur Local Black	10.00	21.00^{a}	50.00^{a}	219.00^{a}	12.00^{a}	28.00^{a}	108.00^{a}	213.00^{a}
Gulbarga Local White	9.00	17.00^{b}	36.00^{b}	64.00^{b}	11.00^{b}	16.00^{b}	33.00^{b}	78.00^{b}
SE±	0.42	0.76	2.86	15.81	0.35	0.87	3.43	6.76
Significant	Ns	*	*	*	*	*	*	*
Interaction								
S x V	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT)
** = Significant only at 5%, Ns = Not significant at 5%, WAS = Weeks after sowing*
S = Spacing and V = Variety

Table 9. Interaction of spacing and variety on the number of branches of sesame at 6WAS during 2015 rainy season at Dry Land Teaching and Research Farm U.D.U.S

	2015 Rainy season		
	6WAS		
	Varieties (V)		
Spacing (S) (cm)	**Ex-sudan**	***Tumkur local black***	***Gulbarga local white***
20 x 40	9.00^{ab}	11.00^{a}	9.00^{ab}
20 x 50	9.00^{ab}	11.00^{a}	8.00^{b}
20 x 60	9.00^{ab}	9.00^{ab}	9.00^{ab}
20 x 70	11.00^{a}	11.00^{a}	11.00^{a}
S.E±		0.85	

Means within a column followed by the same letters are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT), WAS = Weeks after sowing, S = Spacing and V = Varieties of Sesame

in the rest of the growth stages. The interaction effect of spacing and variety at 4, 8, 10 and 4, 6, 8, 10 WAS in the 2015 and 2016 seasons respectively were all not significant (P>0.05).

The interaction of spacing and variety on number of branches of sesame at 6WAS during 2015 season is presented in Table 8. In 2015 season at 6 WAS, highest number of branches was produced by 20x40 and 20x50 cm spacing in combination with Tumkur local black. However, similar results were obtained with 20x70 cm spacing in combination with Ex-sudan and Gulbarga local white while lowest number was produced with 20x50 cm in combination with Gulbarga local white sesame variety. According to Samson, (2005) cited in [20] a significant increase in the number of branches and number of leaves per plant at a wider row spacing of 15 cm has been reported.

3.6 Number of Capsule per Plant

Results on the number of capsule of sesame as affected by Inter-row spacing and Variety during the 2015, 2016 rainy seasons and in the two seasons combined are presented in Table 10. The Number of capsule was significantly ($P<0.05$) affected by inter-row spacing during 2015 season and when combined whereas during 2016 season, no significant difference ($P>0.05$) was observed between the spacing. In 2015 season, inter-row spacing of 20x70 cm significantly ($P<0.05$) had the highest number of capsule while 20x40 cm spacing had the lowest. In 2016 season, the number of capsule of sesame was not significantly ($P>0.05$) influenced by inter-row spacing. When the two seasons were combined, inter-row spacing of 20x70 cm significantly ($P<0.05$) had the highest number of capsule while inter-row spacing of 20x40 cm had the lowest number which was statistically the same with the rest of the spacing (Table 10). This is in line with the findings of [24] who reported that, number of seeds per capsule varied significantly with Inter-row spacing. According to [25], row planting of sesame resulted in higher number of capsule per plant and seed per capsule. In addition, [26] also reported an increase in capsule number per plant due to increase in row spacing in field peas. These findings are in line with that of [27] who reported maximum number of capsules per plant in wider row spacing in sesame.

Number of capsule of sesame was significantly ($P<0.05$) influenced by Variety during 2015, 2016 rainy season and in years combined. In 2015 season, *Gulbarga local white* significantly had the highest number of capsule while *Tumkur local black* had the lowest number. In 2016 season, Tumkur local black followed by *Gulbarga local white* significantly ($P<0.05$) had the highest number of capsule whereas ex-Sudan had the lowest. From these results, it was observed that, there is direct relationship between variety and number of capsule which could be due to the fact that, as a new variety is used in any location, adoptability of that variety to the soil and climatic conditions is directly proportional to growth attributes which are partitioned to the capsule yield. When the two seasons were combined, *Gulbarga local white* followed by ex-Sudan significantly ($P<0.05$) had the highest number of capsule while *Tumkur local black* had the lowest number (Table 10). Increased in number of branches and plant height attributed to increase in the amount of rainfall received during 2016 season indicates a direct inter dependency of the varieties to favorable climatic conditions which are geared toward higher number of capsules. This makes available more photosynthetic surface that triggered growth and development which in turn results in the increased capsuled number. This corroborates with the findings of [28] who reported that, variation exist between varieties of sesame on number of seeds per capsule as a result of suitable climatic conditions. The interaction effect of spacing and variety on number of capsule of sesame during 2015 season and when combined were significant ($P<0.05$), but not significant ($P>0.05$) at 2016 season.

The interaction effect of spacing and variety on the number of capsule of sesame during 2015 season and the two seasons combined are presented in Table 11. In 2015 season, 20x70 cm spacing in combination with *Gulbarga local white* had the maximum number of capsule of sesame while 20x40 cm spacing in combination with ex-Sudan had the minimum number. When the two seasons were combined, 20x70 cm spacing in combination with *Gulbarga local white* had the maximum number of capsule whereas 20x40 cm spacing in combination with ex-Sudan variety of sesame had minimum number of capsule.

3.7 Seed Yield (t ha^{-1})

Results on seed yield of sesame as influenced by Inter-row spacing and Variety during 2015, 2016 rainy season and in the two years combined are presented in Table 12. Seed yield was not significantly ($P>0.05$) influenced by inter-row spacing during 2015 and 2016 trials and when combined. According to [16] wider row spacing resulting to increasing seed yield may be due to larger space and growth resources available per individual plant. Similarly, sowing sesame at wider inter-row spacing of 45cm gave the best distance for seed yield per hectare according to [29].

Seed yield of sesame was significantly ($P<0.05$) influenced by variety during 2015, 2016 rainy seasons and when combined. In 2015 season, significantly ($P<0.05$) heaviest seed yield was recorded with *Gulbarga local white* followed by ex-Sudan while least seed yield was recorded with *Tumkur local black*. The same trend was observed when both seasons were combined

(Table 12). In 2016 season, significantly heaviest seed yield was recorded with *Gulbarga local white* though statistically the same with ex-Sudan while least seed yield was recorded with *Tumkur local black*. According to [2], seed yield is directly determined by yield-related traits and is significantly influenced by both genetic and environmental factors. Differences between the varieties for these characters could have been due to genetic factors and the ability of the different varieties to respond to environmental conditions [30]. Therefore, the high yield of *Gulbarga local white* variety might be as a result of increased number of capsules and capsules yield which in turn leads to reduced competition between individual plants

Table 10. Effect of inter-row spacing and variety on the number of capsule of sesame during the 2015 and 2016 rainy seasons and when combined at Dryland Teaching and Research Farm Usmanu Danfodiyo University, Sokoto

Treatment	2015	2016	Combined
Spacing (cm)			
20 x 40	17.00^{c}	60.00	38.00^{b}
20 x 50	24.00^{b}	60.00	42.00^{b}
20 x 60	22.00^{bc}	63.00	42.00^{b}
20 x 70	38.00^{a}	63.00	51.00^{a}
SE±	2.044	2.548	1.610
Significant	*	NS	*
Variety			
ex-Sudan	34.00^{ab}	53.00^{c}	43.00^{b}
Tumkur local black	30.0^{b}	72.00^{a}	37.00^{c}
Gulbarga local white	39.00^{a}	60.00^{b}	49.00^{a}
SE±	1.770	2.206	1.394
Significant	*	*	*
Interaction			
S x V	*	NS	*

*Means within a column followed by the same letter(s) are statistically not significant at 5% level of probability using DMRT, * = Significant only at 5%, NS = Not significant at 5%, S = Spacing and V = Variety*

Table 11. Interaction of spacing and variety on the number of capsule per plant of sesame during 2015 rainy season and when combined at Dryland Teaching and Research Farm U.D.U.S

	2015		
	Varieties		
Spacing (cm)	**Ex-Sudan**	***Tumkur local black***	***Gulbarga local white***
20 x 40	23.00^{e}	40.0^{b}	24.00^{de}
20 x 50	38.00^{bc}	30.0^{cde}	31.00^{cde}
20 x 60	28.00^{cde}	40.0^{b}	34.00^{cd}
20 x 70	47.00^{b}	33.0^{cd}	67.00^{a}
S.E±		3.551	
	Combined		
Spacing (cm)	**Ex-Sudan**	***Tumkur local black***	***Gulbarga local white***
20 x 40	37.00^{d}	38.00^{d}	41.00^{cd}
20 x 50	46.00^{bc}	37.00^{d}	44.00^{bcd}
20 x 60	39.00^{cd}	38.00^{d}	51.00^{b}
20 x 70	51.00^{b}	37.00^{d}	63.00^{a}
S.E±		2.789	

Means within a column followed by the same letter(s) are statistically not significant at 5% level of probability using Duncan's multiple range test (DMRT)

Table 12. Effect of inter-row spacing and variety on the seed yield (t ha^{-1}) of sesame during the 2015 and 2016 rainy seasons and when combined at Dryland Teaching and Research Farm Usmanu Danfodiyo University, Sokoto

Treatment	2015	2016	Combined
Spacing (cm)			
20 x 40	0.338	0.388	0.363
20 x 50	0.319	0.342	0.330
20 x 60	0.367	0.398	0.383
20 x 70	0.341	0.407	0.374
SE±	0.0226	0.0464	0.0253
Significant	NS	NS	NS
Variety			
ex-Sudan	0.432^{b}	0.432^{a}	0.432^{b}
Tumkur local black	0.24^{c}	0.258^{b}	0.141^{c}
Gulbarga local white	0.568^{a}	0.462^{a}	0.515^{a}
SE±	0.0195	0.0402	0.0219
Significant	*	*	*
Interaction			
S x V	NS	NS	NS

*Means within a column followed by the same letter are statistically not significant at 5% level of probability using Duncan's New Multiple Range Test (DMRT), * = Significant only at 5%, NS = Not significant at 5%, S = Spacing and V = Variety*

due to low plant population density at 70 cm inter-row spacing. In addition, this explains the high ability of *Gulbarga local white* variety to allocate photosynthetic assimilate to economic yield. The interactions of spacing and variety on the seed yield of sesame during 2015, 2016 seasons and in the two seasons combined were all not significant.

4. CONCLUSION

From the finding of this research, it may be concluded that Tumkur Local Black sesame variety planted at 70cm inter-row spacing gave

the highest growth performance compared to Ex-sudan and Gulbarga Local white under the same conditions. It is therefore suggested as the best practice. Similarly, *Gulbarga local white* sesame variety gave the highest seed yield when compared with the two other varieties. However more research work needs to be conducted with other varieties of sesame having higher and or lower levels of Inter-row spacing to substantiate whether the increase and or decrease in levels of inter-row spacing could result in further increase in growth and yield performance of sesame varieties in the study location or otherwise.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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